IMPROVING BAKING QUALITY AND LOCAL MARKETS FOR WHEAT
GROWN IN WESTERN WASHINGTON

By

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the requirements for the degree of

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ABSTRACT

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Winter wheat (Triticum aestivum) is currently grown in crop rotations in western Washington to break disease cycles and improve soil quality. There is interest in creating a local grain system to add value to the crop. Two of the barriers to the creation of a local grain system are increasing protein levels and baking quality in organic systems and understanding attitudes of commercial bakers in western Washington in regards to purchasing western Washington wheat flour. In 2009-2010 and 2010-2011, a blended organic fertilizer (Perfect Blend™ 7-2-2) was surface-applied at five rates ranging from 0 to 90 kg N ha⁻¹ to three varieties of hard winter wheat grown at two locations in western Washington at the crop boot stage. Grain protein, averaged across varieties and locations, was 9.28 percent and 8.50 percent for the 0 kg N ha⁻¹ treatment during the two seasons, respectively, and 10.27 and 9.56 percent for the plots receiving 90 kg N ha⁻¹. Protein quality, measured as SDS sedimentation, averaged across varieties, locations and years was 9.9 cc g⁻¹ for the 0 kg N ha⁻¹ treatment and 10.5 cc g⁻¹ for the plots receiving 90 kg N ha⁻¹ at
the boot stage. More work is required to determine quality thresholds for the intended market of artisan bakers. A survey of 73 commercial bakers in western Washington found that 61 percent were interested in purchasing western Washington wheat/flour. Bakers who used retail strategies to market their products were more likely to be interested in western Washington wheat/flour. The most important factors bakers would consider in purchasing regionally produced wheat/flour were consistency, quality, and reliability of supply. Thirty-four percent of survey respondents defined local as within the state of Washington, 25 percent provided a multi-state definition, and 14 percent provided a flexible (or reflexive) definition that referred to two or more geographic regions. Perceived barriers to purchasing local wheat included supply chain, price, quality, and scale factors. Both opportunities and challenges exist in western Washington and other regions interested in the relocalization of wheat supply chains.
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Chapter 1

Literature Review

1.1 Introduction

1.1.1 Wheat in western Washington

Agriculture in western Washington is composed of small, diversified farms, many of which are located at the rural-urban interface. Small grains, including wheat and barley, are important rotational crops in the region and are typically grown after bulbs, potatoes, or vegetable seed crops to break disease cycles and improve soil quality. However, since wheat is not the primary cash crop for most growers in western Washington, acreage has often been underreported. According to the USDA, in 2007 there were 7,000 acres planted to wheat in all of western Washington (USDA NASS, 2007). However, it has been estimated that Skagit County alone,
western Washington’s largest wheat producing county, has approximately 15,000 acres planted
to wheat annually (D. McMoran, personal communication, 2012).

Though accurate data for wheat acreage in western Washington are not available, it is estimated
that 35,000 acres of field crops (including alfalfa, barley, corn and grass silage, grass, oats, pea
hay and small grains) are grown in Skagit County with a dollar value of $30 million (McMoran,
2012). Increasing interest from producers led to the publication of an extension publication
“Growing Wheat in Western Washington” (Miles et al., 2009), the first extension publication on
small grains in western Washington for several decades. Currently the primary market class of
wheat grown in Washington, including western Washington, is soft white wheat. Eighty five
percent of Washington wheat is sold through the commodity market for export internationally for
cakes, pastries, flatbreads and other uses (Washington Grain Alliance, 2010). Selling wheat
outside of the commodity market to consumers in local metropolitan areas is attractive to
growers in western Washington because of the potential to have more control over the prices
they receive and because it may allow them to capture some of the value associated with the
wheat’s origin (Patzek, 2012). The proximity of large population centers as well as an interest in
local food could make this a viable alternative if the market and supporting infrastructure for
storage and processing were more fully developed (See Appendix I).

Historically, high rainfall zones such as western Washington have not been considered ideal for
the production of hard red wheat, the major source of bread flour. However, recent field trials at
the Washington State University Mount Vernon Research and Extension Center have shown that
it is possible to achieve protein levels of 12-13 percent in hard winter wheat (Jones, 2010). Most
wheat research in Washington State is focused on dryland production areas, which rely on wheat
as their main cash crop, and are largely focused on production for the export market. For this reason, there is a lack of research-based information for wheat growers in western Washington, especially organic wheat growers.

Winter wheat is a good fit for organic growers in western Washington for several reasons: it fits well into existing crop rotations, it is a strong competitor with weeds, and it is harvested earlier in the summer than spring wheat, which means it will more reliably dry down in the climate of western Washington and allow earlier planting of other fall crops. Though growing grain for human consumption offers the highest return for organic growers, the recent increase in demand for organic grains for livestock feed and distilling use offers an important safety net for growers in years where quality standards for human consumption are not met.

1.1.2 Artisan baking

After a 1923 study found that 6 to 10 percent of bread went unsold, US Food and Drug Administration standards were put into place to extend the shelf-life of bread. Beginning during World War II much of the bread produced in the U.S. was made using the Chorleywood process, which involves highly mechanized production with strong wheat flours, high speed mixers, and no preferment, resulting in a tight white crumb, full volume and a high throughput process, but this lacked the flavors and individual characteristics previously found in smaller bakeries (Suas, 2009).

In contrast to the style of baking using the Chorleywood process, artisan baking has come to stand for a “commitment to production methods that employ traditional skills distinct from the highly controlled and automated production systems of the factory bakery.” Rather than sharing
a shape, ingredients or style, their common element is that they were “touched by the hand, assessed by the eye and subject to the baker’s judgment at every step” (Bassetti and Galton, 1998, p. 20).

Starting in the 1970’s public interest increased in hearth loaves, loaves baked without a pan, with creamy-colored open crumb, a complex flavor, and a thin, crisp golden crust made without stabilizers, dough conditioners or preservatives. This type of baking typically uses preferments, where the dough is allowed to ferment at a longer, slower pace and the final proof is extended. In the 1970s bread production took three hours from mixing time until baking. Today the average time between mixing and baking for artisan bread is 6 to 16 hours (Suas, 2009).

The U.S. industrial bread wheat market demands protein levels of 12 to 16 percent (Cauvain et al., 2007; Woolfolk et al., 2002), but in contrast, artisan baking is closer in style to European baking, which typically uses lower protein wheat. In France the minimum protein threshold for organic bread wheat is 10.5 percent of grain dry matter, recently raised from 9 percent (Casagrande et al., 2009). King Arthur, a well-respected flour company based in Norwich, Vermont, sells ‘Sir Galahad,’ lower protein (11.7 percent) flour in their U.S. markets, as an alternative to their standard 12.7 percent protein bread flours. The popularity of artisan bread has resulted in a change in the wheat and flour industry with bakers looking for low protein flour with more ash content (Suas, 2009). Ash content is a proxy for the amount of bran present in flour. It is difficult for stone milling operations to meet rigid standards for low ash content, so this shift in the market means that the flour market may be accessible to millers, even without industrial scale roller mills.

1.1.3 Interest in local organic bread wheat for artisan baking
For growers, artisan bakers offer a promising avenue for getting locally grown bread wheat to the consumer because of the artisan baker’s ability to communicate “the story” of the wheat. Artisan baking may be a good fit for small-scale decentralized wheat production because of the baker’s potential to work with the characteristics of individual batches of wheat through skilled manipulation of different factors in the bread making process. If consumers of artisan bread place importance on local production, as anecdotal evidence suggests, bakers may be willing to deal with slightly more variable flour in order to make use of locally grown wheat.

Many of the same customers who purchase artisan bread are also interested in buying organic. Organic production has the potential to offer farmers the greatest return for wheat production on a per acre basis, which is important given the relatively small size of farms in western Washington. In addition, the market for organic foods continues to grow stronger, even in an otherwise weak economy (USDA, 2009). Acres converted to organic agriculture in Skagit County, one of the main agricultural counties in western Washington, reached 5,627 in the 2011 growing season, and organic production in the county was valued at $13.2 million (McMoran, 2012).

1.2 Baking quality in organic winter wheat

1.2.1 Baking quality and protein

There is no single measurement for determining baking quality of wheat flour. Overall baking quality is affected by factors including ash content, starch damage, particle size, amylase activity, and protein quantity and quality (Abécassis et al., 2008). Comprehensive wheat quality
analysis involves many complex tests requiring specialized equipment such as alveograph, farinograph, and mixograph, none of which are practical or economical to conduct from the perspective of a small-scale grower or baker. For this reason, protein is often used as a proxy for baking quality when it is not practical to run an entire suite of tests.

Protein in wheat can be divided into different fractions based on solubility and molecular weight. The most important of these for bread production are long complex molecules called glutenins and gliadins, which are collectively referred to as gluten. Glutenins provide both elasticity and extensibility to dough while gliadins provide extensibility. It is the balance of dough elasticity and extensibility that determines which end use is the most appropriate for wheat (Gupta et al., 1992).

1.2.2 Factors that affect protein

The factors affecting protein concentrations in wheat can be broadly grouped into the categories of genotype, environment, and management. Numerous studies have investigated the effect of genotype on protein quantity (Baresel et al., 2008; Barraclough et al., 2010) and on protein quality (Hussain et al., 2009). Environmental factors have also been identified as important in influencing wheat protein quantity, including climate and soil moisture (Guttieri et al., 2000).

Stresses such as drought or heat are known to affect grain protein content. Water stress tends to increase protein content while daily temperature over 25 degrees C tends to reduce it (Casagrande et al., 2009). A small amount of drought stress increases percent protein, primarily by limiting endosperm growth, but too much drought stress can decrease protein levels (Jenner et al., 1991). Management related factors such as fertility (Nass et al. 2003; Johansson et al. 2003;
Lerner et al. 2006), seeding rate (Geleta et al. 2002; Gooding et al. 2002), weed competition (Mason and Madin, 1996), and soil biology (Singh and Kapoor, 1999) have also been identified in the literature as influencing wheat protein content.

1.2.3 Nitrogen availability and protein

Nitrogen (N) is an essential plant nutrient because it is an important component of many compounds in plants including amino acids, the building blocks of protein. It is well understood that N availability is a key factor controlling protein content in wheat (Lueck et al., 2006). Wheat requires adequate N availability at critical stages of development in order to achieve both yield and protein potential. During the course of plant development, several changes occur related to N storage in wheat. Prior to anthesis (flowering), N is stored in vegetative tissues. Baresel et al. (2008) estimate that 76 percent of N taken up before anthesis is later remobilized to grain protein. After anthesis, most N uptake from the roots is directly transferred to the grain, and remobilization occurs through protein hydrolysis to transfer N from vegetative tissue to the developing grain. Grain N originating from pre-anthesis uptake and subsequent remobilization has been estimated at 71 percent (Kichey et al., 2007).

Generally, N available to the plant up to tillering primarily increases yield, while N available after this point has less effect on yield and a greater effect on protein (Brown and Petrie, 2006). Fowler (1998) describes a “lag phase” in the protein concentration-N response curve in soil in cases of low residual plant available N because initial inputs of fertilizer N often go toward yield, which tends to dilute the protein. Protein is generally negatively associated with yield due to this dilution effect (Simmonds, 1995). The effect of spring-applied N on grain protein seems to depend on crop N status. If the crop is N deficient, the spring-applied N goes towards increasing
yield. In crops with adequate N levels, the application of additional N will increase protein (Fowler, 1998; Lloveras et al., 2001).

Late season N is applied in some conventional wheat systems to raise protein levels, particularly in irrigated or high rainfall systems. However, the protein increase from late season N application is variable from year to year and depends on factors including: rate and timing, yield potential, application method, irrigation system, and plant N status (Brown et al., 2005).

The level of N fertilization can affect not only protein quantity, but also protein quality in conventionally grown wheat. Increasing N fertilization in conventional systems raises the ratio of gliadins to glutenins, resulting in increased viscosity of the gluten, which improves baking quality for biscuit (soft) wheat (Pedersen et al., 2007; Tronsmo et al., 2003). It is logical to assume that amount and timing of available N may affect protein quality in organic systems as well. Though the literature in this area is not conclusive, there are some indications that this may be the case. The protein and gluten contents of spring wheat grown after a grass-clover sod corresponded to those following cereals that received 125-150 kg N ha\(^{-1}\) (112-134 lb N A\(^{-1}\)) of applied fertilizer. However, the loaf volume of wheat from fields with plowed-in sod was consistently better than equivalently yielding plots fertilized with mineral N, possibly as a result of better synchrony between N release and plant demand because of slow release of N by the sod (Eriksen et al., 2006). Fuerst et al. (2008) found that protein quantity was lower in organic wheat, but protein quality (measured as loaf volume per unit protein) was higher in organic wheat than in conventional wheat.

1.2.4 Nitrogen management in organic production systems
In organic agriculture, multiple approaches are needed for a complete fertility program including green manures, crop rotations, intercropping, crop residue management, and soil amendment. These strategies are also, of course, important in organic wheat production (Justes et al., 2009; Kumar et al., 2002). Certified organic growers are restricted to using fertilizers that meet the National Organic Program standards. N is often a limiting nutrient in organic agriculture, and N fertility sources approved for organic use can be cost prohibitive in wheat production. Providing an adequate quantity and the correct timing of plant available N is one of the most challenging and costly aspects of fertility management in organic systems.

Most amendments used in organic agriculture do not contain readily available nutrients (with the exception of potassium), making these systems more dependent on the chemical and biological processes that make soil nutrients available (Stockdale et al., 2002). N availability is often dependent upon mineralization from organic N sources and can vary greatly based on factors such as soil conditions (e.g., temperature, moisture), fertility source, and competition from weeds. N sources in organic systems include manures, legumes in rotation, and compost. Though it is possible to meet crop N needs through green manures and animal manure applications, the timing of N release often does not meet the timing of crop demand (Berry et al., 2002), especially in regions where N leaching is an issue, such as western Washington. This often necessitates the use of bagged fertilizer products with more readily available N. Bagged products usually contain combinations of various types of N-containing co-products such as feather meal, dehydrated poultry manure, Chilean nitrate, fish meal, and various seed meals. These bagged fertilizers can be a costly way to provide crop N, so it is critical that growers optimize their use (Grubinger, n.d.).
1.2.5 Protein in organic wheat

There are numerous studies comparing organically and conventionally grown wheat, often using protein as an indicator of baking quality. Such studies have had inconsistent results, probably due to the confounding factors of variability within conventional and organic systems and between cultivars and environments. These studies either found grain protein quantity in organic systems to be lower (Casagrande et al., 2009; Poutala et al., 1993), not different (Mason et al., 2007), or higher (Annett et al., 2007).

The easiest time to apply manure or fertilizer for winter wheat is before planting. However, in the high rainfall conditions of western Washington winters, much of the plant available N from fall-applied amendments is leached out of the root zone by spring (C. Cogger, personal communication, 2010). Conventional growers approach this issue by topdressing with a soluble or granular fertilizer in the spring. This approach is rarely used by organic grain growers.

Some commercially available organic fertilizers are granular and could be easily applied to wheat at the boot stage, which should, in theory, raise protein levels. Two relevant studies on late season topdressing of organic wheat were found in a review of the literature. Monahan (2009) applied 10 lb N A⁻¹ (11 kg ha⁻¹) in the form of Chilean nitrate at either preanthesis or postanthesis, which resulted in no increase in protein. Several unpublished studies report on N topdressing effects. An application of 20 lb N A⁻¹ (22 kg N ha⁻¹) of a blended organic fertilizer (Pro-Booster 10-0-0 from North Country Organics, Bradford, VT) at flag leaf stage resulted in a protein increase of 2.1 percentage points (from 11.3 to 13.4 percent) in winter wheat in Vermont (Darby, 2010). In 2011, Darby et al. raised protein by 0.9 to 1.2 percentage points from by applying 20 lb N A⁻¹ (22 kg N ha⁻¹) as ProBooster (10-0-0) at either flag leaf stage or a split
application at flag leaf and boot stages. Mallory and Darby (2011) found that a boot stage
application of Chilean nitrate at a rate of 20 lb N A\(^{-1}\) (22 kg N ha\(^{-1}\)) resulted in a protein increase
from 8.1 to 9.3 percent in hard red winter wheat.

There is not enough information in the literature to say with confidence whether topdressing with
organic N to raise the protein of winter wheat would be effective in western Washington. The
field study described in Chapter 2 was designed to answer the question: Is it possible to raise
protein quantity and quality by topdressing with an organic N source?

1.3 “Relocalizing” wheat in the food economies of western Washington

1.3.1 Local foods

The past half century has been a time of dramatic consolidation and industrialization of
agriculture and specialization of crop production. While the industrial agriculture model has
provided cheap food, this has come with considerable environmental and social costs. This
consolidation and industrialization has generated counter-movements challenging the dominant
industrial food system and reasserting values through local and organic foods. Food provides a
particularly powerful focus of resistance due to its “material and symbolic functions of linking
nature, human survival, health, culture and livelihood” (McMichael, 2000, p. 21).

The local food and food sovereignty movements are part of a larger social movement resisting
the homogenizing forces of corporate globalization. The idea of food sovereignty has become
especially relevant in the face of several current issues: the use of genetically modified crops, the
obesity epidemic in the United States, outbreaks of foodborne illness, the threat of climate
change, and the imminent end of cheap oil. Communities are realizing the vulnerability that exists within the consolidated food system, and there has been increased interest in regaining local control of production, processing, distribution, and consumption of food. This interest is being recognized at the federal level, as evidenced by the USDA Economic Research Service’s recent publications titled *Local Food Systems: Concepts, Impacts, and Issues* (Martinez et al., 2010) and *Comparing the Structure, Size, and Performance of Local and Mainstream Food Supply Chains* (King et al., 2010).

In response to the issues stemming from a globalized industrial agriculture, many popular authors and scholars in recent years have promoted the relocalization of food systems as having a variety of benefits. The benefits often cited were summed up well by definition of the term ‘civic agriculture’ (Lyson, 2004) as the emergence and growth of community-based agriculture and food production activities that not only meet consumer demands for fresh, safe and locally produced food, but also create jobs, encourage entrepreneurship, and strengthen community identity.

Benefits of local foods that have been discussed by various authors include environmental (e.g., decreased food miles), social (e.g., improved accountability of agricultural enterprises to local communities; revival of small to mid-sized farms), economic (e.g., jobs in production and associated processing and distribution), nutritional (e.g., greater access to healthy foods for low income people), and embeddedness (e.g., agriculture existing within a specific context) (King et al., 2010; Martinez et al., 2010). Despite many claims and theories about the multitude of potential benefits, Martinez et al. (2010) cited a lack of adequate *empirical* research on all potential benefits of local foods.
Critiques of the local food movement abound and include the concept of “defensive localism” in which homogenous known people in one’s social group are favored over “the other” (Hinrichs, 2003); comparative advantage where the fact that food can be grown less expensively overseas is reason enough to outsource agriculture (Blank, 1999); and arguments that the environmental benefits of decreasing food miles ignore efficiencies of scale and the energy costs that would be associated with increased refrigeration required for truly local food systems (Mariola, 2008).

The local food movement is also criticized for simplifying a complex situation by making “local” the proxy for “good” and “global” the proxy for “bad” (Hinrichs, 2003). In addition, the economic benefits of expanding local food systems can be unevenly distributed between and within communities. “By definition, economic benefits generated via import substitution in one location would result in reduced economic activity in areas from which the goods were previously exported” (Martinez et al., 2010, p. 45).

The idea of local foods has also been criticized for its lack of a firm definition. Many studies have examined the definition of the word ‘local’ by different participants in the food system (Ostrom, 2006; Selfa and Qazi, 2005). Opinions are quite varied on what qualifies as “local,” in some cases relying on political boundaries such as state or county lines, and other times referring to miles travelled, or bioregions. Population density, heterogeneity in growing conditions, and cultural food preferences are among the location-specific factors that make the term ‘local’ difficult to define.

1.3.2 Supply chains

Supply chains serve an important role in the processing, packaging and distribution of food, but longer supply chains can mean less return to the farmer per consumer dollar spent. One way that
farmers can shorten supply chains is through direct-to-consumer marketing. One of the most important features of a short food supply chain is that the product reaches the consumer embedded with information, by way of package labeling or personal communication. This information enables the consumer to connect with the place of production, including the actual producer and the production methods (King et al., 2010). Local food is an example of one kind of shortened supply chain.

1.3.3 Consumer choices and willingness to pay

As research in food systems has turned from focusing solely on producers to including consumers in the equation (see, e.g., Goodman and DuPuis, 2002), so has research on local and organic food systems. There are a multitude of studies in the literature looking at who buys organic food, their motivations, and their choices in the marketplace based on food attributes. These studies are summarized in Martinez et al. (2010) and will only be briefly discussed here.

Most studies of consumer choice based on attributes such as organic or local have focused on fresh products (Constanigro et al, 2010; Darby et al., 2008; Giraud et al., 2005; Nurse et al., 2010). Research conducted in Ohio involving a processed, multi-ingredient food product (blackberry jam) supported the idea that consumers are interested in supporting small family farms with purchases if the product is clearly labeled as such, but were only willing to pay a very modest premium of 13 cents per jar. Taste was the most important factor in repeat purchases (Batte, 2010). Though the concepts of branding, local, organic, origin of product, nutrition and health claims are important determinants in consumer choices involving baked goods, it is unclear whether the Batte (2010) study would be applicable across other types of multi-ingredient food (e.g., bread) or in other regions (e.g., western Washington).
Willingness-to-pay studies have been conducted with a variety of foods and locations. Values for willingness to pay for “local” food range from about 9 percent more for New England specialty products (syrup, salsa) and Colorado potatoes, to 50 percent more for fresh Florida-grown produce. Factors that are likely to contribute to differences in consumer willingness to pay include product perishability, base price, and regional differences in attitudes toward local food and food in general (Martinez et al., 2010).

1.3.4 Feasibility of local food production

Several studies in recent years have focused on the ability of different regions to grow food for their own area. These include research on New York State (Peters et al., 2009), the Willamette Valley in Oregon (Giombolini et al., 2010), and the Waterloo region in Ontario (Desjardins et al., 2010). The first two studies analyze agricultural productive capabilities within a geographic area and capacity for meeting all of the nutritional needs of the local population. In terms of grain needs, the Willamette Valley could meet 67 percent of its annual needs. In the New York State study, grain was not separated from other annual crops in the analysis. In looking at food as a whole it became clear that in some populous states, such as New York, complete self-sufficiency in food production is not possible. Peters (2009) found that even if all food production capabilities in New York State were directed to New York City, this would still only fulfill 55 percent of the city’s food needs. In Washington State, it has been estimated that Skagit County alone could meet the demand for potatoes in the entire state, given a slight increase in production acreage and the addition of some varieties (D. McMoran, personal communication, 2012).

Though this work provides an interesting perspective on possibilities for local food production, factors such as economies of scale and comparative advantage, that are very much a reality in
food systems, are often ignored in these types of studies. Frequently overlooked is the fact that a globalized food system and a local food system do not operate completely separately from one another. These studies do not focus on ways to optimize a shift to local food production taking microclimates, soil types, crop rotation needs, and existing infrastructure such as storage, processing and distribution into account. This is what Duram and Oberholtzer (2010, p. 99) referred to as the “inherent complexity of place and natural resource scale” which is often missing from the discussion. The Waterloo study took a different approach to this type of analysis by incorporating nutritional goals (such as increasing consumption of fresh produce). Desjardins et al. (2010) emphasized the contribution that just a 10 percent shift of land use away from corn and soy and toward fresh produce could provide. Though overall there was an excess of carbohydrate production in the region, there was a need for more whole grains in the diet, a role which local producers could fulfill given sufficient processing and distribution infrastructure.

1.3.5 Why relocalize wheat?

Grains and other staple crops have been largely neglected in the food relocalization movement, as existing research on local foods tends to focus on fresh foods (fruits, vegetables, and animal products) (Martinez et al., 2010). Communities’ ability to grow their own grains was lost during the consolidation and industrialization of food production that occurred during the 20th century. However, since grain production represents a significant amount of agricultural land use and because grains are so important in the diets of humans and livestock, relocalization of grains could have major impacts.
Wheat provides 19 percent of human calories worldwide and is the world’s second largest crop (Atchison et al., 2010). Wheat is a major crop grown in the Pacific Northwest and is the third most consumed food (by weight) in western Washington (American Farmland Trust, 2012). While the wheat head is a ubiquitous symbol in the logos of companies who process, bake, and market grain, very few wheat consumers in the U.S. have any understanding about the growing, harvesting, or processing of our country’s most important staple crop. Much of the process of getting wheat into a final product is highly centralized and “hidden” from the consumer.

A move towards the relocalization of wheat would require investments in local and regional infrastructure for grain storage, processing, and distribution. The wheat processing sector is one of the most highly centralized of any in the food processing sector, with 55 percent of the market controlled by just three corporations: Cargill/CHS, ADM and ConAgra (Hendrickson and Heffernan, 2007). Due to the nature of the industrialized commodity system, the movement of wheat from the farm to the elevator and then into the global wheat supply chain involves a loss of information about where and by whom that wheat was grown. To further complicate matters, wheat of different varieties and from different farms is generally blended together during milling to achieve desired end-use qualities in the resulting flour. Though there is a recent trend toward some level of identity preservation in the grain sector (Elbehri, 2007; Magnan 2011), the scale of this identity preservation occurs at a level which works within the current industrial wheat supply chain, rather than at a level that facilitates preserving “the story” of the wheat and allows consumers to connect with the places and people involved in production of the wheat.

There are several additional benefits that could occur as the result of a relocalized wheat system. Many of the infrastructure needs for other grains and grain legumes are similar to those of wheat.
and could be moved through the same processing and distribution channels used for a relocalized wheat system. Grains and grain legumes, because they can be easily stored, would help to fill the gap in local foods due to the influence of growing season on fresh food production. Year-round product availability is important in all types of supply chains (King et al., 2010) and a relocalized grain supply chain could operate regardless of season.

1.3.6 Value chain (or value-based supply chain)

One type of supply chain, called value chain or value-based supply chain, is one in which production and marketing of differentiated high value products exist. Food products in value chains can be differentiated through attributes that traditional supply chains do not typically monitor or promote, such as the environmental and social benefits of a particular producer’s practices (Cantrell, 2009). The move towards value chains is a response to large national and global markets, in which supply chains are long, anonymous and concentrated; suppliers are interchangeable, commodities are co-mingled, and market share is concentrated among a small number of dominant firms. To meet the demand for value-based supply chains, entrepreneurs are working to build shorter supply chains with a scale of food processing and other infrastructure that matches the market, including the ability to verify who produced the food and where and how it was grown (Cantrell and Lewis, 2010).

1.3.7 Local grain movements in the U.S. and worldwide

Regional movements have arisen both in the U.S. and internationally around relocalization of grains and dry beans. “Locavores” are often missing the staple crops in their pursuit to consume foods grown nearby. Hovis, the most famous baker in Britain has switched from importing 27
million dollars’ worth of grain from Canada to using flour milled from 100 percent British wheat (Washington Grain Commission, 2010). Les Moulins de Soulanges, a specialty flour mill in Québec, Canada, has started sourcing wheat from Québec farms, instead of sourcing solely from the western provinces of Canada. In 2005 the company had 243 hectares (600 acres) of wheat under contract. By 2008 that number had jumped to 5,868 hectares (14,500 acres). The dramatic increase resulted from considerable efforts by Québec’s organic grain farmers, the Ministry of Agriculture, agronomists, and local mills, to identify varieties that met quality standards for milling and baking, and to develop viable production systems. As of 2009, 80 percent of Le Moulins de Soulanges’ wheat was from Québec producers (E. Vachon, personal communication, 2009).

Interest in relocalization of wheat production is occurring in Maine and Vermont, resulting in a multi-million dollar USDA grant titled “Enhancing Farmers’ Capacity to Produce High Quality Organic Bread Wheat” (Mallory et al., 2009). Skowhegan, Maine is the site of the Kneading Conference (a meeting of baking and grain enthusiasts) and a recently built small-scale mill (Burros, 2010). Similar activities are occurring in Trumansburg, New York (Fabricant, 2010), Asheville, North Carolina (Wolfe, 2011), Athens, Ohio (Hanus, 2010), Eugene, Oregon (Dietz, 2011), and Victoria, British Columbia (Hergesheimer and Wittman, 2012).

Momentum and interest are building in western Washington, where a new grain mill may be built for the purpose of connecting growers, processors, and consumers (Hills et al., 2011). Western Washington may be well positioned for relocalizing grains because it is home to a diversified agriculture, existing commercial-scale grain production, and growers who are familiar with direct marketing, and there is a strong potential for connections with restaurants and food
businesses in and along the populated Interstate 5 corridor. Additionally, there is strong interest within many communities in preserving farmland.

1.3.8 Barriers to relocalizing wheat

If local food is so popular, why have staple crops such as grains been left out of the movement? Grains have been largely ignored by the local food movement due to many factors. “Freshness” is often cited as a benefit of local food (Ostrom, 2006). The idea of freshness may be less interesting to the consumer with a product such as grain, which is less perishable than fresh produce or animal products.

Studies on the relocalization of fresh (non-staple) foods consistently report barriers such as lack of infrastructure for processing and central distribution (Cantrell and Lewis, 2010; Vogt and Kaiser, 2008). These issues may present an even greater barrier in the case of staple crops. Much of the non-industrial scale infrastructure that existed historically for regional cleaning, storage, processing, and distribution has been lost over time as centralization occurred. In addition, both regulatory and processing barriers to value-added product sales present significant obstacles to increasing local sales in a wide number of agricultural products (Ostrom, 2006), including grain.

Rarely does grain reach the consumer without going through some form of processing, whether it is dehulling, pearling, rolling, steaming, crimping, cracking, or milling. Each of these forms of processing requires specialized equipment, and thus capital investment. It can be difficult to find appropriately scaled equipment for small to mid-sized processing operations. Wheat destined for human consumption is mostly milled into flour and sold to an intermediate in the supply chain
that uses it as an ingredient to produce the finished product that the consumer buys. Because grains are often purchased as an ingredient in a food product, rather than in their whole form, they are more hidden to the consumer than fresh produce or animal products (Atchison et al., 2010), which has kept them from being a focus of the local food movement. Additionally, in a market that relies on being able to tell the “story” behind the food, it is important to have systems in place for tracing food to its origin. Traceback is more difficult with a processed ingredient, such as flour, than it is with whole produce (Martinez et al., 2010).

Grains are often produced in areas with low population densities, and this limits potential for direct marketing, requiring producers to sell into national or international markets. It may seem that a place with well-established grain production infrastructure would be a logical place for grain relocalization to occur. However, as noted by King et al. (2010), the presence of a strong industry that distributes nationally or internationally does not necessarily help create an infrastructure of knowledge and services that facilitates the development of local food supply chains. This is the case in Washington State, where strong export markets have precluded local supply chains for wheat. Ironically, local wheat movements have become most visible in areas either where both wheat production has disappeared completely and minimal infrastructure exists (New England), or in places where wheat is not considered a major crop (North Carolina and western Washington).

On the other hand, in places where direct marketing or short supply chains are possible, there tends to be a focus on high value fresh fruits or vegetables. Farmers who grow grains in rotation with other crops of higher value, will generally focus their attention on the higher value crops.
Grains may continue to be grown for the benefits they provide as rotation crops but are not given as much focus as the cash crops.

Federal purchasing programs such as the Emergency Food Assistance Program and the Commodity Supplemental Food Program may run counter to relocalization efforts for certain commodities. Without policies in place to encourage local purchases, these national programs may favor purchases from large suppliers who can offer discounts on pricing and can deliver bulk shipments (Martinez et al., 2010). Federal agricultural programs such as loan programs and conservation incentives, are often set up to accommodate large-scale, commodity style agriculture rather than diverse systems catering to local or regional markets.

1.4 Project Significance

This research consists of two distinct, but related, studies involving wheat production and markets in the maritime region of western Washington, and addresses two important information gaps. Though late spring topdressing with organic fertilizer offers a promising way to achieve higher protein and baking quality in organic winter wheat, there is a shortage of research on the effects of organic topdressing in the maritime climate of western Washington. The first study, covered in Chapter 2, describes a field study of the effectiveness of late spring topdressing for raising protein in organic hard winter wheat in western Washington.

On the marketing side, there is a lack of information about the level of interest among commercial bakers and the availability of markets for western Washington wheat and flour. This information is critical for the development of wheat processing and infrastructure in the region,
addressing an important barrier to profitability for wheat production. Chapters 3 and 4 focus on
the market potential for grain relocalization in this area. They each describe different parts of a
survey of commercial bakers in western Washington. Chapter 4 also puts relocalization of wheat
systems in western Washington into a larger context through interviews with knowledgeable
individuals involved in grain relocalization movements in other parts of the U.S. The survey and
interviews examine the opportunities and challenges associated with relocalized grain production
systems. Finally, Chapter 5 summarizes results and conclusions from both the production and
marketing studies.

In addition to the chapters, several appendices present related information. A glossary of terms
can be found in Appendix A. Appendices B, C, D, and E provide weather data, soil analysis,
fertilizer analysis, and additional tables and charts with results, respectively, which supplement
Chapter 2. Appendix F contains the cover letter and questionnaire sent to commercial bakers.
Appendix G summarizes a project that involved making wheat crosses in order to improve
germplasm for growing in Alaska, another place where there is interest in local wheat. Appendix
H describes a meeting of home bakers in Mount Vernon, WA in October, 2010 to test western
Washington flour. The remaining Appendices (I and J) are reprints of popular press articles
written by the author of this dissertation describing aspects of local grain projects in western
Washington and beyond.
1.5 References


certification, nutritional claims and product branding pay in consumer food choices? Paper
presented at the Agricultural & Applied Economics Association Meeting. Denver, CO. July

Is the productivity of organic farms restricted by the supply of available nitrogen? Soil Use
and Management 18: 248-255.


wheat protein enhancement. Pacific Northwest extension publication (PNW578).

Brown B.D. and S. Petrie. 2006. Irrigated hard winter wheat response to fall, spring, and late


Cantrell, P. 2009. “Sysco’s Journey from Supply Chain to Value Chain: Results and Lessons
Learned from the 2008 National Good Food Network/Sysco Corporation Pilot Project to
Source and Sell Good Food.” Wallace Center at Winrock International.

Cantrell, C. and R. Lewis. 2010. Food System Infrastructure: Michigan Good Food Work Group
Report No. 5 of 5. East Lansing, MI: C.S. Mott Group for Sustainable Food Systems at


Giombolini, K.J., K.J. Chambers, S.A. Schlegel, and J.B. Dunne. 2011. Testing the local reality: does the Willamette Valley growing region produce enough to meet the needs of the local


Magnan, A. 2011. Bread and the economy of qualities: The creative reconstitution of the

Mallory, E. and H. Darby. 2011. Topdress nitrogen effects on organic winter bread wheat yield
and quality. Presentation at ASA CSSA SSSA annual meeting. San Antonio TX. 18 October
2011.

Halloran, S. Smith, A. Hazelrigg and D. Lambert. 2009. Enhancing Farmers’ Capacity to
Produce High Quality Organic Bread Wheat. USDA grant # ME02009-01366

Mariola, M. J. 2008. The local industrial complex? Questioning the link between local foods and
energy use. *Agriculture and Human Values* 25: 193-96.

Martinez, S., M. Hand, M. Da Pra, S. Pollack, K. Ralston, T. Smith, S. Vogel, S. Clark, L. Lohr,
S. Low, and C. Newman. 2010. Local Food Systems: Concepts, Impacts, and Issues, ERR-
97, USDA Economic Research Service.

Canadian Western Hard Red Spring wheat under organic management alter its breadmaking

Mason, M.G. and R.W. Madin. 1996. Effect of weeds and nitrogen fertilizer on yield and grain
protein concentration of wheat. *Australian Journal of Experimental Agriculture* 36(4): 443-
450.


Chapter 2

Effectiveness of Late Spring Nitrogen Topdressing for Increasing Baking Quality in Organic Hard Winter Wheat in Western Washington State

2.1 Abstract

Winter wheat (*Triticum aestivum*) is currently used in crop rotations in northwestern Washington to break disease cycles and improve soil quality. The wheat is usually sold through the commodity market and rarely generates much profit for the grower. Recently though there has been a resurgence of interest from growers, bakers and consumers in western Washington for the production of organic bread wheat for local consumption which may lead to new markets. Protein is generally the limiting factor for the production of high quality organic winter wheat for
bread. Late season topdressing with nitrogen (N) fertilizer is sometimes used to increase protein levels in conventional wheat production; however it has not been determined whether this type of technique would be effective or economical in organic systems. Two winter wheat trials were planted at two western Washington locations during the 2009-10 and 2010-11 growing seasons to investigate the effects of cultivar and rate of application of a commercially available blended fertilizer approved for organic production. Three cultivars were planted in replicated blocks. A blended fertilizer (Perfect Blend™ 7-2-2, Perfect Blend LLC, Bellevue, WA) was surface applied at five different rates ranging from 0 to 90 kg N ha⁻¹ at the crop boot stage. Grain protein, averaged across varieties and locations, was 9.28 percent and 8.50 percent for the 0 kg N ha⁻¹ treatment during the two seasons, respectively, and 10.27 and 9.56 percent for the plots receiving 90 kg N ha⁻¹. There were no differences in yield due to fertilizer treatments. Protein quality, measured as SDS sedimentation, averaged across varieties, locations and years was 9.9 cc g⁻¹ for the 0 kg N ha⁻¹ treatment and 10.5 cc g⁻¹ for the plots receiving 90 kg N ha⁻¹ at the boot stage. Topdressing with organic sources shows promise for hard winter wheat in northwest Washington, but requires more work to determine quality thresholds for the intended market, which is artisan bakers.

**Keywords** Baking Quality, Organic, Washington State, Wheat

### 2.2 Introduction

#### 2.2.1 Interest in local bread wheat
Wheat is an important rotation crop in western Washington, but often does not provide growers with a net profit when sold on the commodity market. Growers are interested in connecting with higher value local markets. At the same time, there has been an interest from commercial bakers in western Washington to source locally grown bread wheat (Hills et al., 2012; Patzek, 2012). For growers, artisan bakers offer a promising avenue for getting locally grown bread wheat to the consumer. The U.S. industrial bread wheat market demands protein levels of 12-16 percent (Cauvain et al., 2007; Woolfolk et al., 2002). This high protein wheat is designed for modern quick fermentation and high speed mixing practices that are used to produce typical bread available at any American grocery store. The style of baking termed “artisan” generally involves a longer fermentation process, slower mixing speeds, and is closer in style to European baking, which typically uses lower protein wheat. In France, for example, the minimum protein threshold for organic bread is 10.5 percent, recently raised from 9 percent (Casagrande et al., 2009).

Historically, high rainfall zones such as western Washington have not been considered ideal for the production of hard red wheat, the major source of bread flour, because it can be challenging to achieve protein levels demanded by the market. However, recent field trials at Mount Vernon, Washington have shown that it is possible to achieve protein levels of 12-13 percent in hard winter wheat (Jones, 2010), which would be sufficiently high for the artisan bread market, based on artisan bread flour protein levels of 11 percent or lower.

Anecdotal evidence suggests that many of the same customers who purchase artisan bread are also interested in buying organic. Organic production outside of the commodity market has the potential to offer farmers the greatest return for wheat production on a per acre basis, which is
important given the relatively small average size (41 acres) of farms in western Washington (USDA NASS, 2007). In addition, the market for organic foods continues to grow stronger, even in an otherwise weak economy. According to the USDA, in 2007 there were 7,000 acres (2,832 hectares) planted to wheat in all of western Washington (USDA NASS, 2007). However, it has been estimated that Skagit County alone, western Washington’s largest wheat producing county, has approximately 15,000 acres (6,070 hectares) planted to wheat, mostly conventionally grown (D. McMoran, personal communication, 2012). In 2011, there were 266 certified organic farms in western Washington (west of the Cascades) comprising 25,900 certified organic acres (10,481 hectares) and generating over $59 million in farm gate sales (Kirby and Granatstein, 2011). Winter wheat production is well suited for organic growers in western Washington for several reasons: it fits well into existing crop rotations, it is harvested earlier in the summer than spring wheat and thus will dry down more reliably, and it is a strong competitor with weeds.

2.2.2 Baking quality and protein

There is no single measurement for determining baking quality of wheat flour since overall baking quality is affected by a range of factors including ash content, starch damage, particle size, amylase activity and protein (Abécassis et al., 2008). However, protein is often used as a proxy for baking quality when it is not practical to run an entire suite of tests. The most important proteins for bread production are high molecular weight molecules called glutenins and gliadins, which together form gluten. These components give dough elasticity and extensibility that allow for gas retention and greater loaf volume (Gupta et al., 1992).

Sodium dodecyl sulfate (SDS) sedimentation is a robust method for predicting dough strength potential of wheat meal (Mansur et al., 1990). This test is based on the fact that gluten proteins
swell in dilute lactic acid solution and that the larger glutenin proteins (which are related to greater dough strength and elasticity) sediment more slowly and thus result in a higher sedimentation volume. SDS sedimentation results have been shown to be positively correlated with loaf volume (Uhlen et al., 2004).

2.2.3 Factors that affect protein

The factors affecting protein concentrations in wheat can be broadly grouped into the categories of genotype (Baresel et al., 2008; Barraclough et al. 2010; Hussain et al., 2009), environment (Casagrande et al., 2009; Guttieri et al., 2000), and management. Management related factors such as fertility (Nass et al. 2003; Johansson et al. 2003; Lerner et al. 2006), seeding rate (Geleta et al. 2002; Gooding et al. 2002), weed competition (Mason and Madin, 1996), and soil biology (Singh and Kapoor, 1999) have been identified in the literature as influencing protein levels. In particular, N fertility is one of the management factors most easily influenced by growers.

2.2.4 Effect of nitrogen availability on protein

N availability is one of the key factors influencing protein content in wheat (Lueck et al., 2006). Generally, N available to the plant up to tillering primarily increases yield, while N available after this point has decreasing effect on yield and an increasing effect on protein (Brown et al., 2006). Late season N application is particularly important for producers in irrigated systems and high rainfall zones with conventional wheat. However, the protein increase from N applied late in the season is variable from year to year and depends on factors including: rate and timing, yield potential, application method, irrigation system or rainfall pattern, and plant N status at the time of application (Brown et al., 2005).
2.2.5 Nitrogen challenges in organic production systems

In organic wheat production systems, multiple strategies are important for increasing soil fertility including green manure, crop rotations, crop residue management and soil amendment (Justes et al., 2009; Kumar et al., 2002). Sources of N in organic systems include manures, legumes in rotation, and compost. Though it is possible to meet crop N needs through green manure crops and animal manure applications, the timing of N release from these sources often does not meet the timing of crop demand (Berry et al., 2002). Fertilizer amendments offer another option for organic producers to meet crop N needs and are composed of various types of N-containing co-products such as feather meal, dehydrated poultry manure, Chilean nitrate, fish meal, and various seed meals as single-source or blended organic products. These fertilizer amendments are also a more costly way to provide crop N, so it is critical that growers optimize their use.

In the high rainfall winters of western Washington, much of the plant-available N from fall-applied amendments is leached out of the root zone by spring (C. Cogger, personal communication, 2010). Conventional growers approach this issue by topdressing with a soluble or granular fertilizer in the spring. This approach is rarely used by organic grain growers since most organic fertilizers are not readily soluble, and many do not flow easily through equipment that would be used to apply fertilizer. A possible source of readily soluble N is Chilean nitrate, but this is being phased out of organic systems and is currently limited to 20 percent of total crop N needs (USDA NOP, 2007a). This leaves commercial granular fertilizer amendments as the most viable topdressing option for organic wheat growers.

2.2.6 Protein in organic wheat
Various studies have investigated the effect of the level of N fertilization on protein quality (or the ratio of different types of protein molecules) in conventionally grown wheat. Increasing the rate of conventional N fertilizer increased the ratio of gliadins to glutenins, resulting in increased viscosity of the gluten, which improved baking quality for biscuit (soft) wheat (Pedersen et al., 2007) but decreased loaf volume for bread (hard) wheat (Tronsmo et al., 2003). It is logical to assume that the amount and timing of available N may affect protein quality in organic systems as well. Though the literature in this area is not conclusive, there are some indications that this may be the case. The protein and gluten contents of spring wheat grown after a grass-clover sod corresponded to those following cereals given 125-150 kg N ha\(^{-1}\). However, the loaf volume of wheat from fields with soil incorporated sod was consistently better than equivalently yielding plots fertilized with mineral N, possibly due to better synchrony between N release and plant demand because of slow release of N by the sod (Eriksen et al., 2006). Fuerst et al. (2008) found that protein quantity was lower in organic wheat, but protein quality (measured as loaf volume per unit protein) was higher in organic wheat than in conventional wheat when grown at the same location.

**2.2.7 Timing of nitrogen availability**

One of the primary challenges with N fertility management in any crop is matching nutrient availability to crop need. This is a challenge because nitrate (NO\(_3^–\)) is the most prevalent form of plant-available N and it is mobile in soil, causing many opportunities for leakage from the system. Raun and Johnson (1999) observed average recovery rates of applied N ranged from 20-50 percent for (conventional) winter wheat.
Fowler (1998) describes a “lag phase” in the protein concentration-N response curve in soil with low residual plant-available N because initial inputs of fertilizer N often go toward yield. Because increasing yield effectively dilutes grain protein, protein is generally negatively associated with yield (Simmonds, 1995). The effect of spring-applied N on grain protein seems to depend on crop N status. If the crop is N deficient, the spring applied N goes towards increasing yield. In crops with adequate N levels, the application of more N will increase protein (Fowler, 1998; Lloveras et al., 2001; Monahan, 2009). The application of N between the crop boot stage and anthesis can increase protein in conventional wheat. For example, urea ammonium nitrate applied preanthesis and postanthesis at 34 kg N ha$^{-1}$ increased grain N content by 2.7 and 2.4 g kg$^{-1}$ (or protein content by 15.5 and 13.8 g kg$^{-1}$), respectively (Woolfolk et al., 2002).

In a study of irrigated conventional hard red winter wheat production in the Pacific Northwest, 56 kg N ha$^{-1}$ applied between heading and anthesis increased protein between 3.9 and 4.2 percent. When 168 kg N ha$^{-1}$ was applied before planting the increase was less, between 1.9 and 2.3 percent, and when 168 kg N ha$^{-1}$ was applied in early spring, then the increase was between 1.2 and 1.4 percent (Brown et al., 2006).

2.2.8 Mineralization of surface-applied organic fertilizer

Many commercially available organic fertilizers are granular and could be easily applied to wheat at the boot stage. Monahan (2009) applied 11 kg N ha$^{-1}$ in the form of Chilean nitrate at either preanthesis or postanthesis, and neither resulted in an increase in protein. Researchers in Lithuania found that Provina, an organic fertilizer, applied before the planting of winter wheat, increased protein, gluten, and falling number. This study found that it was most efficient to
apply the fertilizer during tillering in early spring (Pekarskas et al., 2009). Several studies report on N topdressing effects. An application of 22 kg N ha\(^{-1}\) of a blended organic fertilizer (Pro-Booster 10-0-0, North Country Organics, Bradford, VT) at flag leaf stage resulted in a protein increase of 2.1 percent (from 11.3 to 13.4 percent) in winter wheat in Vermont (Darby et al., 2010). In 2011, Darby et al. raised protein from 0.9 to 1.2 percent by applying ProBooster (10-0-0) at 22 kg N ha\(^{-1}\) at either flag leaf stage or as a split application at flag leaf and boot stages. Mallory and Darby (2011) found that a boot stage application of Chilean nitrate at a rate of 22 kg N ha\(^{-1}\) resulted in a protein increase from 8.1 to 9.3 percent in hard red winter wheat.

Topdressing is the application of fertilizer while the crop is in the field; this application is not incorporated into the soil. Mineralization rates of surface-applied organic fertilizer are not well understood. The existing literature on N mineralization of organic fertilizers is focused on soil-incorporated amendments (Gale et al., 2006), which is the preferred method of application. Since N mineralization from organic fertilizers is dependent on soil conditions, especially in the case of surface-applied fertilizers, it is difficult to generalize results across climates. Climatic conditions in western Washington are quite different than those in Maine and Vermont where Darby et al. and Mallory and Darby’s research occurred, making it unclear whether the topdressing technique would be successful in western Washington. Additionally, varieties and organic fertilizers differ among locations.

The goal of this study was to determine the effect of topdressing with an organic N fertilizer on grain yield, test weight, protein quantity, and protein quality of three varieties of hard winter wheat grown in western Washington.
2.3 Materials and Methods

2.3.1 Field Trials

A field trial was replicated at two locations in Skagit County, northwestern Washington over two growing seasons: 2009-10 and 2010-11. The two growing seasons will be referred to by the harvest year (2010 and 2011) from here on. The first location was the Washington State University research and extension center at Mount Vernon. The soil type is Skagit silt loam. This fine silty soil averages less than 15 percent fine and coarser sand, averages 18 to 30 percent clay and contains 20 to 50 percent volcanic glass (Soil Survey of Skagit County, 1989). The second location was Hedlin Family Farm, a diversified organic farm in La Conner, Washington that primarily produces vegetables and vegetable seeds. The soil type at La Conner is Sumas silt loam which consists of fine-silty over sandy or sandy-skeletal with a depth to sand or gravelly sand ranges from 14 to 36 inches. The upper part of the soil profile has 18 to 35 percent clay and less than 15 percent fine sandy or coarser material. The lower part is sand or gravelly sand (Soil Survey of Skagit County, 1989). Both Skagit and Sumas soils are deep poorly drained soils formed on recent alluvium. The exact field site of the trial at each location differed slightly each year and followed the rotations typical at each site. The La Conner site received 340 kg N ha\(^{-1}\) of Proganic 8-2-4 fertilizer (Wilbur Ellis Co., Yakima, WA) prior to planting, following the farm’s typical fertilizer applications. All field trials were planted on certified organic land, except 2010 Mount Vernon which was planted on conventional ground but was managed according to organic standards.
For this study, cultivars of hard winter wheat were chosen that had shown promise in western Washington systems: hard red Bauermeister (Jones et al., 2007a), hard red WA008022 (pedigree =Estica/Finley//Finley; breeder number J000048), and hard white MDM (Jones et al., 2007b). The three cultivars were factorially combined with five rates of late spring-applied organic N amendment. The fertilizer used for both early spring and late spring application was Perfect Blend™ 7-2-2 fertilizer (Perfect Blend LLC, Bellevue, WA). This is a fertilizer that is commonly used by organic growers in the area and meets the National Organic Program standards for use of processed animal manures in organic crop production and because it has been heat treated does not require a specific interval between application and harvest (USDA NOP, 2007b). The N in Perfect Blend 7-2-2 is derived from chicken manure and feather meal. According to analysis provided by the manufacturer, the product consists of 5.5 percent water soluble N and 1.5 percent water insoluble N. An independent analysis of each year’s fertilizer can be found in Appendix D. Fertilizer was applied based on the analysis on the bag.

The resulting 15 factorial treatment combinations were arranged in a randomized complete block design and replicated four times. Field plot width was dictated by the size of available equipment for planting and harvesting. The length of the plots was dependent on the space available, but was 9.1 to 30.5 m, depending on the site year. Wheat was planted in the fall using a Hege 1000 small-plot planter (Hege Equipment, Inc., Colwich, KS) with 6 row double disks on 17.8 cm spacing, and was seeded at a rate of 112 kg ha⁻¹ and a depth of 2.5 to 5 cm. A buffer row was planted around the plots to minimize edge effect. Full details on site preparation and dates of field activities for each growing season are presented in Table 2.1.
An early spring topdressing of Perfect Blend 7-2-2 was spread at the rate of 34 kg N ha\textsuperscript{-1} in mid-March on all plots in order to match standard organic commercial practices for winter wheat fertility management in western Washington. All fertilizer was applied by hand using a Handy Green broadcast spreader (Scotts, Marysville, OH) in order to keep fertilizer within the plot. At boot stage (Feekes growth stage 10) (Feekes, 1941) (mid May to early June, depending on the year), fertilizer treatments were applied at the rates of 0, 22, 45, 67 and 90 kg ha\textsuperscript{-1}. During the growing season, plots were inspected regularly for disease and nutrient deficiency symptoms and weeds in between plots were controlled by mowing. Level and type of weed pressure varied by year and location. Hand weeding was used when weeds presented an issue for harvesting.

Soil samples were taken three times: before planting, in early spring before fertilizer was applied, and in late spring before topdress fertilizer was applied. At each sampling date, samples were bulked for each site. Soil samples were collected with an AMS one piece soil probe (Forestry Suppliers, IL) at a depth of 30 cm at 20 locations throughout the trial area. Soil was thoroughly mixed and a subsample was placed in a paper bag and dried at 50 degrees C for 72 hours and then stored dry until analysis. Soil samples were analyzed by A & L Western Agricultural Laboratories (Portland, OR). Soil test results are presented in Appendix C. Preplant soil tests involved a standard chemical analysis, but in subsequent sampling only nitrate N was measured, since this was the nutrient of interest and was the nutrient most likely to change. Existing soil phosphorus (P) and potassium (K) levels are given in Table 2.1. P and K were adequate for all site years at levels that would not limit plant growth.

Weeds were controlled by mowing between plots and some hand weeding within plots. For each plot prior to harvest, the height of plants at maturity was measured in cm from ground to top of
spike, excluding awns. Degree of lodging (plants fallen over) was scored visually on a percentage scale ranging from 0 to 100 percent. Heading date was recorded for each variety at each site-year as the date on which 50 percent of the culms were fully headed. Level and type of weed pressure varied by site and by year. Plots were harvested using a Wintersteiger plot combine (Wintersteiger AG, Ried im Innkreis, Austria) when grain moisture was 13 percent. After yield was measured, the harvested samples were cleaned with an Almaco air cleaner (Allan Machine Co., Nevada, IA) or a Clipper M-2B seed cleaner (Ferrell-Ross, Oklahoma City, OK). Postharvest measurements included yield, test weight, grain protein, SDS, falling number, flour yield, flour protein and flour ash.

Precipitation and temperature data for each field trial season were obtained from the WSU NWREC AgWeatherNet station and are presented in Appendix B. The 2010 and 2011 sites at Mount Vernon were 300 m and 700 m, respectively, from the WSU NWREC AgWeatherNet station. The La Conner sites were 12 km away from the WSU NWREC AgWeatherNet station.

2.3.2 Data Collection

Yield

Wheat in plots was harvested into an individual bag with a Wintersteiger plot combine (Wintersteiger AG, Ried im Innkreis, Austria), and grain samples were air-dried at room temperature (23 degrees C) to achieve a standard moisture content of 13.5 percent. The weight of each uncleaned grain sample was measured on a digital balance (Mettler-Toledo, Greifensee, Switzerland).

Test weight
Test weight in pounds per bushel was determined using a modification of American Association of Cereal Chemistry method 55-10.01 (AACC, 2000). Uncleaned grain was emptied from a spouted sample pan into a 1 quart (946 mL) cup until overflowing, then the excess grain was scraped off using a stroker and the full cup was weighed. In preparation for further analysis, wheat samples were cleaned of chaff, straw, weeds, and other debris with an air blast seed cleaner (ALMACO, Nevada IA).

**Grain protein**

Samples were mixed by hand and a 500 g subsample of cleaned wheat was collected for protein analysis. Whole grain protein content was measured using a Perten IM9200 Near Infrared (NIR) analyzer (Perten Instruments, Springfield, IL) which had been calibrated with wheat samples grown in the area and sent for total N analysis on a LECO model FP-528 Protein/Nitrogen Determinator (LECO Corporation, Saint Joseph, MI), (AACC approved method 39-25) (AACC, 2000). Grain protein is reported on a 12 percent moisture basis.

**Falling number**

Whole grain wheat samples were prepared for falling number analysis using a Cyclone Sample Mill (Udy Corporation, Fort Collins, CO) to pass through a 0.5-mm mesh screen after the removal of weed seeds, stems and other impurities. The mill was cleaned between samples with a vacuum and brush. Milled samples were stored at room temperature in sealed plastic bags at room temperature until analysis. AACC approved method 56-81.03 was followed to measure Hagberg falling number on a Perten F1500 (Perten Instruments, Springfield, IL) (AACC, 2000). Falling number, which measures grain soundness, was not analyzed for every sample as a difference was not expected based on fertilizer treatments. A study conducted during the same
growing seasons at one of the sites by Patzek (2012) showed that falling number was not sensitive to levels of N applied (0, 95, 190 kg N ha\(^{-1}\)) as poultry feather meal or urea. Instead, falling number was determined for one replicate (15 plots) from each site year to assure that the grain was sound and to test for differences due to treatment. Because there was no apparent relationship between topdressing treatment and falling number, no further falling number analyses were completed.

**SDS sedimentation**

SDS sedimentation was tested using a modification of Carter et al. (1999). Whole grain wheat samples were prepared using a Cyclone Sample Mill (Udy Corporation, Fort Collins, CO) with a 1.0 mm screen. A stock solution of lactic acid was made by mixing 1 part 85 percent lactic acid to 8 parts distilled water. This solution was placed on a stir table for 3-5 minutes and then was refluxed overnight in an 80 degrees C oven to break long chains of lactic acid that form during water addition. An SDS solution was made with 20 g of SDS powder and 50 mL distilled water heated for 5-10 minutes on a stir table and then brought to a volume of 100 ml with additional distilled water. For each whole meal sample, 0.5 g was placed in a borosilicate glass tube (150 mm long, 14 mm inside diameter), held in plastic racks engraved with measurement scales. In each rack of 20 tubes, two standard samples, one with a high sedimentation value and one with a low sedimentation value, were included. Distilled water (4.0 mL) was added to each tube and tubes were mixed using a Genie 2 vortexer (Scientific Industries, Bohemia, NY) for 20 seconds, left for 7 minutes, then vortexed again for 10 seconds and left for 3.5 minutes. Each tube had 12 mL lactic acid/SDS solution added to it. Tubes were capped and put on a modified Rocker2 platform mixer (Boekel Scientific, Feasterville, PA) for 1 minute (40 inversions) at an angle of
20 degrees to each side of horizontal. The platform mixer was stopped for 2 minutes and then shaking was resumed for 1 minute. Racks containing tubes were placed upright and after 10 minutes the height of the sediment interface (in mm) was recorded. Values were then converted to cc g⁻¹ based on a regression line that had been previously established for the test equipment.

Because SDS sedimentation values result from a combination of protein quantity and quality, adjusting the results to a 10 percent protein basis allows one to distinguish between changes in quality, independent of quantity. In order to evaluate differences in protein quality between test samples, SDS sedimentation data were converted to a 10 percent protein basis. This was done by dividing sedimentation values by protein, then multiplying by 10 (Carver, 2009).

**Flour extraction**

Samples were milled using a modified Quadramat Senior (Brabender, Duisburg, Germany) mill at the Oregon State University cereal quality testing laboratory in Corvallis, OR. The day before milling each 500 g sample was tempered to 14.5 percent moisture. Tempering was accomplished by adding water to samples in 946 mL wide mouth polypropylene containers with lids (Thermoscientific, Waltham, MA). Each container was tumbled using a manual Mini-Inversina (Bioengineering AG, Wald, Switzerland) for 1 minute then left to equilibrate for approximately 16 hours. Samples were run through a break mill then using a rotating sieve shaker (Great Western Manufacturing, Leavenworth, KS) were sieved into three components: break flour (<150 µm), middlings (150 – 500 µm), and bran (>500 µm). The sieve shaker was run at a rate of 60 rpm for 1 minute, after which bran was removed. Sieving continued for 2 minutes at which point break flour was weighed and middlings were run through a reduction mill. The results from the reduction mill were sieved on a sieve shaker for 3 minutes to separate reduction flour
(<150 µm) from shorts ( >150 µm). Bran, break flour, reduction flour and shorts were weighed. Flour extraction was calculated as [weight of break flour (g) + weight of reduction flour (g)]/weight of tempered sample (kg) (Posner and Hibbs, 2005).

Flour protein and ash
Flour protein is usually about a full percentage point lower than grain protein as some protein concentrated in the outer layers of the bran and germ are removed with milling of white flour. Protein and ash content of flour was measured using a FOSS Infratec 1241 (Foss, Eden Prairie, MN). The sample from milling was thoroughly mixed and a 5 g subsample was used to analyze using NIR techniques for protein content (AACC method 39-11.01) and ash content (AACC method 08-21.01) (AACC, 2000). Protein was reported on a 14 percent moisture basis and ash is reported on a dry matter basis.

Data analysis
Data were analyzed using SAS 9.2 (SAS Institute Inc., Cary, NC) and checked for normality using normal probability plots and histograms of residuals. Levene's test was used to check homogeneity of variance because all but two variables had normally distributed residuals. The variables SDS and SDS adjusted to a 10 percent protein had non-normally distributed residuals. However, when the top 5 percent of outliers were removed, normal distribution of residuals was achieved and there was no change in the significance of independent variables. PROC GLM was used for determining main effects (year, location, variety, and N treatment) and interaction effects, and LS means was used for means separation.
2.4 Results

Plants displayed no symptoms of nutrient deficiency for any site years. Stripe rust (*Puccinia striiformis* f. sp. *tritici*) was present on plants in the late spring/early summer in all site years, which is typical for the area. Varieties MDM, Bauermeister and 8022 have each been classified as ‘moderately resistant’ to stripe rust in variety evaluations conducted by WSU (Chen, 2009; Chen, 2011) and 8022 has a highly susceptible parent (Finley) (Chen, 2011). The 2010 disease ratings on a percentage scale for MDM, Bauermeister and 8022 were 40, 95 and 40 percent, respectively, in 2010 and 20, 20 and 20 percent in 2011 (data not shown).

2.4.1 Yield

Yield and other grain measurements are summarized in Table 2.2 and p-values for main effects and interactions are shown in Table 2.3. Yield in 2010 was higher, in general, than yield in 2011. In 2010, average yields at the La Conner and Mount Vernon locations were 5.91 and 4.65 t ha\(^{-1}\), respectively, while in 2011 yields at La Conner site in 2011 averaged 4.09 t ha\(^{-1}\) (see Table 2.4). At the La Conner site, 8022 was the highest yielding variety both years. At Mount Vernon in 2010, there were no significant differences in yield. Due to intense weed pressure, primarily ryegrass, the yield at Mount Vernon was extremely low in 2011, ranging from 0.03 to 2.0 t ha\(^{-1}\). Thus, the yield data from this site year was not included in the analysis. However, the quantity of wheat harvested from most of the Mount Vernon plots in 2011 was sufficient for quality analyses. There were significant interactions of year by variety (p=0.0211) and location by variety (p< 0.0001). As expected, yield was not affected by topdressing treatment.

2.4.2 Test weight
The minimum acceptable standard for test weight is 77.2 kg hL⁻¹ for grade 1 hard winter wheat (USDA FGIS, 2006). Test weight across both locations averaged 84.7 and 85.7 kg hL⁻¹ in 2010 and 2011, respectively. Topdressing treatment did not affect test weight at either location in either year. Bauermeister at Mount Vernon in 2011, which averaged 73.4 kg hL⁻¹, was the only variety site year below 77.2 kg hL⁻¹, most likely due to the extreme weed pressure (see Table E3).

2.4.3 Grain protein

Grain protein of individual plots, including all site years, ranged from 7.0 percent to 12.0 percent. Protein was on average higher in 2010 than in 2011, and was higher on average at Mount Vernon than at La Conner. Grain protein, averaged across varieties and locations, was 9.28 percent and 8.50 percent for the 0 kg N ha⁻¹ treatment during the two seasons, respectively, and 10.27 and 9.56 percent for the plots receiving 90 kg N ha⁻¹. Of the three varieties, 8022 had the lowest average grain protein level at La Conner in 2010 (8.36 percent) and at Mount Vernon in 2011 (9.33 percent) (see Table 2.5). In most cases, protein levels for the 90 kg N ha⁻¹ treatment were not significantly higher than for the 67 kg N ha⁻¹ treatment (see Table E4). Protein increase, averaged over varieties (expressed as the difference between 0 kg N ha⁻¹ and 67 kg N ha⁻¹ topdressing treatments), was 0.9, 1.5, and 0.7 percent for 2010 La Conner, 2010 Mount Vernon and 2011 La Conner site years, respectively.

Grain protein showed significant year by location, year by variety, and location by variety interactions as well as a three way year by location by variety interaction. The effect of treatment was significant (p<.0001) with the protein level increasing as a result of increasing level of N application for all three varieties both years (see Figure 2.1), with the variety
Bauermeister showing the greatest increase in protein (see Table E4). The 90 kg N ha\(^{-1}\) treatment had an overall mean of 9.9 percent protein which was not significantly different than the 67 kg N ha\(^{-1}\) treatment which had a mean of 9.8 percent protein (see Table 2.2).

### 2.4.4 Falling number

Falling number results are presented in Table 2.2. The mean falling number of all samples tested (n=60) was 369 s (SE = 14). Of the 60 samples tested, 15 did not meet the minimum standard for falling number, and most of them were MDM in 2010 (data not shown). Falling number under 300 may indicate preharvest sprouting, however there was no visible sprouting of grain in either 2010 or 2011 at either location. Nitrogen treatment did not have a significant effect on falling number (Table 2.3).

### 2.4.5 SDS sedimentation

As with grain protein levels, sedimentation values were, in general, higher in 2010 and higher at the Mount Vernon location. Sedimentation values for plots in all site years ranged from 4.8 to 16.1 cc g\(^{-1}\). Sedimentation values averaged across varieties, locations and years were 9.9 cc g\(^{-1}\) for the 0 kg N ha\(^{-1}\) treatment and 10.5 cc g\(^{-1}\) for the plots receiving 90 kg N ha\(^{-1}\) at the boot stage. As a point of reference, wheat samples between 7 and 12 percent protein that were analyzed at the USDA wheat quality lab in Pullman using whole meal SDS techniques ranged from 6.4 to 19.7 cc g\(^{-1}\), with a mean value of 14.2 cc g\(^{-1}\) (D. Engle, personal communication, 2011).

Though there appeared to be an upward trend in SDS sedimentation values with increasing amounts of fertilizer (see Table E9), when fertilizer treatment was analyzed as a categorical variable, it was not statistically significant (p=0.0751).
In this study, the increase in sedimentation volume appeared to be due to increase in overall protein levels resulting from N application. When sedimentation values were adjusted to a 10 percent protein basis, the upward trend with increasing fertilizer was no longer present (see Table E10). This result suggests that even when N increased overall protein quantity it had no effect on protein quality (ratio of glutenins to shorter chain proteins). If there had been an overall increase or decrease in protein quality due to N fertilizer, this would have been apparent with the adjustment to a 10 percent protein basis.

2.4.6 Flour extraction, flour ash and flour protein content

Overall mean flour extraction rate was 600 g kg\(^{-1}\), but ranged from 344 g kg\(^{-1}\) to 663 g kg\(^{-1}\). Significant main effects on flour extraction rate were year and variety. Flour ash content is an indication of the amount of bran in the flour and ranged between 0.4 percent and 0.7 percent with a mean of 0.5 percent. Neither extraction rate nor flour ash content was significantly affected by N fertilizer treatment (Table 2.3).

Flour samples averaged 0.86 percentage point lower in protein than the corresponding grain samples. Mean flour protein in 2010 was 8.4 percent and 9.5 percent at La Conner and Mount Vernon, respectively. In 2011, mean flour protein at both locations was 8.2 percent. Significant variety and N treatment effects (p<.0001) existed for flour protein. In general, flour protein levels for the 90 kg N ha\(^{-1}\) treatment were not significantly higher than the 67 kg N ha\(^{-1}\) treatment (see Table E7), suggesting that additional N beyond 67 kg N ha\(^{-1}\) did not result in further gains in either grain or flour protein.
2.5 Discussion

As found in other studies where N was added by topdressing, the effectiveness of N application for raising protein levels is highly dependent on environmental conditions and can vary from year to year. In both years there were effects due to N application. Interestingly, protein levels in 2010 were higher than in 2011, and N application was more effective at raising protein in 2010 than in 2011. This may have been due to weather-related factors. In 2010, 83.8 mm of precipitation fell in the 14 days following N application, while in 2011 only 8.9 mm fell in the 14 days after N application (see Appendix B), which may have contributed to the differences in the magnitude of the protein increase. The historical (1994-2012) average precipitation for a two week period during this time of year (mid-May to early June) is 35.2 mm. Because the soil at both locations is silt loam and is relatively heavy, crusting can occur over the winter. The precipitation that occurs soon after N application is needed to allow surface applied nutrients to enter the root zone. Both growing seasons (October to August) had fewer heat units (base 40 degrees F), 3,432 and 3,372, respectively, compared to the historical average (3,461). Additionally, in both 2010 and 2011 the average temperatures during the months of March to July, critical months for the development of winter wheat, were -0.6 and 2.1 degrees C cooler than average, respectively. Cool moist conditions favor the development of stripe rust, which can impact yield and grain test weight (Chen, 2005). Cool conditions also may have limited plant metabolism by limiting N uptake in 2011 compared to 2010.

We expected that protein quality, expressed as sedimentation values adjusted for protein level, may have increased with the N application based on the fact that N taken up at different stages of wheat development may be partitioned into different protein types (Ilas-Rubio et al., 2011).
However, a difference in protein quality was not found between N treatments. The literature on topdressing with conventional N fertilizer states that additional N applied as late-season topdressing is partitioned in gliadin protein rather than in the large molecular weight glutenins that result in wheat with higher sedimentation volume (Doekes and Wennekes, 1982; Gupta et al., 1992; Wieser and Seilmeier, 1998). Gliadins offer extensibility to the dough and are important for a variety of end uses (Popper et al., 2006).

Using average differences in protein between plots treated with 67 kg N ha\(^{-1}\) and those receiving no N fertilizer, we could calculate additional protein attributable to topdressing and use this value to determine additional N that was taken up and assimilated into protein in these plants. For the 2010 La Conner site-year, an additional 10.7 kg N ha\(^{-1}\) were assimilated (which equals 16 percent of the fertilizer N). At Mount Vernon in 2010, 12.0 kg N ha\(^{-1}\) were assimilated (18 percent of the applied N). At La Conner in 2011, only an additional 4.8 kg N ha\(^{-1}\) were assimilated (7 percent of the applied N). The experimental design did not allow us to determine recovery rates of the first N application in early spring. The amount of N recovery seemed reasonable, given the literature. Raun and Johnson (1999) observed average recovery rates of applied N ranged from 20-50 percent for (conventional) winter wheat. Because the organic fertilizer in this experiment was surface applied and was not completely water soluble, it is not surprising that the recovery rates would be lower than those cited by Raun and Johnson (1999).

The varieties used in this study were developed under eastern Washington dryland conditions. As varieties better adapted for maritime Pacific Northwest conditions become available, it may be possible to achieve even greater protein increases with late-spring N applications. White wheat tends to have more issues with preharvest sprouting than red wheat (Flintham and Gale,
1988), so it was not a surprise that MDM had the lowest falling number values. In this study, it was apparent that MDM may be too prone to preharvest sprouting for reliable performance in western Washington conditions.

The level of protein increase seen in these field trials was comparable to that seen by Darby et al. (2010), Darby et al. (2011) and Mallory and Darby (2011); however, in this study protein values were lower on a protein increase per unit of applied N basis than Darby and Mallory’s studies. While it only took 22 kg N ha\(^{-1}\) for the protein to increase 0.9 to 2.1 percent in the Darby and Mallory studies, it required 67 kg N ha\(^{-1}\) to achieve a 0.9 percent protein increase in this study. Yields in our trials in western Washington were higher, in general, than in Darby and Mallory’s trials in Maine and Vermont. Mean yields for site years in western Washington ranging from 4.1 to 5.9 t ha\(^{-1}\) compared to mean yields for site years in the Vermont and Maine studies 1.4 to 5.1 t ha\(^{-1}\). Because additional protein is diluted by yield, the high yields may explain, in part, the lower levels of protein increase in western Washington. These differences may also have to do with the differing conditions of western Washington and the Northeastern U.S., where the Darby and Mallory studies occurred. Other factors that could have limited the protein levels in western Washington were plant N status, soil type, and mineralization rate of surface-applied fertilizer which is highly dependent on soil temperature and moisture.

As of May 2012, the bulk price for the fertilizer used in this experiment, Perfect Blend 7-2-2, was $529 per ton. Perfect Blend 7-2-2 is likely too expensive to be used economically for wheat in a commercial setting. However, it represented an ideal fertilizer with which to test the concept of organic surface-applied fertilizer because of its relatively high available N level, ease of handling, and small particle size (for more rapid nutrient release). Application of raw manure
less than 90 days before harvest of above ground plant parts is prohibited by National Organic Program standards (USDA NOP, 2007b). Because of a special heat treatment process undergone by Perfect Blend 7-2-2, the product has been approved for use within the preharvest interval. The time intervals between topdressing and harvest in this field trial were 94 days and 81 days, in 2010 and 2011, respectively. Other manure-based N fertilizers approved for organic production which are less expensive and should be evaluated when applied to wheat at an earlier stage so that they will not fall within the 90 day preharvest interval.

2.6 Conclusion

This study demonstrates the potential for increasing protein levels of organic wheat through the application of late-season N in western Washington. However, more work is needed to determine the quality parameters that artisan bakers require when they purchase flour outside of the commodity market, both for whole wheat and white flour. Anecdotal evidence suggests that some artisan bakers may be willing to adjust baking processes in order to use local wheat flour that may have different technical specifications than standard flour on the market, but there have not been any studies on how much flexibility bakers will have.

Two commercial bread bakers in western Washington evaluated flour samples of Bauermeister from the La Conner 2010 site-year, and though not part of this study, their results are worth noting. One of the bakers found that using a 2 hour preferment at 26 degrees C gave a depth and complexity of flavor to the bread made from this wheat and found that the wheat had high enzymatic activity, great strength, a grassy aroma, and sweet flavor (S. Mangold, personal communication, 2011). The second baker stated that Bauermeister from the La Conner 2010 site-year was “a little tricky in the oven, but well worth it” (G. De Pasquale, personal
These commercial bakers are excited about the flavor of the wheat grown in this study and the potential to connect with local agriculture by using wheat grown in western Washington (Jones, 2012).

For reasons discussed in Chapters 3 and 4, it is unlikely that wheat produced in western Washington will yield flour that is exactly like flour currently used by bakers. However, anecdotal evidence suggests that bakers who are interested in working with western Washington wheat might be willing to accept flour that is not exactly like their current supply. More information is needed on other possible (non-bread) end uses (e.g., pastry, cake, cookies, tortillas) for flour that does not meet minimum protein levels for use in bread. This study contributes to the literature on N fertility management in organic bread wheat, and will help inform the development of a decentralized wheat supply chain in northwestern Washington and other regions.
2.7 References


Table 2.1 Summary of conditions, cultural practices and soil nutrient status in 2010 and 2011 at La Conner and Mount Vernon.

<table>
<thead>
<tr>
<th></th>
<th>La Conner (LC)</th>
<th>Mount Vernon (MV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil series</td>
<td>Sumas silt loam</td>
<td>Skagit silt loam</td>
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<td>Growing season</td>
<td>2010</td>
<td>2010</td>
</tr>
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<td>Preplant SOM</td>
<td>3.5%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Preplant SOM</td>
<td>3.5%</td>
<td>4.1%</td>
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<tr>
<td>Preplant P</td>
<td>104 VH</td>
<td>153 VH</td>
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<tr>
<td>Preplant K</td>
<td>285 H</td>
<td>405 H</td>
</tr>
<tr>
<td>Preplant NO\text{$_3$} &amp; 34</td>
<td>12</td>
<td>26</td>
</tr>
<tr>
<td>Planted</td>
<td>Oct 15</td>
<td>Oct 6</td>
</tr>
<tr>
<td>Pre-fertilizing NO\text{$_3$} &amp; 34</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Fertilized</td>
<td>Mar 22</td>
<td>Apr 8</td>
</tr>
<tr>
<td>Pre topdressing NO\text{$_3$} &amp; 4</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>Topdressed</td>
<td>May 15</td>
<td>Jun 1</td>
</tr>
<tr>
<td>Heading</td>
<td>May 21</td>
<td>Jun 7</td>
</tr>
<tr>
<td>Harvest</td>
<td>Aug 17</td>
<td>Aug 21</td>
</tr>
</tbody>
</table>

$^a$ The year listed is the year of harvest

$^b$ Soil organic matter

$^c$ Soil phosphorus analysis used a weak Bray extraction

$^d$ ppm in soil. Relative levels according to A&L Laboratories Inc. (Portland, OR) are included for P and K (L=low, M=medium, H=high, VH=very high)

$^e$ Fertilized at a rate of 34 kg ha$^{-1}$

$^f$ Topdressed at rates of 0, 22, 45, 67, or 90 kg ha$^{-1}$
Table 2.2 Marginal means and standard error by year, location, variety, and N application rate for yield, test weight, grain protein, falling number, sedimentation volume, sedimentation volume adjusted to 10% protein, flour extraction, flour protein, and flour ash content.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Yield (t ha⁻¹)</th>
<th>Test Weight (kg hL⁻¹)</th>
<th>Grain Protein (%)</th>
<th>FN 🟢</th>
<th>SV 🟢</th>
<th>SV₁₀p 🟢</th>
<th>Flour Extraction (g kg⁻¹)</th>
<th>Flour Protein (%)</th>
<th>Flour Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>5.28 ± 1.01</td>
<td>84.1 ± 0.4</td>
<td>9.9 ± 0.1</td>
<td>295 ± 16</td>
<td>10.8 ± 0.2</td>
<td>10.8 ± 0.1</td>
<td>610 ± 3</td>
<td>8.9 ± 0.1</td>
<td>0.52 ± 0.01</td>
</tr>
<tr>
<td>2011</td>
<td>4.09 ± 0.11</td>
<td>85.2 ± 0.8</td>
<td>9.0 ± 0.1</td>
<td>446 ± 9</td>
<td>9.5 ± 0.2</td>
<td>10.5 ± 0.2</td>
<td>587 ± 5</td>
<td>8.2 ± 0.1</td>
<td>0.55 ± 0.01</td>
</tr>
<tr>
<td><strong>Location</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>La Conner</td>
<td>5.00 ± 0.12</td>
<td>86.1 ± 0.5</td>
<td>9.1 ± 0.1</td>
<td>347 ± 17</td>
<td>9.5 ± 0.2</td>
<td>10.4 ± 0.2</td>
<td>600 ± 4</td>
<td>8.3 ± 0.1</td>
<td>0.53 ± 0.01</td>
</tr>
<tr>
<td>Mount Vernon</td>
<td>4.65 ± 0.09</td>
<td>81.6 ± 0.5</td>
<td>9.8 ± 0.1</td>
<td>391 ± 21</td>
<td>10.7 ± 0.2</td>
<td>11.0 ± 0.2</td>
<td>601 ± 4</td>
<td>9.1 ± 0.1</td>
<td>0.54 ± 0.01</td>
</tr>
<tr>
<td><strong>Variety</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bauermeister</td>
<td>4.45 ± 0.11</td>
<td>82.9 ± 0.8</td>
<td>9.7 ± 0.1</td>
<td>405 ± 17</td>
<td>10.9 ± 0.2</td>
<td>11.3 ± 0.2</td>
<td>594 ± 5</td>
<td>9.0 ± 0.1</td>
<td>0.58 ± 0.01</td>
</tr>
<tr>
<td>MDM</td>
<td>4.64 ± 0.12</td>
<td>83.0 ± 0.6</td>
<td>9.6 ± 0.1</td>
<td>316 ± 30</td>
<td>10.7 ± 0.2</td>
<td>11.1 ± 0.2</td>
<td>587 ± 5</td>
<td>8.8 ± 0.1</td>
<td>0.53 ± 0.01</td>
</tr>
<tr>
<td>8022</td>
<td>5.55 ± 0.17</td>
<td>87.6 ± 0.5</td>
<td>9.0 ± 0.1</td>
<td>388 ± 17</td>
<td>8.8 ± 0.3</td>
<td>9.7 ± 0.2</td>
<td>618 ± 4</td>
<td>8.1 ± 0.1</td>
<td>0.49 ± 0.01</td>
</tr>
<tr>
<td><strong>N rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>4.84 ± 0.22</td>
<td>85.3 ± 0.9</td>
<td>8.9 ± 0.1</td>
<td>374 ± 31</td>
<td>9.9 ± 0.3</td>
<td>10.9 ± 0.3</td>
<td>608 ± 5</td>
<td>8.2 ± 0.2</td>
<td>0.51 ± 0.01</td>
</tr>
<tr>
<td>22</td>
<td>4.95 ± 0.19</td>
<td>84.3 ± 0.9</td>
<td>9.3 ± 0.1</td>
<td>371 ± 29</td>
<td>9.8 ± 0.3</td>
<td>10.5 ± 0.3</td>
<td>592 ± 8</td>
<td>8.5 ± 0.1</td>
<td>0.53 ± 0.01</td>
</tr>
<tr>
<td>45</td>
<td>4.95 ± 0.20</td>
<td>84.5 ± 0.9</td>
<td>9.4 ± 0.1</td>
<td>370 ± 30</td>
<td>10.2 ± 0.3</td>
<td>10.8 ± 0.3</td>
<td>600 ± 7</td>
<td>8.6 ± 0.1</td>
<td>0.53 ± 0.01</td>
</tr>
<tr>
<td>67</td>
<td>4.78 ± 0.21</td>
<td>84.6 ± 1.0</td>
<td>9.8 ± 0.2</td>
<td>372 ± 36</td>
<td>10.3 ± 0.3</td>
<td>10.5 ± 0.2</td>
<td>601 ± 4</td>
<td>9.8 ± 0.2</td>
<td>0.53 ± 0.01</td>
</tr>
<tr>
<td>90</td>
<td>4.90 ± 0.18</td>
<td>84.3 ± 1.0</td>
<td>9.9 ± 0.2</td>
<td>359 ± 30</td>
<td>10.5 ± 0.3</td>
<td>10.6 ± 0.3</td>
<td>600 ± 7</td>
<td>9.0 ± 0.2</td>
<td>0.54 ± 0.01</td>
</tr>
</tbody>
</table>

*Hagberg Falling Number analyses were performed on a subset of the samples from each location year to check for significant treatment differences*

*Sedimentation volume

*Sedimentation volume adjusted to 10% protein basis

*14% moisture basis

*Nitrogen application rate in kg ha⁻¹
Table 2.3 P-values for PROC GLM main effects (year, location, variety, treatment and block) and interactions on yield, test weight, grain protein, falling number, sedimentation volume, sedimentation volume adjusted to 10% protein, flour extraction, flour protein, and flour ash content.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Yield (t ha⁻¹)</th>
<th>Test Weight (kg hL⁻¹)</th>
<th>Grain Protein (%)</th>
<th>FNᵃ</th>
<th>SVᵇ</th>
<th>SV₁₀ᵖᶜ</th>
<th>Flour Extraction (g kg⁻¹)</th>
<th>Flour Protein (%)</th>
<th>Flour Ash (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year</td>
<td>&lt;.0001***</td>
<td>0.2601</td>
<td>&lt;.0001*</td>
<td>&lt;.0001*</td>
<td>0.0282*</td>
<td>&lt;.0001**</td>
<td>&lt;.0001*</td>
<td>&lt;.0001*</td>
<td>&lt;.0001*</td>
</tr>
<tr>
<td>Location</td>
<td>&lt;.0001***</td>
<td>&lt;.0001**</td>
<td>&lt;.0001**</td>
<td>&lt;.0001*</td>
<td>0.0030*</td>
<td>0.0844</td>
<td>&lt;.0001*</td>
<td>0.0004*</td>
<td></td>
</tr>
<tr>
<td>Variety</td>
<td>&lt;.0001***</td>
<td>&lt;.0001**</td>
<td>&lt;.0001**</td>
<td>&lt;.0001*</td>
<td>&lt;.0001*</td>
<td>&lt;.0001**</td>
<td>&lt;.0001*</td>
<td>&lt;.0001*</td>
<td>&lt;.0001*</td>
</tr>
<tr>
<td>Treatment e</td>
<td>0.7688</td>
<td>0.8054</td>
<td>&lt;.0001**</td>
<td>0.995</td>
<td>0.0751</td>
<td>0.2492</td>
<td>0.4776</td>
<td>&lt;.0001*</td>
<td>0.4755</td>
</tr>
<tr>
<td>Block</td>
<td>&lt;.0001***</td>
<td>0.0003**</td>
<td>0.0076**</td>
<td>NA</td>
<td>0.1306</td>
<td>0.6746</td>
<td>0.4349</td>
<td>0.0012*</td>
<td>0.0246*</td>
</tr>
<tr>
<td>Year*Location</td>
<td>NA</td>
<td>&lt;.0001**</td>
<td>&lt;.0001**</td>
<td>0.2550</td>
<td>&lt;.0001**</td>
<td>&lt;.0001*</td>
<td>&lt;.0001*</td>
<td>&lt;.0001*</td>
<td></td>
</tr>
<tr>
<td>Year*Variety</td>
<td>0.02112*</td>
<td>0.0027**</td>
<td>0.1579</td>
<td>&lt;.0001*</td>
<td>&lt;.0001*</td>
<td>&lt;.0001*</td>
<td>0.3050</td>
<td>0.0437*</td>
<td>0.9633</td>
</tr>
<tr>
<td>Year*Treatment</td>
<td>0.6476</td>
<td>0.2284</td>
<td>0.1815</td>
<td>0.9650</td>
<td>0.0548</td>
<td>0.0629</td>
<td>0.6251</td>
<td>0.1374</td>
<td>0.6981</td>
</tr>
<tr>
<td>Location*Variety</td>
<td>&lt;.0001***</td>
<td>0.0472*</td>
<td>&lt;.0001**</td>
<td>0.1100</td>
<td>&lt;.0001*</td>
<td>&lt;.0001*</td>
<td>0.2779</td>
<td>0.0019*</td>
<td>0.0365*</td>
</tr>
<tr>
<td>Location*Treatment</td>
<td>0.9006</td>
<td>0.9373</td>
<td>0.6364</td>
<td>0.4253</td>
<td>0.4955</td>
<td>0.1146</td>
<td>0.8953</td>
<td>0.8214</td>
<td>0.8754</td>
</tr>
<tr>
<td>Treatment*Variety</td>
<td>0.7626</td>
<td>0.8635</td>
<td>0.8479</td>
<td>0.3305</td>
<td>0.6394</td>
<td>0.4280</td>
<td>0.2114</td>
<td>0.5580</td>
<td>0.6706</td>
</tr>
<tr>
<td>Year<em>Loc</em>Variety</td>
<td>NA</td>
<td>&lt;.0001**</td>
<td>0.0114*</td>
<td>0.0153*</td>
<td>0.0969</td>
<td>0.4576</td>
<td>0.0292*</td>
<td>0.0950</td>
<td>&lt;.0001*</td>
</tr>
</tbody>
</table>

*a* significant at the α=0.05 level  
** significant at the α=0.01 level  
*** significant at the α=0.001 level

ᵃ Hagberg Falling Number analyses were performed on a subset of the samples from each location year to check for significant treatment differences.  
ᵇ Sedimentation volume  
ᶜ Sedimentation volume adjusted to 10% protein basis  
ᵈ 14% moisture basis  
ᵉ Treated as categorical variable
### Table 2.4 Yield (kg ha$^{-1}$) by location variety combination for each year

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Year</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2010</td>
<td></td>
<td>2011</td>
</tr>
<tr>
<td>La Conner</td>
<td>Bauermeister</td>
<td>5.04 c</td>
<td>3.66 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>5.57 b</td>
<td>3.67 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>7.12 a</td>
<td>4.94 a</td>
<td></td>
</tr>
<tr>
<td><strong>mean</strong></td>
<td></td>
<td>5.91</td>
<td>4.09</td>
<td></td>
</tr>
<tr>
<td>Mount Vernon</td>
<td>Bauermeister</td>
<td>4.64 cd</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>4.68 cd</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>4.61 d</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td><strong>mean</strong></td>
<td></td>
<td>4.65</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

Means that are not significantly different within each column year share a letter

+ 2011 yield data was not included for Mount Vernon due to crop failure from weed pressure.

### Table 2.5 Grain protein (%) by location variety combination for each year

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Year</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2010</td>
<td></td>
<td>2011</td>
</tr>
<tr>
<td>La Conner</td>
<td>Bauermeister</td>
<td>9.84 b</td>
<td>9.14 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>9.50 b</td>
<td>9.50 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>8.36 c</td>
<td>8.28 c</td>
<td></td>
</tr>
<tr>
<td><strong>mean</strong></td>
<td></td>
<td>9.24</td>
<td>8.97</td>
<td></td>
</tr>
<tr>
<td>Mount Vernon</td>
<td>Bauermeister</td>
<td>10.51 a</td>
<td>9.33 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>10.47 a</td>
<td>9.28 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>10.55 a</td>
<td>8.66 b</td>
<td></td>
</tr>
<tr>
<td><strong>mean</strong></td>
<td></td>
<td>10.51</td>
<td>9.08</td>
<td></td>
</tr>
</tbody>
</table>

Means that are not significantly different within each column share a letter
Table 2.6  Sedimentation volume (cc g\(^{-1}\)) by location variety combination for each year

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Year 2010</th>
<th>Year 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Conner</td>
<td>Bauermeister</td>
<td>10.2 b</td>
<td>11.2 a</td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>10.0 b</td>
<td>11.0 ab</td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>7.5 c</td>
<td>7.3 d</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>9.3</td>
<td>9.8</td>
</tr>
<tr>
<td>Mount Vernon</td>
<td>Bauermeister</td>
<td>11.9 a</td>
<td>10.2 bc</td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>12.4 a</td>
<td>9.7 c</td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>12.6 a</td>
<td>7.7 d</td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>12.3</td>
<td>9.2</td>
</tr>
</tbody>
</table>

Means that are not significantly different within year share a letter
Figure 2.1 Mean grain protein (all varieties) and standard error by level of N application for 2010 and 2011 at Mount Vernon (MV) and La Conner (LC).
Chapter 3

Commercial Bakers and the Relocalization of Wheat in Western Washington State

Accepted for publication in *Agriculture and Human Values* on July 25, 2012.

3.1 Abstract

Interest is growing in the relocalization of staple crops, including wheat, in western Washington (WWA), a nontraditional wheat-growing area. Commercial bakers are potentially important food chain intermediaries in the case of relocalized wheat production. We conducted a mail
survey of commercial bakers in WWA to assess their interest in sourcing wheat/flour from WWA, identify the characteristics of bakeries most likely to purchase wheat/flour from WWA, understand the factors important to bakers in purchasing regionally produced wheat/flour, and identify perceived barriers to making such purchases. Sixty-one percent of survey respondents were interested in purchasing WWA wheat/flour. Bakers who used retail strategies to market their products were more likely to be interested in WWA wheat/flour compared to those not using retail methods. Bakers’ current purchases of Washington wheat/flour were not related to their interest in purchasing WWA flour. The most important factors bakers would consider in purchasing regionally produced wheat/flour were consistency of flour quality, quality of flour, and reliability of supply. Cost was the most frequently mentioned barrier to the purchase of regionally produced wheat/flour. Our results are relevant for other areas attempting to reconnect grain producers, commercial bakers, and consumers in mutually beneficial ways.

**Keywords** Commercial Bakers, Local Foods, Relocalization, Short Supply Chains, Washington State, Wheat

**Abbreviations**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EWA</td>
<td>Eastern Washington</td>
</tr>
<tr>
<td>WWA</td>
<td>Western Washington</td>
</tr>
</tbody>
</table>

**3.2 Introduction**

The past half century has been a time of dramatic industrialization of agriculture, industry consolidation, and specialization of crop production. While the industrial agriculture model has provided cheap food, this has come with considerable environmental and social costs (see, e.g.,
Agricultural industrialization has generated counter-movements challenging the dominant industrial food regime and reasserting values through local and organic foods (see, e.g., Hinrichs and Lyson, 2007; Wright and Middendorf, 2008). “Relocalization” is one of these counter-movements and is described by Hendrickson and Heffernan (2002, p. 363) as a “connection of people to place through food. Food in a local system is rooted in a space that enables and constrains production and consumption through its own unique characteristics.”

The local food movement thus far has focused primarily on fresh produce and animal products, but has largely neglected staple crops. Wheat provides 19 percent of human calories worldwide (Mitchell and Mielke, 2005) and is the world’s largest crop by production area and second largest crop by quantity produced (USDA-FAS, 2011). In 2009, United States annual per capita consumption of wheat flour products was 61 kg or 69 percent of total flour and cereal products (USDA-ERS, 2009), making wheat the most important staple crop in the U.S. While images of grains, stalks, sheaves, and fields of wheat are common in the logos of companies who process, bake, and market grain, very few U.S. wheat consumers have an understanding of the growing, harvesting, or processing of wheat.

Wheat has characteristics that make it a unique subject of study as a component of local food systems. It is traded as a commodity, which means that prices are typically set by a board of exchange, and usually information about where the wheat is from and who produced the wheat is lost as the product moves along the supply chain downstream from the producer. Wheat is often used as an ingredient in foods for its unique physiochemical properties, rather than being a highlighted food product. Most of the processing to turn wheat into flour is hidden from both the wheat producer and the consumer, and knowledge of these processes is contained within the
highly centralized wheat-processing sector. These factors, as well as the ubiquity of wheat in
day-to-day life, make it an interesting grain to examine from the perspective of local production,
processing, and distribution.

This study investigates the potential for relocalization of wheat production, processing, and
consumption in western Washington State (WWA), an area where there seems to be interest in
relocalization (Hills et al., 2011). By surveying an important intermediary in the supply chain,
the commercial baker, we assess interest in and availability of a market for WWA wheat/flour
and explore what is important to bakers in their wheat/flour purchases. While our results may
not be generalizable to other areas, they can inform relocalization efforts by revealing the
inherent challenges and opportunities in reconnecting staple crop (e.g., wheat) producers,
commercial bakers, and consumers. Our case study also contributes to the nascent literatures on
staple crop relocalization and the perspectives of supply chain intermediaries.

3.3 Literature review

3.3.1 Local foods

In response to the environmental and social costs associated with globalized industrial
agriculture, many popular authors and scholars in recent years have promoted local food systems
as having a variety of benefits (King et al., 2010; Martinez et al., 2010). The benefits often cited
are summed up by the definition of the term “civic agriculture,” which Lyson (2004, p.2)
describes as “the emergence and growth of community-based agriculture and food production
activities that not only meet consumer demands for fresh, safe, and locally produced food but
create jobs, encourage entrepreneurship, and strengthen community identity.” The benefits of local foods have been identified as environmental (e.g., decreased food miles), social (e.g., improved accountability of agricultural enterprises to local communities, revival of small to mid-sized farms), economic (e.g., more jobs in production, processing, and distribution), nutritional (e.g., greater access to healthy foods for low-income people), and embeddedness (e.g., agriculture existing within a specific context). The term “relocalization” has been used to describe the movement away from a “globalized” food system and towards what Kloppenburg et al. (2000) describe as a food system that is relational, proximate, diverse, ecologically sustainable, economically sustaining, just/ethical, sacred, knowledgeable/communicative, seasonal/temporal, healthful, participatory, culturally nourishing, and sustainably regulated.

The term “local food” has many definitions and can vary based on consumer perceptions and preference. Definitions can include geographical distance or political boundaries, or can be rooted in ethics, community, or other factors not directly related to food miles (Adams and Salois, 2010). Opinions are quite varied on what qualifies as “local,” in some cases relying on political boundaries such as state or county lines and other times referring to miles traveled or bioregions (Martinez et al., 2010). The idea of local foods has been criticized for its lack of a firm definition. Studies have examined the definition of the word “local” by different participants in the food system (Ostrom, 2006; Selfa and Qazi, 2005). Population density, heterogeneity in growing conditions, and cultural food preferences are among the location-specific factors that can affect the definition of local food.
3.3.2 Supply chains

Less frequently mentioned, but often implicit, in public discourse on local food systems is supply chain length. Supply chains serve an important role in the processing, packaging, and distribution of food. Longer supply chains can mean less return to the farmer per consumer dollar spent. Direct-to-consumer marketing (through farmers markets, Community Supported Agriculture programs, and other strategies) is an example of a shorter supply chain. In a comparison of local and mainstream food supply chains, the USDA Economic Research Service found that prices received by producers through both direct market and intermediated supply chains (in which local products reach consumers through one or more intermediaries) were consistently decoupled from commodity prices, and tended to be more closely linked to production and distribution costs than longer mainstream supply chains (King et al., 2010). One of the most important features of a short supply chain is that the product reaches the consumer embedded with information, by way of package labeling or personal communication. This information enables the consumer to connect with the place of production and often the actual producers and production methods. One type of short food supply chain is one in which consumers seek products grown or raised in a certain geographic region (Marsden et al., 2000).

An important part of marketing local food is capturing “the story behind the food” which includes factors such as the personality and ethics of the grower, and the attractiveness of the farm and surrounding landscape. The term “provenance” describes the method or tradition of production that is attributable to local influences and is sometimes used in descriptions of this component of the local food definition. Small direct-market producers are not the only ones aware of the demand for provenance. Sysco, a large U.S. food distributor, is testing the sourcing
of local foods in three of its regional hubs. Retired Sysco CEO, Rick Schnieders, stated that systems developed over decades to meet demand for “fast, convenient, and cheap” do not accommodate the product details and diversity that customers now demand. Meeting the new demand for “romance, memory, and trust” will require developing new systems (Cantrell, 2009).

Supply chains play an important role in making local food accessible at a scale not possible through direct sales alone. In fact, most local food may not be direct-to-consumer. According to Martinez et al. (2010), the research firm Packaged Facts found that local food sales through all marketing channels in the United States were $5 billion in 2007, compared to $1.2 billion in direct-to-consumer sales. The existence of supply chains that convey the story of the food may be even more important for foods typically considered ingredients (e.g., flour) and more likely to reach consumers through an intermediary (e.g., miller, processor, or baker), rather than by sale to the consumer in original form. Much of the process of getting wheat into a final product is “hidden” to the consumer, making the intermediaries of the supply chain, particularly commercial bakers, important in conveying the “story” of wheat.

3.3.3 Commercial bakers as food chain intermediaries

Missing from many discussions of local food systems are the roles of retailers and processors as they mediate and translate social concerns through their participation in the ‘alternative’ food market. This void is especially notable in urban settings given the growing importance of urban populations and the critical role that processors and retailers play in the food system (Blay-Palmer and Donald, 2007). Because fewer meals are prepared at home than in the past and home baking is limited, significant demand for local wheat is dependent on institutions (e.g., schools, hospitals) and food businesses (e.g., bakeries). Commercial bakers are familiar with marketing
their products and, if branding tools are provided, could effectively “tell the story” of the wheat. Moreover, some commercial bakeries could use their local wheat/flour products to set themselves apart from bakeries using wheat/flour from greater distances.

Despite the abundance of recent research on local foods, there are relatively few studies assessing the perspective of food chain intermediaries. Starr et al. (2003) examined the development of a “local foodshed” by investigating methods for and barriers to connecting Colorado restaurants and institutions with local (produce) farmers. In their study of Ohio chefs’ use of local foods, Inwood et al. (2009) looked at characteristics of early adopters, motivations for using local foods, and barriers to adoption of local foods. Vogt and Kaiser (2008) wrote a review summarizing results of nineteen studies of farm-to-institution and farm-to-school linkages. These studies consisted of interviews and surveys of food service directors, distributors, and farmers and found that while farm-to-institution marketing has the potential to improve both community nutrition and the financial stability of farmers, institutional support is needed to transition to this method of purchasing. This literature supports the idea that lack of infrastructure and financial support for processing and central distribution are critical barriers for food services and farmers in creating local food connections. While informative, the above studies do not explore the use of local grains.

3.3.4 Why relocalize wheat?

Existing research on local foods tends to focus on fresh foods (e.g., fruits, vegetables, and animal products) and ignore staple crops. Staple crops are those crops that provide a majority of calories in human diets. Worldwide, they include rice, cassava, corn, wheat, and potatoes. In the U.S. staple crops are mostly grains. Most U.S. communities historically grew their own grains,
but this capacity was lost during the consolidation and industrialization of food production that occurred during the 20th century. Grains have been largely neglected in the food relocalization movement for reasons such as less emphasis on freshness, the lack of small-scale processing equipment, the fact that they are often grown in areas with low population density, and their frequent use as unrecognizable ingredients in food rather than being served intact and in a recognizable form as the focus of a meal. However, because grains are so important in human and livestock diets and their production represents a significant amount of agricultural land use, a shift towards localization of grain production and processing could have important economic, social, and environmental benefits. Relocalizing the grain-processing sector would create jobs and fit well into a local food system, with processed products used for food, distilling, and feed.

Currently in diverse cropping rotations like those that exist in western Washington, the motivation for growing wheat is more for improving soil health and breaking disease cycles than for economic reasons. Growers currently try to “lose less money” by growing wheat and sell that wheat on the commodity market at prices sometimes below cost of production. Unlike many larger producers in eastern Washington (EWA), smaller-scale WWA growers have fewer protections (e.g., subsidies) from economic risk. WWA wheat growers want other options for their wheat besides the commodity market and see local processing, distribution, and end use as possible means of adding value to their wheat while preserving its identity.

A move towards the relocalization of wheat would require investments in local and regional infrastructure for grain storage, processing, and distribution. There would also need to be a reversal of the specialization that has occurred within the crop, which has left many areas of the country growing only one market class of wheat. For example, 2,285,000 acres of wheat were
planted in Washington in 2010 with a value of $778,734,000 (USDA-NASS, 2010). The majority of these acres are devoted to soft white wheat, which is used for noodles and pastry flour, and 85 percent of Washington wheat is exported internationally (Washington Grain Alliance, 2010).

Due to the nature of the industrialized commodity system, the movement of wheat from the farm to the elevator and then into the global wheat supply chain involves a loss of information about where, by whom, and under what conditions that wheat was grown. To further complicate matters, wheat of different varieties and from different farms is generally blended together during milling to achieve desired end-use qualities in the resulting flour. Though there has been a general movement towards some level of identity preservation in the grain sector (Elbehri, 2007), the scale of this identity preservation occurs at a level that works within the current industrial wheat supply chain (preserving information about the region in which the wheat was grown) rather than at a level that facilitates preserving “the story” of the wheat (preserving information about the individual farm).

The wheat processing sector is one of the most highly centralized of any food processing sector, with 55 percent of the U.S. flour milling market controlled by three corporations: Cargill/CHS, Archer Daniels Midland, and ConAgra (Hendrickson and Heffernan, 2007), while five major companies (Cargill, Archer Daniels Midland, Bunge, Louis Dreyfus Commodities, and ConAgra) control 80 percent of the global grain trade (Measner, 2007). The consolidation is such that even in a major wheat growing state, such as Kansas, it can be difficult to source local flour (Henning, 2011).
The supply chain for wheat involves, at a minimum, a grower, broker, miller, distributor, and manufacturer of the final product. The price the grower receives is set on the commodity market and does not necessarily reflect the cost of production. One of the motivations for shortening supply chains in all crops, including wheat, is to allow growers to recover a greater percentage of the consumer’s food dollar. For cereals and baked goods, the average farm share of the retail price was only 8 percent in 2006–2008, which was lower than for meat, dairy, eggs, fresh vegetables, and fresh fruits. The farm share for a five-pound bag of flour was 19 percent, and for bread it was only 5 percent (Schnepf, 2009).

Local grain movements in the U.S. and worldwide

There are regional movements arising both internationally and in the U.S. involving relocalization of grains and dry beans. Examples of places where these movements are occurring include Great Britain (Washington Grain Commission, 2010), Quebec (E. Vachon, personal communication, 2009), British Columbia (Hergesheimer and Wittman, 2012), North Carolina (Wolfe, 2011), Ohio (Hanus, 2010), the Pacific Northwest (Hills et al., 2011), and New England (Burrows, 2010). “Locavores” are often missing staple crops in their pursuit to consume foods grown or raised locally.

More attention is being paid in the popular press to the problematic distinction between wheat as commodity and wheat as food. For example, in an article titled “The Food Bubble: How Wall Street Starved Millions and Got Away With It,” Kaufmann (2010) describes how speculative investment in agricultural commodities led to an 80 percent increase in world food prices from 2005 to 2008, sparking riots in 30 countries and driving the worldwide number of “food insecure” to over one billion for the first time in history. Sarah Kavage, an activist from Seattle,
Washington led a project called Industrial Harvest, in which she purchased nine tons of wheat through a futures contract, had it milled into flour, and gave it away as a way of educating the public about the disconnect between agricultural products as tradable commodities and as staple foods that sustain life (Bayne, 2010).

Discussion of wheat and other staple crop relocalization is difficult to find in the academic literature. Bingen and Siyengo describe Michigan dry bean farmers and their movement to regain “contextualized, personalized and place-based transactions” in place of the corporate-based relationships they experience as a result of the consolidations and integration of the dry bean industry (2002, p. 321). Mulvaney (2008) discusses vulnerabilities in the California rice production system as opportunities for restructuring the producer/consumer connection. Mulvaney proposes the use of existing commodity subsidies as “multifunctionality payments” for environmental conservation such as providing waterfowl habitat.

Sharpe et al. (2008) examine the coexistence of two types of supply chains in the United Kingdom. The dominant bread supply chain involves intensive production of wheat, industrial manufacturing, and supermarkets, while a coexisting small “craft” chain has smaller production units, less mechanization, more time-consuming manufacturing methods, and lower levels of inputs and additives. The authors note that there are many different levels of identity preservation that could be possible in wheat, but those that allowed consumers to know the exact location where their wheat was grown may not be compatible with blending practices of millers to achieve consistent quality. This is an issue that relocalized systems involving a blended product will need to address.
Although the literature on local foods is extensive, there is limited discussion of staple crop relocalization, especially the opinions of food chain intermediaries (e.g., commercial bakers) in relocalized wheat supply chains. We aim to fill this gap by investigating the attitudes of commercial bakers regarding relocalized wheat supply chains in one geographic location (western Washington) where there is growing interest in relocalized wheat systems.

### 3.3.5 Washington State

Washington State is divided by the Cascade Mountain Range into two distinct areas (see Figure 3.1), differing in population density, agricultural production, and direct-to-consumer sales of agricultural products. Eastern Washington (the twenty counties east of the Cascades) has a low population density (36 people per square mile) compared to western Washington (the nineteen counties west of the Cascades), which has a population density of 214 people per square mile (State of Washington, 2011). Dryland farming and large-scale commodity production (e.g., wheat) predominate in EWA, while WWA agriculture is more diverse and smaller-scale. Because it contains major population centers (Seattle, Tacoma, Olympia), WWA farmers rely to a greater extent on direct-to-consumer sales compared to EWA farmers.

Many WWA farmers grow wheat as a rotation crop with other crops such as flower bulbs and potatoes. Much of the agriculture is located at the rural-urban interface. This situation is both detrimental to the farms because they face development pressure, and at the same time beneficial as the proximity to population centers offers direct marketing opportunities. WWA may be well positioned for relocalizing grains because it is home to a diversified agriculture that already includes grain production, many growers are already familiar with direct marketing to restaurants
and food businesses along the populated Interstate-5 corridor, and many communities have a strong interest in preserving farmland.

Because of their geographic location and familiarity with direct marketing, many WWA wheat growers have expressed interest in moving from commodity marketing to a value-chain approach. However, the level of interest in WWA wheat/flour among commercial bakers in the region is not known. It is not clear if shorter supply chains for WWA wheat/flour would interest bakers, particularly those already purchasing a brand of value-chain wheat sold through Shepherd’s Grain, a group of no-till wheat farmers in eastern Washington who market their wheat as part of a value chain including identity preservation on each bag of flour (Stevenson, 2009).

In a typical supply chain for bread wheat, quality needs are dictated by the baker and met by the miller by blending wheat to meet certain parameters. Anecdotal evidence suggests growers and bakers in the region want to connect, but a mill is needed to mediate quality. One barrier to scaling up milling capacity in the area is uncertainty about a market. Collecting information about WWA bakers’ interest in local wheat/flour and factors important to them is a critical step in understanding the potential for shortening the supply chain for WWA wheat and in understanding unique factors influencing local grain systems as opposed to other local food systems.

This study investigates the potential for relocalization of wheat production, processing, and consumption in western Washington. By surveying commercial bakers, important intermediaries in the supply chain, we assess interest in and availability of a market for WWA wheat/flour and
explore what is important to bakers in their wheat/flour purchases. More specifically, we seek to answer the following questions:

- Are commercial bakers in WWA interested in purchasing wheat/flour from WWA?
- What are the characteristics of commercial bakeries most interested in purchasing WWA wheat/flour in terms of number of employees, geographical distribution of final products, marketing strategy, and other factors?
- What are the main factors commercial bakers would consider if they were to purchase regionally produced wheat/flour?
- What are the most important barriers commercial bakers see to purchasing regionally produced wheat/flour?

While our results may not be generalizable to other regions in the U.S. and worldwide, they can inform wheat relocalization efforts by revealing the inherent challenges and opportunities in staple crop relocalization.

### 3.4 Methods

Using a modified Tailored Design Method\(^1\) (Dillman et al., 2009), we sent questionnaires to commercial bakers in the nineteen counties of Washington west of the Cascade Mountain Range. Grocery store bakeries and large national chain bakeries were not included in our study because

\(^1\) The Tailored Design Method includes carefully timed mailings, personalized correspondence, visually appealing questionnaire layout, First Class postage, and other procedures to reduce survey errors from measurement and nonresponse (Dillman et al. 2009).
we attempted to target bakers that may have a greater ability to adjust processes or try new ingredients at the individual bakery level rather than having to conform to strict formulas as large chain or franchise bakeries might be required to. Because the WWA flour supply chain is still quite limited, it would not be realistic for WWA wheat growers to supply the large market share represented by grocery store bakeries and franchises. Although large-scale bakeries may have interest in local wheat flour systems, we deemed them outside the scope of our survey project. We also excluded bakeries that sell exclusively cakes, cupcakes, doughnuts, and/or pies because we assumed their customers might be less attuned to local foods. Names and addresses of bakeries were obtained through a variety of sources including the Washington State Department of Agriculture’s list of licensed food processors, King County Public Health Department’s list of inspected food service establishments, and an email announcement sent by the Bread Baker’s Guild of America to its members. We also searched for the word “bakery” in Google Maps.

The region of focus was chosen because the areas to the east and west of the Cascade Mountain Range are quite different in terms of climate, population density, and other factors (Qazi and Selfa, 2005; Goldberger, 2011). The majority of Washington’s population and, thus, the majority of bakeries in the state are concentrated in the western part of the state. Even though eastern Washington is known for its wheat production, western Washington has 424,226 acres of cropland (USDA-NASS, 2007), on which some grains are grown in rotation with other crops and usually sold on the commodity market.

Several professional bakers outside of the survey area were consulted during the development of the questionnaire. Individuals responsible for making purchasing decisions for commercial bakeries were instructed to complete the questionnaire. We collected general information on the
characteristics of the bakeries (e.g., number of locations, number of employees, and percentage of direct-to-consumer sales), current sourcing of flour, and interest in purchasing flour from western Washington. In other questions, respondents were asked about regionally produced flour. We used the term “regionally produced” rather than “local” because we asked bakers to define “local” in a specific survey question. Because common definitions of “local” used in the popular press (e.g., 100-mile radius) and by the USDA (e.g., within state lines or 400 miles) may not be feasible in the case of grains, we were interested in bakers’ conceptualizations of “local.” We intentionally left “regionally produced” undefined in the survey because we wanted to allow respondents to reflexively define the term rather than use a single definition (provided by us). Because the predominant supply chain for wheat flour operates on a national scale, many of the same barriers exist for supply chains operating within a smaller geographic area, whether a county or a several state region.

To help inform the development of a WWA grain economy, we wanted to find out which factors (e.g., price, quality, brand name, etc.) would be important to bakers in future purchases of “regionally produced” flour. Because flour quality is not easily apparent at purchase, bakers sometimes rely on technical specifications to make sure the flour meets their standards. We asked bakers which technical specifications (e.g., falling number, protein, ash, etc.) would be important to them in their future flour purchases.

A cover letter and questionnaire were sent to 267 commercial bakers on March 31, 2011. A reminder postcard was sent on April 7 followed by a final mailing to non-respondents on April 28. The survey closed on November 10 with 73 eligible bakers responding (33 percent response
rate). Eighty-nine percent of survey respondents were bakery owners, 43 percent were head bakers, 4 percent were assistant bakers, and 11 percent played other roles (e.g., manager). \(^2\)

3.5 Results

Characteristics of surveyed bakeries

Table 3.1 presents descriptive statistics for the surveyed bakeries. Nearly half (45 percent) of the bakeries were located in heavily populated King County, which includes Seattle. Most bakeries (97 percent) were not part of franchises or chains, and 88 percent had only one location. Half (49 percent) of the bakeries employed four or fewer full-time workers, while 25 percent had more than ten full-time employees. Sales strategies included retail (84 percent), wholesale (60 percent), and cafe/restaurant (57 percent). Nearly 70 percent of the surveyed bakeries obtained more than 75 percent of their sales from direct-to-consumer sales. Most bakeries (over 60 percent) sold cookies, pastries, bread, cakes, cupcakes, and pies. Pizza and doughnuts were sold by a smaller percentage of bakeries. For the majority of bakeries (57 percent), bread sales made up less than 25 percent of total sales. Sixty percent distributed their bakery products only within their own counties, 18 percent sold within neighboring counties, 7 percent sold within Washington, 8 percent sold within the Pacific Northwest, and 7 percent sold nationally.

\(^2\) Respondents could select more than one role in the bakery.
Annual flour use among the survey respondents ranged from 54 kg for a bakery and deli in a rural area to over 700,000 kg for a pita bread bakery with national distribution. Of the respondents, 32 percent were currently purchasing some Washington-grown flour (primarily from Shepherd’s Grain, an eastern Washington company). Only 7 percent of the bakeries milled some of their own flour. This flour accounted for only 5,116 kg annually or 12 percent of total wheat flour used by those bakers owning mills and 0.15 percent of wheat flour used by all respondents.

**Are commercial bakers in western Washington interested in purchasing wheat/flour from western Washington?**

One of the most important goals of this study was to determine the level of interest in WWA wheat among commercial bakers. We focused on the western part of the state because of the growing interest among some producers and consumers in creating regional markets in WWA. When asked if they had an interest in purchasing WWA flour/wheat, 61 percent of respondents answered “yes,” 36 percent selected “don’t know,” and 3 percent answered “no.” The bakers who expressed interest represent 2,337,240 kg of total flour use annually. Bakers were asked about their use of different types of flour (e.g., whole wheat, white, bread, pastry). White bread flour had by far the highest annual use by respondents (2,540,217 kg) with 63 percent of that use representing respondents interested in purchasing WWA wheat/flour. Other wheat/flour types listed in order of use were: white pastry flour (413,241 kg), whole wheat bread flour (346,182 kg), all-purpose flour (53,206 kg), whole wheat pastry flour (32,604 kg), cracked grains (27,662 kg), and wheat berries (5,650 kg). Table 3.2 presents total flour use by survey respondents in all
categories as well as the percentage of each flour class represented by those respondents interested in WWA wheat/flour.

**What are the characteristics of commercial bakers most interested in purchasing wheat/flour from western Washington?**

If certain characteristics of bakers are related to their interest in purchasing WWA wheat/flour, then bakers fitting these characteristics could be targeted for product testing or marketing. We expect bakeries with fewer employees and a smaller geographic distribution range to be more interested in WWA wheat/flour. These bakeries may have more flexibility and interest in supporting local foods compared to their larger or more widely distributed counterparts. We also expect bakeries with a larger percentage of direct-to-consumer sales and bread sales to be more interested in WWA wheat/flour. Bakeries with a close connection with consumers (through retail sales) may be more likely to respond to consumer interest in local foods. Customers interested in local foods are often health conscious and, thus, may be more likely to purchase breads than other less healthy bakery products.

Cross tabulation and chi-square analysis were used to determine which types of bakeries were most interested in purchasing WWA wheat. Since very few bakers (3 percent) responded to this question with a “no,” we combined the “no” and “don’t know” categories into a new category (“not yes”). Table 3.3 presents percentage distributions for bakers’ interest in purchasing WWA wheat/flour by bakery characteristics. The characteristics of individual bakeries were largely unrelated to interest in purchasing regionally produced wheat/flour. We found no statistically significant difference in WWA wheat/flour interest for five bakery characteristics: bakery size (number of employees), product distribution range, percentage of total sales from direct-to-
consumer sales, percentage of sales from bread, and current use of some Washington wheat. These results do not support our expectations (described above) about bakery size, distribution range, direct-to-consumer sales, and bread sales. Perhaps bakery characteristics not included in our survey would help explain bakers’ interest in WWA wheat/flour.

We did find a statistically significant relationship between bakers’ interest in WWA wheat/flour and use of retail sales (see Table 3.3). Bakers using retail sales strategies for their products were more likely to be interested in purchasing wheat/flour from WWA. The retail setting allows the commercial baker to transmit the “story” of the wheat/flour to the customer. It might be expected that commercial bakers operating in retail settings would be more responsive to the interests of customers. Or perhaps bakers who have direct relationships with their customers are more inclined to have a direct relationship with their supplier.

Despite some variation among our survey respondents, our survey was not designed to target national chains or supermarket bakeries. If we had included these types of businesses in our study population, we would have had more variation in bakery size and distribution range, and, consequently, possibly stronger relationships between bakery characteristics and interest in WWA wheat/flour.

What are the main factors commercial bakers would consider if they were to purchase regionally produced wheat/flour?

Bakers were asked about the importance of eighteen factors for future purchases of regionally produced flour. Respondents rated each factor on a 1 (not important) to 5 (very important) response scale. Table 4 lists mean scores and standard deviations. The most important factors
for bakers were consistency of flour quality (4.90), quality of flour (4.85), and reliable supply (4.78). Where the flour was grown was rated only 3.59, while where the flour was milled was rated 3.38. Certified organic was rated only 2.67, suggesting that there were relatively few surveyed bakeries producing certified organic products or interested in using organic wheat/flour.

“Technical specifications” in general rated only 3.63 (Table 3.4) and had a low response rate relative to the other factors, which averaged a response rate of 99 percent. Respondents were then asked to rate specific technical measurements including protein, ash, farinograph, and falling number. These measurements are generally used by the most experienced professional bakers, who examine the specifications of each lot of flour they receive. Protein was recognized as an important technical measurement (mean score of 4.11), while ash, falling number, and farinograph received lower scores (3.35, 3.25, and 3.14, respectively). Only 58 percent of the survey respondents provided responses for all four of the technical specifications. The lower scores and low response rates suggest technical specifications may not always be used by commercial bakers. Bakers often purchase a specific blend, and rely on the miller to keep the technical specifications consistent between orders. Bakers with greater skills or who use baking processes that are more sensitive to variation between flour shipments may pay more attention to the technical specifications of flour and make adjustments as possible. These findings also highlight the importance of the miller in controlling these factors in the supply chain and keeping the end product consistent.
What are the most important barriers commercial bakers see to purchasing regionally produced wheat/flour?

In an open-ended question, survey respondents were asked: “In your opinion, what are the greatest barriers to purchasing wheat grown in your region?” Responses were coded and grouped according to themes (Table 3.5). Cost was the most frequently mentioned barrier (38 percent of respondents). Other perceived barriers included availability/quantity (23 percent of respondents), suppliers/delivery (23 percent), and quality (including protein and gluten) (18 percent). Some examples of barriers mentioned by survey respondents are listed below:

“Price and availability. Most customers say they want to support local.”

“Price and distribution at high volume—we are very price sensitive.”

“Not really ‘knowing’ where wheat was grown. Having to keep tabs on my suppliers—it’s hard enough keeping tabs on my staff.”

“I am a small bakery, so finding a distributor willing to deliver in small amounts can be difficult.”

The three most frequently mentioned barriers (cost, availability/quantity, and suppliers/delivery) are scale-related and could be addressed by increasing the scale of production and distribution.

Western Washington has enough wheat acreage to supply a significant portion of WWA bakeries’ wheat/flour use. For example, in Skagit County alone there were 4,886 acres of wheat in 2007 (USDA-NASS, 2007). At a yield of 100 bushels per acre, which is easily achievable in this region, Skagit County could produce approximately 14,658 tons of wheat per year.
Assuming a 70 percent flour extraction rate during milling, this amount of wheat could provide 10,260 tons of flour or more than two and a half times the total amount of flour used by all 73 surveyed bakeries. Not all wheat will make the quality grade for use as food, but this example demonstrates the production capacity in one of the counties with the largest wheat acreage in WWA.

Currently there are only small bags of WWA wheat/flour being marketed within the region, and these are sold at a cost that is prohibitive for commercial bakers. For example, two growers of WWA wheat are milling their own wheat and in 2010 were selling the flour for $3–$4 for a two-pound bag or an average of $1.75 per pound (personal communication). At that same time, a bakery in WWA reported paying $0.44 per pound for eastern Washington flour from Shepherd’s Grain. Many bakeries are quite sensitive to even small changes in flour price. There is little information in the academic literature on commercial bakers’ willingness to pay for “local” wheat/flour. In an interview conducted in WWA as part of a feasibility study for a wheat mill, a commercial baker who currently sources some of the wheat he uses from farms within 50 miles stated that his bakery cannot sustain more than a 25 percent premium at the retail selling price for specialized artisanal loaves made from local wheat (ISE Consultants, 2011). Any premium that commercial bakers would be willing to pay for regionally grown wheat would depend on factors such as customer demand, quality, delivery options, and reliability of supply.
3.6 Discussion and Conclusion

Though some aspects of this project are specific to western Washington, similar barriers to relocalization of wheat/flour exist in other places that have lost the ability to grow, process, and distribute grains on a regional scale. Thus results of this study are relevant for other areas in the U.S. involved in reconnecting grain producers, commercial bakers, and consumers in mutually beneficial ways. Though the level of interest in local grains may vary by location, we believe many of the factors considered most important by commercial bakers for purchases of regional wheat/flour and the perceived barriers to purchasing regional wheat/flour would be similar across geographic locations. Factors such as supply reliability and consistent quality of ingredients are general needs of any food business turning raw materials into a finished product for sale. The factors that may relate to preferences (such as placing importance on where the wheat was grown or milled) may vary by geographic location based on the baker’s and customers’ levels of interest in locally produced food and the awareness of wheat production in the region.

Most of the bakery characteristics we examined were not significantly correlated with interest in purchasing WWA wheat/flour. One explanation for this finding is that very few survey respondents (only 3 percent) were not interested in purchasing WWA wheat/flour. It is likely that bakers with some interest in sourcing local or regional ingredients were more likely to participate in the survey. We do not know why certain bakers chose not to participate.\(^3\) Non-responses could have been due to lack of interest in regional wheat/flour or other reasons (e.g.,

\(^3\) We did not contact non-respondents to find out why they had not participated in the study. Identifying nonresponse bias (if present) would have helped our interpretation of the survey results.
business closed, not a bakery, lack of time or motivation, etc.). Our results may have been very different if we had included a wider variety of bakeries (e.g., supermarket bakeries and bakeries focused exclusively on cakes, cupcakes, doughnuts, and/or pies).

Most of the wheat in Washington is grown east of the Cascade Mountain Range, where dry conditions limit growers’ choice of crops. A particular EWA-based business, Shepherd’s Grain, has used the value-chain approach to market wheat grown by farmers using reduced tillage practices (Stevenson, 2009). Some of the survey respondents regularly purchase flour from Shepherd’s Grain. One interesting survey result was that respondents’ use of some Washington-grown wheat was not related to interest in purchasing WWA wheat/flour. The reasons for this are not clear, but could be related to a sentiment expressed by these bakers that they are purchasing locally *enough* by sourcing flour from within the state. For example, one respondent stated: “I use Shepherd's Grain flour for my all-purpose and whole-wheat and really appreciate what they are doing with their products. I feel like that supports local enough.”

The question of how local is “local enough” is an important consideration. Eastern and western Washington are separated by the Cascade Mountain Range (see Figure 3.1) which only has two highways open year round connecting the state. The mountain range forms a divide between more densely populated WWA, with its abundance of farmers markets and rain-fed agriculture, and more sparsely populated EWA, characterized by dryland farming. Though EWA is a major wheat producer, most of its wheat is exported internationally. The type of system preferred by WWA wheat growers would be, by necessity, much smaller in scale and would involve identity preservation for the wheat already being grown in WWA. Currently this wheat loses its identity when it joins the existing commodity chain.
When asked to define “local” in relation to purchasing wheat/flour for their bakeries, most survey respondents provided answers based on geopolitical boundaries (e.g., states) rather than bioregions (e.g., coastal Northwest) or a distance radius (e.g., 100 miles). However, local was defined quite broadly by respondents and ranged from within the same town or county to within several nearby states. Seventeen percent of respondents gave multiple answers when asked to define local, implying that they saw the idea of local as a flexible concept. Location-specific factors such as climate and land value, as well as respondents’ knowledge of the regionality of primary crops, may have contributed to the level of flexible localism expressed by respondents.

The idea of “flexible” or “reflexive” localism was introduced by Morris and Buller (2003) in their study of the local food sector in Gloucestershire, England. They state that the term “flexible localism” implies that the emphasis on local food provisioning is a means to an end, rather than an end in itself. Morris and Buller found that the retailers in their study used “local” in a fluid sense which related to their need to maintain supplies, sometimes referring to “British” as local and other times “within a 25 mile radius.” Producers in this study also used the notion of flexible localism to buy products from outside the county in order to ensure the output of locally branded product. Selfa and Qazi (2005) found that producers in urban King County, Washington, identified closely with face-to-face direct markets in their own and adjacent peri-urban counties when defining their local food system, while producers in more sparsely populated Grant and Chelan Counties (in eastern Washington) were more likely to define “local” in terms of the entire state or northwest region.

Ilbery and Maye’s (2006) discussion of flexible localism reflects the inherent complexities of food systems, and acknowledges that the distinction between local/alternative and
global/conventional may obscure the hybrid nature of many food supply chains that involve both local and global food products. Embeddedness, the goal of “local,” has more to do with community, economy, and social relations resulting from the food system than with a set definition based on factors such as political boundaries or distance.

Interestingly, we found a statistically significant relationship between distribution area of a bakery and the baker’s definition of local. That is, bakeries that distributed only within their county were more likely to include a larger area in their definition of “local” than those who distributed in areas outside their counties. It is possible that bakeries with smaller distribution areas were more aware of constraints on sourcing “local” ingredients. The reasons for this relationship are not clear, but may be of interest to those marketing local wheat. The definition of local may be different for grains compared to other crops because the common reasons cited for purchasing local foods (freshness, taste, nutrition) may be less applicable to grains than fresh produce or animal products.

A relocalized wheat system faces similar challenges as the development of other local food systems: the roles of processors and wholesalers need to be clearly defined, and the planning and building of infrastructure must be a priority (Adams and Salois, 2010). Similar to the findings of Starr et al. (2003) and Inwood et al. (2009), we found distribution issues such as suppliers and convenience to be very important factors in local food purchasing for commercial bakers. In the academic literature, local food supply chains are often discussed in direct opposition to mainstream food supply chains; however, in a study of local specialist food chains in Great Britain, Maye and Ilbery (2006) found that local specialty food producers often made use of existing mainstream distribution networks to access markets. Likewise, for the most widespread
access for bakers of flour, especially at an early stage, it may be useful for the local flour in WWA to be distributed through a mainstream distributor already used by bakers. This has been the approach taken by Shepherd’s Grain, which uses major distributors such as Food Services of America to directly access wholesale markets (Stevenson 2009). In contrast to the findings of Starr et al. (2003) in their interviews of Colorado restaurant buyers, we found price to be an important consideration in commercial bakers’ decisions to purchase regionally produced ingredients. There may be more price sensitivity around buying staple crops as opposed to fresh produce or animal products.

As previously noted, regional specialization has taken place not only in the species of crops that are grown in an area, but also between market classes of the same species. For example, the Pacific Northwest has largely specialized in soft white wheat for noodles and pastries and the Northeast specializes in soft red wheat. This is largely a product of markets and distribution and sometimes due to growing conditions. Because each market class of wheat has its own specific “best use” there may be some interest in bringing back types of wheat that had a historical presence but are no longer commonly grown in certain regions. Another consideration in the rebuilding of a local grain system is the importance of having outlets for wheat that does not meet quality specifications for the food market. Having nearby outlets for this lower grade wheat as feed or distilling material will be important to minimize the financial risk to growers.

Some characteristics of wheat make it more challenging to direct market compared to many other crops. Grains have a lower “value to volume ratio,” increasing the importance of efficiency in processing and distribution to keep costs low. Unlike some other local products such as fresh fruits and vegetables, determining quality in grains is more complex. Important functional
differences in whole grain or flour quality are often not easily observable and require specialized equipment to measure. Fine-tuned quality control is generally the realm of the processor (miller) who fractionates and blends batches of wheat to obtain the desired quality characteristics for the type of flour being produced and to maintain consistency over time. For this reason some bakers are not aware of the quality parameters they need—they simply know the specific brand and blend of flour they use works for them. The highly centralized nature of the processing and quality control of wheat is one of the main challenges in regaining local production, processing, and use necessary to have a relocalized grain economy.

It is unlikely that a well-developed local wheat/flour supply chain would function exactly like its conventional counterpart in the realms of the grower, processor, distributor, or baker. With relocalized grain systems still in their early stages in the United States, wheat and flour present opportunities to shorten supply chains and to regain the importance of place for staple crops that play a critical role in the human diet.
3.7 References


Tasting food, tasting sustainability: Defining the attributes of an alternative food system with

Lyson, T. 2004. *Civic agriculture: Reconnecting farm, food, and community*. Medford, MA:
Tufts University Press.


Martinez, S., M. Hand, M. Da Pra, S. Pollack, K. Ralston, T. Smith, S. Vogel, S. Clark, L. Lohr,
Economic Research Report 97. Economic Research Service, United States Department of
Agriculture.

Maye, D., and B. Ilbery. 2006. Regional economies of local food production: Tracing food chain
links between ‘specialist’ producers and intermediaries in the Scottish-English borders.

Measner, A. 2007. The global grain trade and the Canadian Wheat Board. In *Our board, our
business: Why farmers support the Canadian Wheat Board*, ed. T. Pugh, and D.A.

*Global agricultural trade and developing countries*, ed. M.A. Aksoy, and J.C. Beghin, 195-


**Figure 3.1** Farmers market locations and wheat producing counties in Washington State

1. J. Sage, personal communication, 2012
2. Compendium of Washington agriculture, 2011
Table 3.1 Descriptive statistics for surveyed bakeries

<table>
<thead>
<tr>
<th>Bakery characteristic</th>
<th>N</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>King County</td>
<td>33</td>
<td>45.2</td>
</tr>
<tr>
<td>Other counties</td>
<td>40</td>
<td>54.8</td>
</tr>
<tr>
<td><strong>Part of franchise or chain</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>2</td>
<td>2.7</td>
</tr>
<tr>
<td>No</td>
<td>71</td>
<td>97.3</td>
</tr>
<tr>
<td><strong>Number of full-time employees</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 or fewer</td>
<td>36</td>
<td>49.3</td>
</tr>
<tr>
<td>5–10</td>
<td>19</td>
<td>26.0</td>
</tr>
<tr>
<td>More than 10</td>
<td>18</td>
<td>24.7</td>
</tr>
<tr>
<td><strong>Sales strategies</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wholesale</td>
<td>42</td>
<td>60.0</td>
</tr>
<tr>
<td>Retail</td>
<td>59</td>
<td>84.3</td>
</tr>
<tr>
<td>Cafe/restaurant</td>
<td>40</td>
<td>57.1</td>
</tr>
<tr>
<td><strong>Percentage of sales from direct-to-consumer sales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 25%</td>
<td>7</td>
<td>10.1</td>
</tr>
<tr>
<td>25–75%</td>
<td>14</td>
<td>20.3</td>
</tr>
<tr>
<td>More than 75%</td>
<td>48</td>
<td>69.6</td>
</tr>
<tr>
<td><strong>Products sold</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cookies</td>
<td>56</td>
<td>76.7</td>
</tr>
<tr>
<td>Pastries</td>
<td>51</td>
<td>69.9</td>
</tr>
<tr>
<td>Bread</td>
<td>48</td>
<td>65.8</td>
</tr>
<tr>
<td>Cakes/cupcakes</td>
<td>45</td>
<td>61.6</td>
</tr>
<tr>
<td>Pie</td>
<td>45</td>
<td>61.6</td>
</tr>
<tr>
<td>Pizza</td>
<td>11</td>
<td>15.1</td>
</tr>
<tr>
<td>Doughnuts</td>
<td>9</td>
<td>12.3</td>
</tr>
<tr>
<td>Other products</td>
<td>20</td>
<td>27.4</td>
</tr>
<tr>
<td><strong>Percentage of sales from bread</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>17</td>
<td>24.6</td>
</tr>
<tr>
<td>Less than 25%</td>
<td>22</td>
<td>31.9</td>
</tr>
<tr>
<td>25–75%</td>
<td>24</td>
<td>34.7</td>
</tr>
<tr>
<td>More than 75%</td>
<td>6</td>
<td>8.7</td>
</tr>
<tr>
<td><strong>Product distribution range</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within county</td>
<td>44</td>
<td>60.3</td>
</tr>
<tr>
<td>Within neighboring counties</td>
<td>13</td>
<td>17.8</td>
</tr>
<tr>
<td>Within Washington</td>
<td>5</td>
<td>6.9</td>
</tr>
<tr>
<td>Within Pacific Northwest</td>
<td>6</td>
<td>8.2</td>
</tr>
<tr>
<td>Nationally</td>
<td>5</td>
<td>6.9</td>
</tr>
</tbody>
</table>

* Respondents could check more than one answer.
Table 3.2  Total annual flour use by surveyed bakeries in western Washington and anticipated annual use of western Washington wheat

<table>
<thead>
<tr>
<th>Flour type</th>
<th>Annual use by all respondents (kg)</th>
<th>Annual use by respondents interested in purchasing western Washington wheat (kg) and as a percentage of use by all respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>White bread</td>
<td>2,540,217</td>
<td>1,600,562 (63%)</td>
</tr>
<tr>
<td>White pastry</td>
<td>413,241</td>
<td>391,853 (95%)</td>
</tr>
<tr>
<td>Whole wheat bread</td>
<td>346,182</td>
<td>272,022 (79%)</td>
</tr>
<tr>
<td>All purpose</td>
<td>53,206</td>
<td>20,004 (38%)</td>
</tr>
<tr>
<td>Whole wheat pastry</td>
<td>32,604</td>
<td>32,550 (99%)</td>
</tr>
<tr>
<td>Cracked grains</td>
<td>27,662</td>
<td>15,078 (55%)</td>
</tr>
<tr>
<td>Wheat berries</td>
<td>5,650</td>
<td>5,171 (92%)</td>
</tr>
<tr>
<td>Total</td>
<td>3,418,762</td>
<td>2,337,240 (68%)</td>
</tr>
</tbody>
</table>
Table 3.3 Percentage distribution of interest in purchasing western Washington wheat/flour by bakery characteristics

<table>
<thead>
<tr>
<th>Bakery characteristic</th>
<th>Percentage interested in purchasing western Washington wheat/flour</th>
<th>Chi-square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of full-time employees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 4</td>
<td>55.6</td>
<td></td>
</tr>
<tr>
<td>5 to 10</td>
<td>63.2</td>
<td></td>
</tr>
<tr>
<td>More than 10</td>
<td>72.2</td>
<td>1.435</td>
</tr>
<tr>
<td>Product distribution range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Within county</td>
<td>61.4</td>
<td></td>
</tr>
<tr>
<td>Within neighboring counties</td>
<td>69.7</td>
<td></td>
</tr>
<tr>
<td>Within Washington</td>
<td>40.0</td>
<td></td>
</tr>
<tr>
<td>Within Pacific Northwest</td>
<td>66.7</td>
<td></td>
</tr>
<tr>
<td>Nationally</td>
<td>60.0</td>
<td>1.378</td>
</tr>
<tr>
<td>Retail sales</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>67.8</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>36.4</td>
<td>3.924*</td>
</tr>
<tr>
<td>Percentage of sales from direct-to-consumer sales</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 25%</td>
<td>71.4</td>
<td></td>
</tr>
<tr>
<td>25–75%</td>
<td>71.4</td>
<td></td>
</tr>
<tr>
<td>More than 75%</td>
<td>60.4</td>
<td>0.767</td>
</tr>
<tr>
<td>Percentage of sales from bread</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>58.8</td>
<td></td>
</tr>
<tr>
<td>Less than 25%</td>
<td>59.1</td>
<td></td>
</tr>
<tr>
<td>25–75%</td>
<td>75.0</td>
<td></td>
</tr>
<tr>
<td>More than 75%</td>
<td>66.7</td>
<td>1.688</td>
</tr>
<tr>
<td>Currently purchasing Washington wheat</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>65.2</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>67.6</td>
<td></td>
</tr>
<tr>
<td>Don’t know</td>
<td>46.7</td>
<td>2.061</td>
</tr>
</tbody>
</table>

* p ≤ 0.10 (Pearson chi-square test)
Table 3.4  Mean scores and standard deviations for importance of factors in future purchases of regionally produced flour

<table>
<thead>
<tr>
<th>Factor</th>
<th>Mean score</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistency of flour quality</td>
<td>4.90</td>
<td>0.32</td>
</tr>
<tr>
<td>Quality of flour</td>
<td>4.85</td>
<td>0.43</td>
</tr>
<tr>
<td>Reliable supply</td>
<td>4.78</td>
<td>0.66</td>
</tr>
<tr>
<td>Flavor</td>
<td>4.51</td>
<td>0.75</td>
</tr>
<tr>
<td>Price</td>
<td>4.48</td>
<td>0.71</td>
</tr>
<tr>
<td>Protein</td>
<td>4.11</td>
<td>1.05</td>
</tr>
<tr>
<td>Nutritional value</td>
<td>4.01</td>
<td>0.79</td>
</tr>
<tr>
<td>Fineness of grind</td>
<td>3.83</td>
<td>1.00</td>
</tr>
<tr>
<td>Carried by preferred (or current) supplier</td>
<td>3.68</td>
<td>1.27</td>
</tr>
<tr>
<td>Technical specifications</td>
<td>3.63</td>
<td>1.14</td>
</tr>
<tr>
<td>Where the wheat was grown</td>
<td>3.59</td>
<td>1.05</td>
</tr>
<tr>
<td>Trusted brand name</td>
<td>3.39</td>
<td>1.30</td>
</tr>
<tr>
<td>Where the flour was milled</td>
<td>3.38</td>
<td>1.13</td>
</tr>
<tr>
<td>Ash</td>
<td>3.35</td>
<td>1.25</td>
</tr>
<tr>
<td>Falling number</td>
<td>3.25</td>
<td>1.45</td>
</tr>
<tr>
<td>Farinograph</td>
<td>3.14</td>
<td>1.34</td>
</tr>
<tr>
<td>Personal relationship with grower</td>
<td>2.85</td>
<td>1.25</td>
</tr>
<tr>
<td>Certified organic</td>
<td>2.67</td>
<td>1.24</td>
</tr>
</tbody>
</table>

\(^a\) Mean scores are on a scale from 1 (not important) to 5 (very important)
Table 3.5 Perceived barriers to the purchase of wheat grown in commercial bakers’ region

<table>
<thead>
<tr>
<th>Barrier</th>
<th>Number of respondents</th>
<th>Percentage of respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>28</td>
<td>38</td>
</tr>
<tr>
<td>Availability/quantity</td>
<td>17</td>
<td>23</td>
</tr>
<tr>
<td>Suppliers/delivery</td>
<td>17</td>
<td>23</td>
</tr>
<tr>
<td>Quality (gluten, protein)</td>
<td>13</td>
<td>18</td>
</tr>
<tr>
<td>Climate</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Don’t know</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Post-harvest storage</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Time to research/test new products</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Labeling</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Production</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Minimum purchase amount</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Need organic</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
Chapter 4

Commercial Bakers’ Views on the Meaning of “Local” Wheat and Flour in Western Washington State

4.1 Abstract

Most existing efforts toward revitalizing local food production have focused on fresh produce and animal products, largely neglecting staple crops such as grains. There has been increasing interest in many parts of the United States in relocalizing grain production. Wheat is the most commonly consumed grain in the United States. Commercial bakers could be important supply chain intermediaries for locally grown wheat, but little is known about their attitudes toward local wheat and how they define local. We surveyed commercial bakers in western Washington State and interviewed experts involved with local wheat movements in other regions. Thirty-
four percent of survey respondents defined local as within the state of Washington, 25 percent provided a multi-state definition, and 14 percent provided a flexible (or reflexive) definition that referred to two or more geographic regions. Perceived barriers to purchasing local wheat included supply chain, price, quality, and scale factors. We conclude with discussion of the opportunities and challenges for the relocalization of wheat flour supply chains.

**Keywords** Commercial Bakers, Local Food, Short Supply Chains, Washington State, Wheat

### 4.2 Background

Recently, local food systems have received attention in the academic literature (Bloom and Hinrichs, 2010; Ostrom, 2006; Peters et al., 2009), the popular press (Kingsolver, 2007; Pollan, 2006), and government initiatives such as the U.S. Department of Agriculture’s “Know Your Farmer, Know Your Food” program (USDA, n.d). The local food movement was born out of the environmental movement with concerns about “food miles” and long distance transport of food (Pirog and Rasmussen, 2008); the community food security movement with concerns about access to healthy, affordable food (Feenstra, 1997); and as a response to the conventionalization of organic agriculture (Fonte, 2008). The local food movement has an emphasis on supporting local farmers and encouraging consumers to understand the origin of their food (Ilbery and Maye, 2005). The benefits attributed to local food fall into several categories: economic (e.g., jobs in production, processing, and distribution), environmental (e.g., decreased food miles) and social (e.g., increased accountability of agricultural enterprises to local communities).
While various authors have sought to define local foods (Dunne et al., 2010; Giovannucci et al., 2010; Ostrom, 2006; Pirog and Rasmussen, 2008; Sefa and Qazi, 2005), there is a shortage of literature on how “local” is defined in the context of staple crops, like wheat. This study aims to better understand the definition of local wheat from the perspective of commercial bakers, important supply chain intermediaries. Through a mail survey of commercial bakers in western Washington, our goal was to learn how commercial bakers define local in the context of purchase of wheat/flour for their bakeries, and to understand what they perceived as barriers to the purchase of local wheat. In addition, we conducted telephone interviews with three knowledgeable individuals involved in wheat relocalization in other parts of the U.S. to add perspectives from other regions. While our survey results may not be generalizable to other areas, they can inform grain relocalization efforts by revealing the inherent challenges and opportunities in connecting staple crop (e.g., wheat) producers, supply chain intermediaries (e.g., processors and bakers), and consumers. In addition, they contribute to the nascent literatures on staple crop relocalization and the perspectives of supply chain intermediaries.

4.2.1 Definition of local

Local is one of many attributes that can be attached to a food product to communicate value to consumers. For these attributes to be trusted by consumers it is helpful to have agreed-upon definitions. However, unlike other attributes (e.g., certified organic, fair trade) included on food product labels in the United States, third party certifiers do not set the definition nor regulate the use of the term “local.”

The concept of local food has been criticized for its lack of a firm definition. Some popular definitions that have been proposed include those based on political boundaries (e.g., within a
particular state), distance (e.g., 100 miles), or bioregion (Martinez et al., 2010). Pirog and Rasmussen (2008) found in a survey of consumers that most respondents in the West (13 state region) considered local to be within a 100-mile radius. The U.S. Congress in the 2008 Food, Conservation, and Energy Act defined the total distance that a product can be transported and still be considered a locally or regionally produced agricultural food product as “less than 400 miles from its origin, or within the state in which it is produced.” In a study of food retailers’ definition of local, Dunne et al. (2010) found that definitions of local varied widely and were neither strict nor tightly regulated. Further discussion of the definition of local can be found in Giovannucci et al. (2010) and Martinez et al. (2010).

4.2.2 Complicating factors in the definition of local

Local food has inherent complexities that defy a firm definition of the term. In the case of plant-based foods, definitions of “local” may depend on whether the crop is grown in one’s region, and on the existence of infrastructure and supply chains to make the identity-preserved local crop available. What qualifies as local for one type of food crop may not be the same as for another type of food crop. For example, a consumer in Washington State may consider California avocados to be local, but expect that apples advertised as local come from within the state (or even within the county).

The idea of “flexible” or “reflexive” localism was introduced by Morris and Buller (2003) and refers to an elastic definition of local depending on the ability to source supplies within a short distance or further away (Ilbery and May, 2006). Flexible localism can also exist in terms of producers marketing products. Qazi and Selfa (2005), in a survey of agricultural producers in two counties in Washington, determined that a higher percentage of producers in heavily
populated King County (66 percent) versus sparsely populated Grant County (20 percent) defined their local market to be their own or surrounding counties.

Flexible localism implies that the emphasis on local food provisioning is a means to an end, rather than an end in itself. Ilbery and Maye (2006) note that flexible localism reflects the inherent complexities of food systems and acknowledge that the distinction between local/alternative and global/conventional may obscure the hybrid nature of many food supply chains that involve both local and global food products. Embeddedness, the goal of local, has more to do with community, economy, and social relations resulting from the food system than with a set definition based on factors such as political boundaries or distance.

When local foods are expanded beyond whole foods and into processed and multi-ingredient products, the idea of local is further complicated. What percentage of the ingredients must be local for the product to be considered local? Is local based on where products are grown (or raised) or where they are processed? Even more questions arise when considering the involvement of multinational corporations in marketing of local food. Frito-Lay advertised the use of local ingredients in the states where the company sources potatoes for Lay’s potato chips (Severson, 2009). Wal-Mart is reaching out to local farm suppliers to satisfy customer demand for local produce (Cantrell and Lewis, 2010). To the most dedicated believers, supporting locally grown food is “part of a broad philosophical viewpoint that eschews large farming operations, the heavy use of chemicals and raising animals in confined areas” (Severson, 2009, p. D1). Often part of this viewpoint includes keeping dollars in the local economy by supporting locally owned stores rather than multinational corporations.

4.2.3 Grains as local food
Much of the attention in local food systems has been focused on produce and animal products, with very little attention paid to staple crops such as grains. Staple crops are those crops that provide a majority of calories in human diets and are also critical as livestock feed. Wheat is one of the most important staple crops, providing 19 percent of human calories worldwide (Mitchell and Mielke, 2005). Wheat is the world’s largest crop by production area and second largest crop by quantity produced (USDA-FAS, 2011). In 2009, U.S. annual per capita consumption of wheat flour products was 61 kg or 69 percent of total flour and cereal products (USDA-ERS, 2009), making wheat the most important staple crop in the U.S.

Wheat is considered a “commodity crop” meaning that it is essentially interchangeable on the market. The price paid to the grower is determined by a board of exchange, which represents “… one of the largest, most impersonal of systems shaping our relationship to food. Although it is almost completely divorced from real grain, its influence is seen well beyond the trading floor—on the farm and in the grocery store, and all over the world” (Kavage, n.d.). Movements aimed at food system reform have problematized food’s treatment as a simple commodity and have called for “decommodifying food” (McClintock, 2010).

Commodity agriculture, which involves the production of staple crops such as wheat, corn, and soybeans, is often viewed as antithetical to sustainable agriculture by sustainable agriculture advocates (Lyson, 2004). The system of commodity agriculture is often blamed for the abundance of cheap processed food in the U.S. and the epidemics of obesity and diabetes (Carolan, 2011). Food deserts are defined, in part, by a shortage of fresh fruits and vegetables (Ver Ploeg, 2009) rather than by a shortage of wheat-based carbohydrates (though it could be argued that most food deserts have a shortage of whole grain options). Despite these issues,
staple crops such as wheat still play an important role in food systems in general and sustainable agricultural systems as food, feed, and malt.

Grains are fundamentally different from the produce and animal products that currently dominate the local food market. Wheat shares many qualities with other grains and staple crops and thus many of the same issues in terms of its place in a local food system. Over the past two generations, consolidation within the grain industry has resulted in a dismantling of grain production and processing infrastructure in many communities that once produced much of their own grain. With concern about food security and the vulnerabilities inherent in our modern food system (Hanus, 2010), staple crops such as wheat may play an increasingly important role in relocalization efforts, as communities attempt to reestablish the infrastructure necessary for local food systems. The relocalization movement attempts to extend sustainability to the entire supply chain, including processing, packaging, and transport (Fonte, 2008).

The perspectives of producers and consumers have been a frequent subject of study in research on local food systems, but the importance of supply chain intermediaries is a topic that has been less frequently explored in the literature on local food systems. Better understanding of the perspectives of supply chain intermediaries has the potential to reveal the barriers and opportunities for connecting consumers with local food resources (Dunne et al., 2010; Feenstra, 1997). A USDA study that analyzed 2008 Agricultural Research Marketing Service data found that most sales of local food occur through intermediated marketing channels, such as regional distributors and grocery stores, restaurants, and other local retailers. In 2008, at least 60 percent of the value of local foods reached consumers through intermediated channels (distributor, grocery, restaurant) (Low and Vogel, 2011).
Existing literature on the perspectives of supply chain intermediaries includes several studies of direct sales to restaurants, schools, and other institutions. In a USDA rural development report, Painter (2008) reviews existing farm-to-school programs and farmer-to-chef collaboratives as methods for marketing differentiated farm products. Starr et al. (2003) examine the connections between Colorado restaurants and institutions and local (produce) farmers. Inwood et al. (2009) look at the characteristics of early adopters, motivations for using local foods, and barriers to adoption of local food use by Ohio chefs. Vogt and Kaiser (2008) found in their review of nineteen studies of farm-to-institution and farm-to-school linkages that institutional support was needed to transition to this method of purchasing. This literature points to lack of infrastructure and financial support for processing and central distribution as the most important barriers in the creation of local food connections. As with most literature on local food, local grain was not mentioned in these papers.

Despite the lack of literature in relation to local food systems, supply chain intermediaries are especially important with a food such as wheat, which typically involves more processing, blending, and other intermediary activities compared to many other foods. A key difference in local grain systems (as opposed to commodity markets) is that generally the identity of the grain is preserved through processing and distribution, so that information about who grew the grain and where it was grown are available to the end consumer. While wheat is an ingredient in many different products, much of the anecdotal interest on the purchasing side of local wheat has involved small-scale, artisan bakers (Hills et al., 2011).

4.2.4 Bakers as potentially important intermediaries in local wheat value chains
Since the 1970s there has been growing interest in a return to “artisan” bread made without stabilizers, dough conditioners, and preservatives (Suas, 2009). Artisan baking has come to stand for a “…commitment to production methods that employ traditional skills distinct from the highly controlled and automated production systems of the factory bakery” (Bassetti and Galton, 1998, p. 20). Rather than sharing a shape, ingredients, or style, artisan breads’ common element is that they were “touched by the hand, assessed by the eye and subject to the baker’s judgment at every step” (Bassetti and Galton, 1998, p. 20). John Yamin, CEO of La Brea Bakery (a bakery chain based in southern California) estimated that artisan bread accounted for 13 percent of the bread market measured in dollars. He attributed this to a greater awareness among customers of the quality of the food they consume (Whitaker, 2007). Commercial and artisanal bakers are the focus of our project because they have the potential to get locally grown wheat to the consumer while preserving the “story” of the wheat.

Commercial bakeries, particularly artisan bakeries, offer a promising way to get local wheat to the consumer. Commercial bakers have a unique perspective on the possibilities of using local wheat because of their position in the supply chain between processors and consumers. They are also closer to the wheat than their customers are and, because of that, may have a greater interest in the origin of the wheat.

Even large multinational companies such as ConAgra are recognizing the consumer demand for food that has traveled fewer miles and has traceable provenance or origin (Severson, 2009). A bakery consultant at Great Harvest Franchising Inc (Dillon, MT). said consumers are increasingly looking for locally produced baked products made from sustainable products (Thilmany, 2010).
While extensive literature exists on the definition of local food (see, e.g., Dunne et al., 2010, Givoanucci et al., 2010; Pirog and Rasmussen, 2008), there is a lack of available research on what local means with respect to staple crops such as wheat and how it is defined by commercial bakers, important food chain intermediaries in the case of wheat/flour. One exception to this is a study of social relations between organic cereal and bread producers, processors, and marketers in Austria, in which Milestad et al. (2010) described a pragmatic definition of local based on availability of products locally and the location of potential consumers. It was not clear whether the results of Milestad et al. would be relevant for western Washington or other regions of the US and across organic and conventional supply chains. We aim to address this gap in the literature with the research outlined below focused on the definition of local by commercial bakers in western Washington State.

4.2.5 Western Washington

In 2008, Washington State produced $745 million worth of wheat (Brady and Taylor, 2010), 85 percent of which is exported internationally (Washington Grain Alliance, 2010). The Cascade Mountains divide the state into two distinct bioregions, with the majority of the wheat produced in the eastern part of the state and the majority of the population residing in the western part. Eastern Washington has some of the greatest production of commodity wheat in the nation, produced for an export-driven market and moved through a well-established network facilitating the transport of commodity wheat. While western Washington is more commonly known for the production of horticultural crops such as berries, tulips, and vegetables, wheat is an important rotation crop grown to improve soil quality and break disease cycles. Its value as a rotation crop makes wheat worthwhile growing, even if growers do not profit from the wheat. This wheat is usually
sold on the commodity market and offers growers very little return; usually the grower is trying to “lose less money” on the wheat crop. This lack of profit is due to the smaller scale of the farms and the higher land values in western compared to eastern Washington, as well as the lack of support programs (e.g., subsidies) that are more available to their larger counterparts in eastern Washington. Because vegetable processors have largely left the area, western Washington growers are left with fewer options for their crop rotation, making it more important for each part of the rotation, including wheat, to generate profit. These growers have used vertical integration and identity preservation to maintain their economic competitiveness in other markets (e.g., potatoes, bulbs, berries). Thus, selling their wheat to nearby metropolitan areas whose consumers are concerned with local food and farmland preservation is of great interest to growers (Patzek, 2012). Developing a market for local wheat would benefit growers and make the wheat component of the rotation more profitable.

Low and Vogel (2011) found that proximity to a metropolitan area, access to farmers’ markets and farmland, and location in the coastal regions of the U.S. are drivers of direct-to-consumer sales. This suggests that local food sales have the greatest potential for economic development in specific places and regions of the country. Skagit County in northwestern Washington had over $2.5 million in direct-to-consumer sales of farm products in 2007 and is part of a trend of local food production in the Pacific Northwest concentrated in the areas of higher population density, west of the Cascade Mountains. Western Washington has a higher population density than eastern Washington, and has over 424,000 acres (171,586 hectares) acres of farmland (USDA-NASS, 2007), on some of which grains are grown in rotation with other crops. The
density of farmers markets, which could be used as a proxy for interest in local foods, is quite high west of the Cascade Mountains (see Figure 3.1).

Western Washington is one of many areas of the country where there are movements underway aimed at bringing back the local production of grains for local consumption in areas where they were historically grown and processed (see Appendix J). Bakers in Victoria, British Columbia; Mount Vernon, Washington; Athens, Ohio; and Asheville, North Carolina are connecting with growers to reform parts of the supply chain lost over time to consolidation and industrialization of the wheat milling sector. The goal is often to shorten the supply chain so growers can receive more of the market share of the final product (Appalachian Staple Food Cooperative, n.d.; Hanus, 2010; Hergesheimer and Wittman, 2012; Wolfe, 2011).

Because western Washington is not far from a large area of commodity wheat production and has some existing commodity wheat production, there are both challenges and opportunities for relocalization of wheat. Some bakers in western Washington are buying Washington-grown wheat from a company called Shepherd’s Grain, a group of no-till wheat farmers in eastern Washington who market their wheat, which is milled by Archer Daniels Midland (ADM), as part of a value chain including identity preservation on each bag of flour (Stevenson, 2009). This brings up the question of what is “local enough” for bakers and their customers, and in the case of baked goods, for commercial bakers. Though for fruits and vegetables consumers and food chain intermediaries such as chefs might consider a 100-mile radius as necessary to be considered local, it is not clear how perceptions change when considering wheat flour used in a multi-ingredient product. Food chain intermediaries represent “control points” of a local food system as decisions that they make influence the system (Dunne et al. 2010). Commercial
bakers are the intermediary with the most ability to buy local wheat flour in large quantities. Understanding commercial bakers’ views of local when it comes to flour purchases will provide new insight into local foods in general and local staple crops, in particular.

The overall goal of this project was to better understand the important complexities associated with the relocalization of a wheat/flour system by examining the practices and perspectives of commercial bakers. The primary questions addressed are:

- How do commercial bakers define “local” in relation to purchasing wheat/flour for their bakeries?

- How do commercial bakers’ opinions of local wheat/flour compare to their perceptions of their customers’ opinions of local wheat/flour?

- What are commercial bakers’ perceptions of their customers’ willingness to pay a premium for products made with Washington-grown versus western-Washington-grown wheat?

- What do commercial bakers see as barriers to the development of a local wheat system?

To address these questions, we surveyed commercial bakers in western Washington State. In addition, we conducted interviews with intermediaries (either millers or bakers) involved in newly formed wheat relocalization movements to explore grain relocalization efforts in other parts of the United States.

While the results of this study may not be generalizable to other regions in the U.S. or worldwide, they can inform wheat relocalization efforts by revealing the complexities as well as the inherent challenges and opportunities in staple crop relocalization.
4.3 Methods

4.3.1 Survey

Using a modified Tailored Design Method (Dillman et al., 2009), we sent questionnaires to commercial bakers in the nineteen counties of Washington west of the Cascade Mountains. (See Appendix F for full questionnaire.) Grocery store bakeries and large national chain bakeries were not included in our study because we wanted to target bakeries with a greater ability to adjust processes or try new ingredients. We also excluded bakeries that sell exclusively cakes, cupcakes, doughnuts, and/or pies because we assumed their customers might be less attuned to local foods. Names and addresses of bakeries were obtained through a variety of sources including the Washington State Department of Agriculture’s list of licensed food processors, King County Public Health Department’s list of inspected food service establishments, and an email announcement sent by the Bread Bakers Guild of America to its members. We also searched for the word “bakery” in Google Maps (Google Inc., Mountain View, CA).

The region of focus was chosen because the areas to the east and west of the Cascade Mountains are quite different in terms of climate, population density, and other factors (Qazi and Selfa, 2005). In fact, the region of focus was defined as a “foodshed” in a recent publication (American Farmland Trust, 2012). The majority of Washington’s population and, thus, the majority of bakeries in the state are concentrated in the western part of the state.

Several professional bakers outside of the survey area were consulted during the development of the questionnaire. Individuals responsible for making purchasing decisions for commercial bakeries were instructed to complete the questionnaire. We collected general information on the
characteristics of the bakeries (e.g., number of locations, number of employees, and percentage of direct-to-consumer sales), current sourcing of flour, and interest in purchasing flour from western Washington. In other questions, respondents were asked about regionally produced flour. We intentionally left “regionally produced” undefined because we wanted to allow respondents to reflexively define the term rather than rely on a single definition provided by us. Because the predominant supply chain for wheat flour operates on a national scale, many of the same barriers exist for supply chains operating within a smaller geographic area, whether within a county or a multi-state region.

A cover letter and questionnaire were sent to 267 commercial bakers on March 31, 2011. A reminder postcard was sent on April 7 followed by a final mailing to non-respondents on April 28. The survey closed on November 10 with 73 eligible bakers responding (33 percent response rate)\(^4\). Data were analyzed using Minitab 16 (Minitab Inc., State College, PA).

4.3.2 Interviews

To supplement the information from the survey, we conducted semi-structured interviews with three individuals who have been active in wheat relocalization efforts in the southeastern and northeastern U.S. The interviews took place in June 2012 and were conducted by phone. Interviewee 1 has 39 years of experience in the baking industry. Currently a consultant for a well-known independently owned mill, he works with commercial bakers, and offers technical support and advice to local grain enthusiasts. Interviewee 2 is a commercial baker who operates

\(^4\) We did not contact non-respondents to find out why they had not participated in the study. Identifying non-response bias (if present) would have helped our interpretation of the survey results.
a bakery with 40 full-time employees and sources 20 percent of his flour from wheat grown within his state (which is not known for its wheat production). He is familiar with the challenges and benefits of using local wheat in his bakery. Interviewee 3 was a professional baker for 14 years and is now a central figure in her region’s effort to revitalize small grain processing and has led a project to open a small mill that is providing locally grown wheat to bakers in her area.

4.4 Results

4.4.1 Characteristics of survey respondents

Table 3.1 presents descriptive statistics for the surveyed bakeries. Of the 73 survey respondents, 45 percent were located within heavily populated King County, which includes Seattle. Eighty nine percent were bakery owners, 88 percent had only one location, 49 percent employed four or fewer people, 60 percent distributed their products only within their own counties, and 90 percent made at least one quarter of their sales from direct-to-consumer sales. For 57 percent of respondents, bread sales made up less than 25 percent of their total sales. Annual flour use ranged from 120 lb (54 kg) for a bakery and deli in a rural area to over 1.5 million lb (over 700,000 kg) for a pita bread bakery with national distribution. Only 7 percent of the bakers milled some of their own flour. This flour accounted for only 11,278 lb (5,116 kg) annually or 12 percent of total wheat flour used by those bakers owning mills and 0.15 percent of wheat flour used by all respondents.

4.4.2 How do commercial bakers define “local”? 
Survey respondents were asked to define local in relation to purchasing flour/wheat for their bakery. Most respondents provided answers based on geopolitical boundaries (state or multi-state region) rather than bioregion (e.g., coastal Northwest) or distance (e.g., 100 miles) (Table 4.1). Approximately one third (34 percent) of respondents defined local as within Washington State. Twenty five percent defined local in terms of a multi-state region. Some respondents referenced the “Pacific Northwest” or “western region” without listing specific states, while other respondents listed two or more specific states or provinces (Washington, Oregon, Idaho, Montana, Wyoming, California, and British Columbia). Only seven percent of respondents defined local in terms of a county or multi-county region (i.e., western Washington State). Eight percent of respondents provided a distance-based definition of local (e.g., 100 miles or 10-hour drive). Twelve percent of respondents either did not answer the question or provided a definition that did not fit the geopolitical boundary or distance categories.

It is worth noting that 14 percent of respondents provided a flexible (or reflexive) definition of local (Table 4.1). These respondents mentioned two or more definitions of local, such as: “In-state or in-county,” “Vashon Island or WA State,” “Surrounding counties or states,” and “Western Washington—Washington State—Northwest region of U.S.” Several respondents who provided flexible definitions indicated a preference for a smaller rather than larger geographic range: “Within Washington State but mostly within county limits,” “Pacific Northwest as a general rule, state centric preferred,” “Regional—as local as we can get it,” and “Within the western one fourth of the U.S., although I’d love if it came from Washington.”

Interviewees were also asked how they defined local with respect to wheat flour.
Interviewee 1, a mill consultant, had the following thoughts about the term “local” as it applies to wheat flour and other foods:

“What means local for one thing is not necessarily the same as for another. Let’s look at quality. Obviously you want a local tomato, local lettuce because there’s just a huge difference, you want local fresh eggs. Even if you don’t think of the economy and the social structure, even if all you’re looking at is end product, local is good when you talk fruits, vegetables, eggs, but with grain it’s kind of hard. The wheat that I mill today that I bought from western Kansas is going to be in every bit as good a condition as wheat that I got today that was grown [nearby]. There’s no quality difference because it’s local. So I think that local bakers, manufacturers, and their customers have to be convinced for other reasons that it’s important for them to support local small grain agriculture.”

Here, the mill consultant recognizes that supporters of local grains may tend to have reasons based on societal benefits (e.g., environmental benefits and local economic development) rather than individual benefits (e.g., personal health and freshness).

Interviewee 2, a commercial baker, responded:

“If we’re calling something local, the agreed upon definition in this area is within 100 miles of wherever it’s being consumed. I can accept that. I don’t adhere rigidly in my own diet or not even close to that in our purchases at the bakery—it would be unrealistic. But I do think it would be dishonest marketing to market wheat flour as local if it was milled by a local miller but with wheat grown further away.”
Interviewee 2, a baker who has gone to considerable effort to work with farmers to source 20 percent of his wheat from within his state, sees differences between sourcing local flour and other local products:

“It’s interesting with wheat and wheat flour because wheat flour is produced in such large quantities all over the world that we don’t even really value it any more. I sometimes referred to it as the canvas, upon which we as bakers do our work. And I don’t mean to minimize it by saying that, it’s just that unbleached wheat flour, while it is extremely important, it gets transformed significantly in the baking process so it’s not the same as getting a plate of local beef at a restaurant where it’s really easy to connect the farmer to the meal you have in front of you.”

Interviewee 2 also acknowledged some of the complexities involved in labeling a product as local. After developing a specific recipe featuring local wheat, including packaging that stated that it was made from 100 percent in-state grown wheat, a poor growing season resulted in a limited supply of wheat from one of the two growers supplying the bakery. Because of that, the bread was made with 85 percent in-state grown wheat. The baker had to change the label on the bread to adjust to the change in the origin of the wheat.

These complexities in the definition of local illustrate reasons why bakers may adopt a flexible definition of local that reflects regionally relevant factors such as the availability of products.

4.4.3 Relationship between bakery characteristics and bakers’ definition of local

We conducted cross tabulations and chi-square tests (available upon request) to examine the relationships between selected bakery characteristics and bakers’ definition of local. We found
no statistically significant relationships between definitions of local and the following bakery characteristics: bakery size (number of employees), percentage of total sales from direct-to-consumer sales, percentage of sales from bread, geographic distribution of bakery products, and sales strategies (i.e., wholesale, retail, café/restaurant).

Interestingly, we found a statistically significant relationship between distribution area of a bakery and the baker’s definition of local. Bakeries distributing only within their county were more likely to include a larger area in their definition of local than those who distributed in areas outside their own counties. Though the reasons for this are not clear, it may be that bakeries that distribute only within their counties are more aware of the limitations on sourcing local ingredients.

4.4.4 Importance of wheat origin to commercial bakers and their customers

To begin to understand bakers’ awareness of and interest in wheat origin, we asked bakers if they were currently purchasing any Washington-grown wheat/flour. Approximately one third (32 percent) of survey respondents were purchasing Washington-grown wheat/flour (mostly Shepherd’s Grain from eastern Washington, milled by ADM), 47 percent were not, and 21 percent did not know the origin of their wheat/flour. We then asked bakers if they were interested in purchasing flour made from wheat grown in western Washington State. Sixty one percent of respondents were interested in western Washington wheat/flour, only 3 percent were not interested, and 36 percent did not know if they were interested. Chi-square analysis indicates no statistically significant relationship between current purchasing of Washington-grown wheat/flour and bakers’ definition of local. However, we find a slight relationship (chi-square=7.891; p=0.096) between interest in purchasing western Washington wheat/flour and
bakers’ definition of local. Commercial bakers who defined local in terms of western Washington State and those who provided a flexible definition of local were more interested in purchasing flour made from western Washington wheat compared to bakers who defined local in other ways.

We also asked bakers about the importance of wheat origin for their bakery products, as well as their perceptions of the importance of wheat origin for their customers. The level of importance was measured on a scale from 1 = “not important” to 5 = “very important.” Over one quarter (26 percent) of bakers felt wheat origin was “very important” (with a mean score of 3.6 on the scale of importance). Only 10 percent of bakers perceived that their customers feel wheat origin is “very important” (with a mean score of 2.9 on the scale of importance). Fifty five percent of survey respondents scored the importance of wheat origin higher for themselves than their customers, while 38 percent scored the importance equally. Increasing demand by bakery customers for products made from local wheat could convince bakers to take the extra steps to source wheat from a closer geographic region (e.g., Washington State or western Washington).

We asked commercial bakers to rate the importance (on a scale from 1 = “not important” to 5 = “very important”) of certain factors in their future purchases of regionally produced flour. The mean scores for “where the wheat was grown” and “where the flour was milled” were 3.6 and 3.4, respectively (Hills et al., 2012). We found that bakers who place a greater importance on where wheat is grown were more likely to be already purchasing Washington wheat/flour ($p=0.003$), while bakers who place a greater importance on where wheat is milled also expressed a greater interest in purchasing flour made from wheat grown in western Washington ($p=0.013$).

**4.4.5 Bakers’ perceptions of customers’ willingness to pay price premiums**
When asked whether their customers would be willing to pay a price premium for products made with wheat grown in Washington, 34 percent of survey respondents answered yes, 24 percent answered no, and 42 percent did not know. When the same question was asked about products made from wheat grown in western Washington, 17 percent answered yes, 28 percent answered no, and 55 percent did not know. Of the respondents who said their customers would be willing to pay a premium for products made from Washington wheat, 52 percent did not know if their customers would be willing to pay a premium for products made from western Washington wheat. These results suggest a greater level of uncertainty regarding consumer interest in products made from western Washington wheat versus Washington wheat, possibly because of the lack of an established supply chain for western Washington wheat.

4.4.6 Perceived barriers to purchasing regionally produced wheat

Overall, there was some uncertainty about sourcing wheat/flour from western Washington, which is not surprising because the supply chain infrastructure to connect local growers to local consumers has been dismantled over the past two generations and has not yet been fully replaced. Moreover, wheat grown in the area is often overshadowed by crops more easily recognized by the public such as tulips, vegetables, and berries. Survey respondents and interviewees were asked to elaborate on barriers (or potential barriers) to the purchase of wheat/flour from their region. Understanding barriers perceived by market intermediaries is an important way to advance local food systems. The majority of comments focused on four main areas: supply chain, price, quality and scale. Though some aspects of the survey and interviews are specific to western Washington and the locations of the interviewees, respectively, we
believe that these topics have relevance for people in other areas working to relocalize grain production. We will further explore each of these topics below.

Supply chain

The lack of an existing supply chain for western Washington wheat was mentioned by many of the survey respondents, as was the importance of using existing distributors that are able to source identity-preserved flour. The processing of wheat usually involves some degree of blending wheat from different farms to achieve desired end-use qualities, a step that makes identity preservation uncommon in standard flour supply chains. Survey respondents’ comments reflected these challenges:

“No really ‘knowing’ where wheat was grown. Having to keep tabs on my suppliers—it’s hard enough keeping tabs on my staff.”

“Unfamiliar territory of where to purchase small quantities in [all-purpose] flour or even available.”

“I would use it almost exclusively if I could get a stable supply.”

“It’s hard to find local products that my distributor carries.”

A barrier in the supply chain that was identified by bakers was the lack of processing equipment in western Washington for the most commonly used flour in bakeries: white flour. One baker stated that unbleached white flour constituted 90 percent of his bakery’s flour usage and he needed sifted stone-ground or roller-milled flour. The existing organic mill sourcing from local growers offers hammer-milled whole wheat flour and does not sift out bran. White flour is usually produced using a roller mill, a much more expensive piece of equipment that produces a more consistent particle size than either a stone or hammer mill. Though many bakers have
whole grain offerings, the majority of flour used by the survey respondents (88 percent) was white flour.

**Price**

Price was a concern mentioned by 38 percent of survey respondents. Because the existing infrastructure for processing wheat in western Washington consists of a relatively small organic mill and several small mills housed in bakeries, the limited amount of flour available commercially from western Washington is relatively expensive, with a 2 lb (0.9 kg) bag selling in some cases for $4.00 or more. Faced with the prospect of paying these prices, which were more than eight times as high as commercial flour prices, it is likely that commercial bakers would not be interested. The redevelopment of infrastructure around grain processing in western Washington would help to drive the price of flour down through economy of scale. However, it is unclear what the price would be at various levels of production or if the bakers (and hence their customers) would be willing to pay premiums for local wheat. One baker in western Washington, interviewed prior to our survey, said that his customers’ threshold was paying 25 percent more for a loaf of bread if it was made from local wheat. A survey respondent described economic concerns well:

“Volume of use for us would be limited to a function of price—there are only so many customers willing to pay extra for local. Unable to convert to all local at a premium price, can farmers make a margin selling direct to mill (vs. commodity), so miller and distribution rates bring flour at market rates or close?”
Scale of production and processing as well as the farmers’ expectation for return affect the price charged for local flour. Interviewee 1 commented on price issues:

“It’s so much more expensive to buy the locally milled, locally grown flour than it is to buy something, even an organic something, [grown] in the middle of the country. Part of it is cost of production, part of it is that the growers seem to think they ought to get the same per acre on wheat as they did for tobacco, which is not going to happen, or as they do for carrots or whatever their other cash crops are. I think that’s a real issue. It’s fine if you’re selling flour at the farmers market, but if you’re trying to sell to a bakery they will say ‘I have to pay you three times as much for this stuff?’ How much of a premium can the bakery ask?”

Interviewee 2 said of local flour: “The prices are very close at this point. Even though there are just a few farmers in [my state] doing their own thing, they are actually quite tied to the global wheat market. If nothing else, just because their prices need to match what people are generally paying for flour.”

He also said that with both farmers (one using his own stone mill and one contracting with a local roller mill): “We’re paying roughly the same per bag of flour as we are for flour coming out of Kansas. The farmers are getting more and the truckers are getting less because they’re not going nearly as far.”

Interviewee 3 discussed price as one of the drivers for the mill she opened. In 2008 the price of flour spiked 130 percent. Bakers were having enough trouble with availability and quality of their standard flour sources to be willing to take a risk by using local wheat. She said “We came
into this not just to get cheap flour for bakers, but to figure out how we can create real pricing: the best possible price to the grower at an affordable cost to the baker, something that would enable them both to thrive.” The motivation for the mill was, in part, to create a more equitable system where pricing is determined by the growers and the bakers involved, rather than by the global commodity market.

**Quality**

One part of the survey asked bakers to rate the importance of various factors for future purchases of regionally produced flour. Of the 18 factors listed, flour quality and consistency of flour quality were rated as the most important (Hills et al., 2012). A significant amount of effort goes into developing a formulation used in a bakery. If a new batch of flour does not perform as expected, there is potential for wasted time and product. Commercial bakers have come to expect the consistency between batches of flour they purchase, much like consumers have come to expect a high level of consistency in the products they purchase in the supermarket.

This sentiment was supported in comments made by the survey respondents:

“The flour would have to perform consistently. If the flour was priced well and available all the time and most importantly delivers the same results every time I would give it a try.”

“We have tried other local flours but we feel they don't work as well as the one we already use.”
“Quality is the [number one] priority, along with consistency. Lack of equipment for processing in [western Washington] leads to problems.”

“The main concern would be the ability of farmers to have a consistent crop every year.”

These comments point to the importance of the miller in the wheat supply chain. The miller’s role involves quality control and blending to achieve a consistent product.

**Scale**

Recent literature on local food systems has focused on the “scaling up” of these systems, beyond farmers market and farm-to-institution initiatives to penetrate the mainstream food market. As noted by King et al. (2010), mainstream markets such as supermarkets use a hub and spoke distribution system that allows for extremely efficient movement across great distance. These distribution systems favor large-scale suppliers who can reliably provide large quantities of products, which can be difficult for many producers of local food to provide. Local food may be a better fit for mid-scale distributors who may have more flexibility in sourcing from local suppliers.

The importance of efficient processing and distribution systems was highlighted by Interviewee 2, in comparing his two sources of local flour:

“For the flour that comes from [the local roller mill] and is milled from wheat grown on [one of our supplying farms], it goes right into [the warehouse] and comes on a truck right to us, which in my opinion is just how it should be done, if we’re going to ramp it up in terms of quantity. . . And that to me speaks to what a good thing it is to get
connected to an efficient distribution system and an efficient milling system. [The other farmer] is the first one to say that he doesn’t mill on a scale large enough to really be priced competitively. [His flour] falls into more of the category of a specialty flour.”

The mill consultant (Interviewee 1) pointed out the implications of scale when it comes to a product such as flour that is blended to achieve consistent quality:

“The other issue is consistency. The larger mills, they can do in a couple of days what we’re doing … but their flour is consistent around the year. They are carefully testing every wheat that they buy and they put blends together so that the flour they’re milling this week is like the flour that they are going to be milling the third week of December, which is the same as what they’ll be milling in May. And that’s a tough thing for small mills to do.”

Interviewee 1 pointed out that with a local wheat system as small as his, quality between batches is actually more consistent than buying blended flour:

“The mill that we buy from in Kansas is a small organic mill that is quite connected to their farmers and doesn’t have the ability to blend and get absolutely the same result from lot to lot so we’re quite used to paying attention to changes. So in reality, making breads with the local wheat in the two years that we’ve been doing it has actually been easier because you’re dealing with one crop year [from the same two farms] for the entire year. The type of adjustment we made once a year was equivalent to the adjustment we do every couple of weeks with the wheat that’s coming out of Kansas.”
Just as the scale of the supplier has an important effect on quality of the product, the scale of the bakery has an effect on quality tolerances, as stated by Interviewee 1: “Someone who is baking three dozen loaves and is selling at the farmers market can afford to have different criteria [for quality] than someone who is selling at the Whole Foods store.”

4.5 Discussion

There are important differences to consider between grains and fresh foods that present both challenges and opportunities for the incorporation of grains such as wheat into a local food system. Wheat is usually consumed in a processed form and typically undergoes some level of blending during the milling process to achieve the desired end-use qualities in the resulting flour. It is used frequently in multi-ingredient products and often is not used as a “center of plate ingredient” (HGCA, 2009). Because of their relatively low water content, grains and flour typically have a longer shelf life than some other types of food products, hence “freshness” is not usually as much of a concern for a bag of white flour compared to a cut of steak or a head of lettuce. Freshness can be important when it comes to whole grain flour as fresh milled flour is known to have improved flavor. Local processing (milling) of flour presents an opportunity to add value to wheat grown in the region.

Another difference is that the price a producer receives for his/her wheat in the U.S. is set by a board of exchange and does not necessarily reflect the cost of production. Factors affecting the price of wheat are global in nature and include weather conditions in other wheat-producing countries, politics, and price speculation. It is unclear to what extent those growing wheat for local markets can detach from global wheat prices.
The Home-Grown Cereals Authority (HGCA), the organization responsible for use of cereals and oilseed levies in the United Kingdom, produced a report titled “Provenance in the cereal products sector: Current issues and future opportunities” (HGCA, 2009). The authors found that for provenance (the method or tradition of production that is attributable to local influences) to become a more widespread factor in cereal products, there will need to be a change in the way these products are viewed. Flour is currently viewed as a mass-produced product. Brands are viewed as the quality indicator because consumers find it difficult to compare quality differences across flour.

4.5.1 Challenges

Grains have different infrastructure requirements than fresh produce in terms of production, storage, and processing. The grain sector is among the most highly consolidated sectors in the food system, with five major companies (Cargill, Archer Daniels Midland, Bunge, Louis Dreyfus Commodities, and ConAgra) controlling 80 percent of the global grain trade (Measner, 2007). The level of consolidation in the grain processing industry is so high that a Kansas baker may find it difficult to source local whole wheat flour (Henning, 2011). This may explain the minimal role that grains have played in the local foods market so far.

Mount (2012) posits that farmers who produce commodities that require processing will be challenged to access the added value that comes from eliminating profit-taking intermediaries. Alternatively, these farmers could become part of vertically integrated food value chains by doing their own milling and marketing the flour, allowing them to capture the added value.
Given the challenges in the development of a local wheat flour supply chain, it may be more realistic for supply chain intermediaries to encourage bakers to incorporate a percentage of local flour with their conventionally supplied flour. This could be seen as an intermediate step that would allow bakers to support the development of a western Washington wheat flour supply chain without taking the risk of using 100 percent western Washington flour. This supply chain will have an improved ability to control quality as it matures due to the inclusion of more producers and the education of these producers on which varieties and agronomic practices will ensure good baking quality.

A question that was beyond the scope of the survey but could be important for the local wheat market is whether bakers and their customers would be willing to pay a price premium for a blended product (for example, 50 percent western Washington wheat and 50 percent other wheat). Very little is available in the academic literature about willingness to pay for blended local products. Batte et al. (2007) found that consumers in Ohio were willing to pay a price premium for multi-ingredient processed foods with less than 100 percent organic ingredients. When asked about a variety of characteristics that might command a price premium in the supermarket, respondents had a mean willingness to pay a premium of $0.42 for a box of breakfast cereal with 100 percent local ingredients that would normally be $3.00 for a conventional product. It is unclear whether similar results would occur for products that contained less than 100 percent local ingredients.

Because it is not feasible for consumers to keep track of the origin of every ingredient in baked products they purchase, it is likely that they will put trust in a baker to source ingredients that are produced in a sustainable manner. One part of this sustainability may include where the wheat
was produced and processed. This is similar to the way that direct market customers of non-certified organic farms put trust in the grower to make sustainable choices in the way that he or she manages the farm, rather than requiring that they adhere to a strict set of standards, such as the National Organic Program. Especially important in the case of processed or multi-ingredient products is the trust that one intermediary puts in another intermediary in the food chain downstream of the producer, such as between retailers and processors (Dunne et al., 2010) or, in the case of wheat flour, between bakers and flour processor (miller).

The obstacles to purchasing local wheat that were mentioned by survey respondents were similar to those identified by Painter (2008) related to restaurant purchases, including inconsistent availability and quality, difficulty identifying reliable local suppliers, difficulty in making purchases (due to farmers’ ordering procedures), and inconvenience of dealing with multiple suppliers. In the current industrial food system, it is much easier for businesses to source material from one or two distributors that can reliably ensure access than to work with many small suppliers. Local grain movements may benefit from the experiences of restaurants using local foods, many of which have successfully overcome similar obstacles.

4.5.2 Opportunities

While challenges exist for relocalizing wheat production, there are also opportunities that exist in the local grain sector. One major opportunity to add value is through identity preservation, or maintaining information about where the grain is grown and by whom, throughout the supply chain.
According to the HGCA (2009), cereal products are responsible for a relatively small percentage of the total shopping bill, making consumers less likely to compare price than they would with other, higher priced items on their shopping list. Because there has been little focus on origin in the grain sector, “producers, processors and manufacturers have a blank canvas to develop an association between their region and cereal products and fill the local food ‘gap’. This is relevant to both artisan/small scale producers and larger scale producers that can emphasize their links to a specific region” (HGCA, 2009). Also, their ability to be stored allows local grains to be available year round, filling in the seasonal gaps in local fresh produce. The opportunity to produce gluten-free grains for the burgeoning market for gluten-free baked goods in the U.S may offer a niche market for growers of some types of grains.

Interestingly, while we anticipated that bakers focusing on bread might be the most interested in local flours, survey respondents’ level of interest in local wheat flour was not related to the percentage of their sales from bread. This may indicate an opportunity to market local wheat flour for use in pastries, pita bread, cakes, cookies, or other products, which have different quality parameters from those required for bread production. Grocery store bakeries and large national chains were not included in this survey but may offer additional markets for local wheat.

4.6 Conclusion

The results of this study can inform grain relocalization efforts by revealing the inherent challenges and opportunities in connecting staple crop (e.g., wheat) producers, supply chain intermediaries (e.g., processors and bakers), and consumers. Our results also contribute to the
nascent literatures on staple crop relocalization and the perspectives of supply chain intermediaries.

Most commercial bakers who responded to our survey defined local as either in the state of Washington or in a multi-state region. Fourteen percent of respondents gave reflexive definitions of local, reflecting the complexities of food systems in general and wheat flour supply chains in particular. Location-specific factors such as climate and land value, as well as respondents’ knowledge of the regional production of crops, may have contributed to the level of flexible localism expressed by respondents. There are also indications that commercial bakers’ definition of local is highly influenced by factors such as availability of product. There may be differences in the way that commercial bakers define local for wheat/flour as opposed to other types of ingredients. The expression of flexible localism in this study was similar to Morris and Buller’s (2003) study of local food retailers and Milestad et al.’s (2010) study of actors in the cereal supply chain, though flexible localism was not quantitatively measured in these studies.

We found that definitions of local varied widely among commercial bakers in western Washington similar to Dunne et al.’s (2010) finding among food retailers in Oregon. The bakers’ definitions were often based on political boundaries, but also included definitions based on miles or driving time. It is likely that in defining local, supply chain intermediaries may take factors such as the existence of processing infrastructure and distribution into account more than producers or consumers would. Our results supported those of Milestad et al. (2010), in which actors in an organic cereal/bread supply chain in Austria expressed flexible localism based on location of inputs and consumers. In Dunne et al. (2010), transportation systems were mentioned as a factor among food retailers in Oregon when proposing a definition of local. While questions
about transportation were not included in our survey, distribution was cited by survey respondents as one of the barriers to the use of regionally produced wheat/flour.

Dunne et al. (2010) found that smaller retailers used smaller spatial boundaries for defining local. In contrast, our study found that bakers distributing within smaller spatial boundaries (i.e., their county) were likely to define local using larger boundaries. This may be due to the differences in sourcing and distribution systems between bakeries and food retailers such as grocery stores.

Similar opportunities and challenges exist in the relocalization of staple crops (e.g., grain) as exist for other local food systems. Reestabilishment of what Hergesheimer and Wittman (2012) refer to as “place-based grain systems” in locations that historically grew their own grain has the potential to increase crop diversity and improve farm profitability, resulting in the preservation of farmland. The barriers related to lack of infrastructure and cost effective processing and distribution pose challenges for the development of local grain supply chains, much as they have for local food supply chains as identified by Starr et al. (2003), Inwood et al. (2009), and Vogt and Kaiser (2008). As with other types of food, economies of scale in a local grain system can be difficult to achieve without the product volumes to access the mainstream supply chain. One strategy for dealing with this could be vertical integration, in which growers incorporate processing (or even baking) into their businesses. Through brand identification and consumer trust, commercial bakers could play a key role in the relocalization of wheat.

Research on the process of relocalization is still in its early stages (Sonnino and Marsden, 2006), but studies of food chain intermediaries (e.g., commercial bakers) have the opportunity to provide insight into relocalization efforts, especially for staple crops, which have been underrepresented in the local foods movement despite their importance in human diets. The
staple crop relocalization movement is still evolving in western Washington and other regions. Answers to remaining questions may become clear as local grain movements involving bakers and growers work on parallel fronts to shorten supply chains in ways that are beneficial for businesses, communities, and consumers, to reaffirm the connection between producers and consumers of staple crops, and to transform grains from an anonymous interchangeable commodity to a food grown on a farm by a farmer to provide human sustenance.
4.7 References


   Washington State University IMPACT Center Fact Sheet.


**Table 4.1 Commercial bakers’ definitions of “local” in relation to purchasing wheat/flour**

<table>
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<th>Definition of “local”</th>
<th>Number of respondents</th>
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<tr>
<td>Miles or distance(^a)</td>
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<td>8.2</td>
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<tr>
<td>Within county</td>
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<tr>
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<tr>
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<tr>
<td>Flexible definition(^c)</td>
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</tr>
<tr>
<td>Other definitions(^d)</td>
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<td>4.1</td>
</tr>
<tr>
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<td>8.2</td>
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<tr>
<td><strong>Total</strong></td>
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<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

\(^a\) Answers included 50 miles, 100 miles, 200 miles, 10-hour drive, and 1-day drive.

\(^b\) These answers referred to the “Pacific Northwest,” “western U.S.,” or listed two or more specific states or provinces (Washington, Oregon, Idaho, Montana, Wyoming, California, British Columbia).

\(^c\) These answers included two or more definitions of local, such as: “In-state or in-county,” “Vashon Island or WA State,” “Within Washington State but mostly within county limits,” “San Juan County, primarily; west of the Cascades, secondarily,” “Surrounding counties or states,” and “Pacific Northwest as a general rule, state centric preferred.”

\(^d\) Other definitions included: “Can be delivered within a week,” “Local distribution,” and “I don’t know if it is grown local or not unless it says on the bags.”
Chapter 5

Conclusion

The results of the field study in Chapter 2 suggest that it is possible to raise protein levels in organic hard winter wheat grown in western Washington by a late-season application of organic fertilizer. The level of protein increase was influenced by variety, growing season and location. For hard winter bread wheat, the minimum protein requirement should be determined based on the needs of end users, and met through a combination of fertility practices, one of which may be late season topdressing. Topdressing should not be used as a primary fertility management strategy in organic systems, both because the practice would not be the most economical way to provide crop N and because the production principles of organic agriculture emphasize management of long-term soil organic matter. However, topdressing can be effectively used as part of a comprehensive N fertility management strategy including crop rotation, green manures, animal manures, and other strategies that build soil organic matter and long-term soil nitrogen.
reserves. The importance of choosing varieties that are well-adapted to the region west of the Cascades was highlighted by this study. As better varieties become more available to growers through the breeding program at WSU Mount Vernon and other sources, the chances of meeting quality standards for hard winter wheat will be improved.

In regions such as western Washington, where climate may result in pre-harvest sprouting that reduces the wheat grade, it will also be important to investigate other marketing options for organic hard and soft winter wheat. Other marketing options may include local markets for pastry flour, organic feed, or local distilleries. As the sales of grain for unique uses outside of the commodity market is still not widespread, price structures have not yet been developed. An understanding of prices that growers can charge for wheat of varying quality grades will help them in making economical management decisions.

The survey results presented in Chapter 3 suggest that while there are commercial bakers in western Washington who express interest in purchasing wheat/flour grown in the region, there exists uncertainty around the perceived barriers of cost, availability, suppliers, and quality. Survey respondents were not likely to rate technical specifications as holding high importance, though this may be more as a result of the quality control already built into the processing step in the wheat/flour supply chain. Upon further analysis, it becomes clear that grains possess unique features which make them different than other types of foods typically seen in the local food movement such as ingredient status, level of processing, perishability, and value to volume ratio. These characteristics of relocalized wheat/flour supply chains are important factors to consider in the goal of recreating systems that are beneficial for the grower, processor, distributor, and consumers of grains.
Chapter 4 presents survey results and interviews related to how commercial bakers in western Washington and some key players in local grain movements in other parts of the U.S. define ‘local’ in terms of wheat/flour. As with other studies attempting to identify how specific actors in the food system define ‘local,’ results varied widely and included definitions based on political boundaries, distance, and driving time. Fourteen percent of respondents offered a reflexive definition of ‘local’, highlighting the inherent complexities of place that make it difficult to define ‘local.’

Though some aspects of this project presented in Chapters 3 and 4 are specific to the region, many similar challenges and opportunities are faced in places that have lost the ability to grow, process, and distribute grains on a regional scale. Results of this study should hold relevance for other areas in the U.S. that are trying to reconnect grain producers and consumers in a mutually beneficial way.

It is my hope that the results of these studies will inform the development of robust local grain systems in western Washington and in other regions. In many ways, wheat production and processing epitomize the success of the dominant food system’s highly centralized and industrialized methods of delivering an interchangeable commodity to the consumer. For this reason, wheat offers a fascinating perspective from which to study the relocalization of food systems. The contrasts between commodity food systems and alternative food systems are especially stark with a crop such as wheat. The act of reclaiming wheat is, for these reasons, perhaps the most radical and potentially transformative type of relocalization that can occur in the food system. A small but active group of growers, processors, and consumers are engaged in the relocalization of wheat and reclaiming the United States’ most important staple crop from its
status as an anonymous commodity and recognizing it as a healthy food touched by human hands and meant to sustain human life.
Appendices

Appendix A: Glossary of terms

**Anthesis** – The stage of wheat plant development characterized by flowering (also called Feekes growth stage 10.5) (Wise et al., 2011).

**Artisan baking** – A style of baking that employs traditional skills distinct from the highly controlled and automated production systems of the factory bakery (Basetti and Galton, 1998).

**Ash** – Mineral content of grain or flour. Because ash is more concentrated in the bran, the amount of ash is a convenient assay for the presence of bran in flour (Posner and Hibbs, 2005).

**Bran** – The seed coat of the wheat kernel which makes up about 14 percent of the kernel weight and is included in whole wheat flour. The bran contains a small amount of protein, trace minerals and dietary fiber (primarily insoluble) (WMC, 2004).

**Boot stage** – The stage in the development of a wheat plant characterized by the head developing and becoming visible in the leaf sheath directly below the flag leaf (also called Feekes growth stage 10) (Wise et al., 2011).

**Crumb** – A term that bakers use to describe the pattern of holes inside of a loaf. By looking at the way the cell structure of the crumb is formed, and the shape and size and color of the cells, a baker can analyze the hydration, flour types, and yeast amounts as well as how the dough was mixed and shaped (Papanikolas, 2000).
**Endosperm** – Comprises the majority of the wheat kernel (83 percent) and is made up of starch granules embedded in a protein matrix. Endosperm is the source of white flour and contains the greatest share of protein, carbohydrates, iron, and the major B-vitamins in wheat (WMC, 2004).

**Extensibility** – The dough’s ability to stretch without breaking (WMC, 2004).

**Elasticity** – The dough’s ability to return to its initial position after stretching (Suas, 2009).

**Falling number** – A measure of the enzyme activity in a wheat flour or flour sample expressed as time in seconds. A sample with a falling number of 300 seconds or more is considered sound wheat. Wheat with a falling number under 300 seconds has sprout-damage (WMC, 2004).

**Farinograph** – Device that characterizes the quality of the flour by measuring the resistance of a dough to mixing to determine absorption capacity, development time, and stability time (Suas, 2009).

**Flexible (or reflexive) localism** – A term implying that the emphasis on local food provisioning is a means to an end, rather than an end in itself and, thus, allows for some adjustment of the definition of ‘local’ in food provisioning depending on specific conditions (Morris and Buller, 2003).

**Germ** – The embryo or sprouting section of the seed. It is often separated from flour because the fat content (10 percent) limits shelf life. (WMC, 2004) The germ is relatively high in protein, sugar, oil and ash (Hoseney, 1986).

**Gliadin** – One of the two proteins that combine to form gluten. Gliadin affects the extensibility of the dough (Suas, 2009).
**Gluten** – The storage proteins of wheat (Hoseney, 1986).

**Glutenin** – One of two primary proteins in wheat. Glutenin has some effect on the elasticity of dough (Suas, 2009).

**Heading** – The stage of wheat plant development in which the head emerges from the flag leaf. (also known as Feekes 10.1-10.5) (Wise et al., 2011).

**Hearth bread** – Bread baked directly on the oven floor, as opposed to pan breads which are baked in a vessel (bread pan or sheet pan) (Færgestad et al., 2000).

**Market class** (of wheat) – U.S. wheat class is identified by endosperm texture (hard or soft), color (red or white), and the planting and growing cycle (spring or winter). The six classes of economic significance are hard red winter (HRW), soft red winter (SRW), hard red spring (HRS), soft white (SW), hard white (HW), and durum (McFall and Fowler, 2009).

**Mineralization** – Microbial catabolism of soil organic matter to mineral nitrogen through ammonification or nitrification (Epstein and Bloom, 2005).

**Near Infrared (NIR) Spectroscopy** – based on the absorption of electromagnetic radiation at wavelengths in the range 780–2500 nm. NIR spectra of foods comprise broad bands arising from overlapping absorptions corresponding mainly to overtones and combinations of vibrational modes involving C-H, O-H, and N-H chemical bonds (Osborne, 2006).

**Preferment** – Dough or batter that is created from a portion of the total formula’s flour, water, yeast (natural or commercial), and sometimes salt. It is prepared prior to mixing the final dough,
allowed to ferment for a controlled period of time at a controlled temperature, and added to the final dough (Suas, 2009).

**Provenance** – the method or tradition of production that is attributable to local influences (HGCA, 2009).

**Relocalization** – A term used to describe the movement away from a “globalized” food system towards a food system that is relational, proximate, diverse, ecologically sustainable, economically sustaining, just/ethical, sacred, knowledgeable/communicative, seasonal/temporal, healthful, participatory, culturally nourishing, and sustainably regulated (Kloppenburg et al., 2000).

**Roller mill** – Modern industrial style of mill that grinds wheat through pairs of cast-iron rolls before the material is sieved and then reground and sieved four or five times (Cauvain and Young, 2007).

**Rotation crop** – A crop that is grown in part for benefits that it provides as part of a crop rotation (e.g., breaking disease cycles, improving soil quality) (Magdoff and van Es, 2000).

**Sodium dodecyl sulfate (SDS) sedimentation** – A widely used method of measuring dough strength potential based on the principle that gluten proteins swell in a dilute lactic acid solution and those related to higher dough strength sediment more slowly (Ross and Bettge, 2009).

**Staple crops** – Those crops that provide a majority of calories in human diets. Worldwide, they include rice, cassava, corn, wheat and potatoes (UN FAO, 1995).
**Stone mill** – Older style of mill that grinds wheat between two stones (or metal burrs replicating stones) and produces a flour that includes all parts of the wheat kernel (Cauvain and Young, 2007).

**Supply chain (food)** – A food supply chain is a network of food-related business enterprises through which food products move from production through consumption, including pre-production and post-consumption activities (Steve and Pirog, n.d.).

**Tailored design method** – A survey method that includes carefully timed mailings, personalized correspondence, visually appealing questionnaire layout, First Class postage, and other procedures to reduce survey errors from measurement and nonresponse (Dillman et al., 2009).

**Technical specifications (of flour)** – Laboratory measurements that provide information on how a specific flour will perform (e.g., falling number, protein, ash) (Hoseney, 1986).

**Test weight** – A test of soundness of grain. The minimum acceptable standard for test weights is 60 lb bu$^{-1}$ for grade 1 hard winter wheat (USDA FGIS, 2006).

**Tillering** – The stage in the development of a wheat plant characterized by the production of axillary or side shoots (also known as Feekes 2 and 3) (Wise et al., 2011).

**Topdressing** – Adding fertilizer to an existing crop (as opposed to adding fertilizer before planting) (Lal, 2006).

**Value chain** – Food products in value chains can be differentiated through attributes that traditional supply chains do not typically monitor or promote, such as the environmental and social benefits behind a particular producer’s practices (Cantrell, 2009).
References


Appendix B: Temperature and precipitation data

Figure B1  Temperature and precipitation for 2009-10 and 2010-11 at WSU NWREC, Mount Vernon WA
Table B1  Weather conditions 2009-2010 and 2010-2011 at WSU NWREC, Mount Vernon WA

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<td>106</td>
<td>23</td>
<td>35</td>
<td>11</td>
</tr>
<tr>
<td>Departure from average</td>
<td>-47</td>
<td>-23</td>
<td>+1</td>
<td>+52</td>
<td>-15</td>
<td>+10</td>
<td>+40</td>
<td>+52</td>
<td>-23</td>
<td>+14</td>
<td>-25</td>
</tr>
<tr>
<td>Mean Heat Units (base 40 F)</td>
<td>369</td>
<td>157</td>
<td>132</td>
<td>99</td>
<td>55</td>
<td>177</td>
<td>157</td>
<td>373</td>
<td>536</td>
<td>638</td>
<td>680</td>
</tr>
<tr>
<td>Departure from average</td>
<td>+37</td>
<td>+3</td>
<td>+44</td>
<td>+14</td>
<td>-45</td>
<td>+15</td>
<td>-108</td>
<td>-69</td>
<td>-26</td>
<td>-41</td>
<td>-13</td>
</tr>
</tbody>
</table>

*a Historical average data from 1994-2012*
Appendix C: Soil test results

Table C1 Preplant soil test results for La Conner and Mount Vernon in 2010 and 2011

<table>
<thead>
<tr>
<th>Growing season</th>
<th>La Conner</th>
<th>Mount Vernon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
<td>2011</td>
</tr>
<tr>
<td>Preplant SOM</td>
<td>3.5%</td>
<td>4.1%</td>
</tr>
<tr>
<td>Soil pH</td>
<td>5.8</td>
<td>6.6</td>
</tr>
<tr>
<td>P</td>
<td>104 VH</td>
<td>153 VH</td>
</tr>
<tr>
<td>K</td>
<td>285 H</td>
<td>405 H</td>
</tr>
<tr>
<td>Mg</td>
<td>195 M</td>
<td>293 M</td>
</tr>
<tr>
<td>Ca</td>
<td>1387 L</td>
<td>2091 M</td>
</tr>
<tr>
<td>Na</td>
<td>49 L</td>
<td>37 L</td>
</tr>
<tr>
<td>C.E.C.</td>
<td>11.7</td>
<td>14.9</td>
</tr>
<tr>
<td>SO$_4^-$S</td>
<td>10 L</td>
<td>11 M</td>
</tr>
<tr>
<td>NO$_3$N</td>
<td>34</td>
<td>12</td>
</tr>
</tbody>
</table>

Percent Cation Saturation

<table>
<thead>
<tr>
<th></th>
<th>La Conner</th>
<th>Mount Vernon</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td>6.2</td>
<td>6.9</td>
</tr>
<tr>
<td>Mg</td>
<td>13.7</td>
<td>16.1</td>
</tr>
<tr>
<td>Ca</td>
<td>59.2</td>
<td>69.9</td>
</tr>
<tr>
<td>H</td>
<td>19.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Na</td>
<td>1.8</td>
<td>1.1</td>
</tr>
</tbody>
</table>

---

a The year listed is the year of harvest. Soil tests were taken prior to planting in October of the previous year.
b Soil organic matter.
c Soil phosphorus analysis used a weak Bray extraction.
d ppm in soil. Relative levels (according to A&L Laboratories Inc., Portland, OR) are included for P, K and SO$_4$-S (L=low, M=medium, H=high, VH=very high).
e Cation Exchange Capacity meq 100g$^{-1}$.
Appendix D: Perfect blend fertilizer analysis by Soiltest Farm Consultants, Inc. (Moses Lake WA)

Table D1  Perfect blend fertilizer analysis results

<table>
<thead>
<tr>
<th>Growing season</th>
<th>2010</th>
<th>2011</th>
<th>Product Label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent solids</td>
<td>87.68</td>
<td>85.45</td>
<td>n/a</td>
</tr>
<tr>
<td>TN&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>7.71</td>
<td>7.00</td>
<td>7.00</td>
</tr>
<tr>
<td>P&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.74</td>
<td>1.80</td>
<td>2.00</td>
</tr>
<tr>
<td>K&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.62</td>
<td>1.73</td>
<td>2.00</td>
</tr>
<tr>
<td>S&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.97</td>
<td>3.04</td>
<td>3.00</td>
</tr>
<tr>
<td>Ca&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.56</td>
<td>10.84</td>
<td>7.00</td>
</tr>
<tr>
<td>Mg&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.54</td>
<td>0.53</td>
<td>0.70</td>
</tr>
<tr>
<td>Na&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.31</td>
<td>0.29</td>
<td>0.10</td>
</tr>
<tr>
<td>Zn&lt;sup&gt;c&lt;/sup&gt;</td>
<td>439</td>
<td>270</td>
<td>500</td>
</tr>
<tr>
<td>Mn&lt;sup&gt;c&lt;/sup&gt;</td>
<td>446</td>
<td>227</td>
<td>500</td>
</tr>
<tr>
<td>Cu&lt;sup&gt;c&lt;/sup&gt;</td>
<td>271</td>
<td>118</td>
<td>500</td>
</tr>
<tr>
<td>Fe&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2875</td>
<td>1730</td>
<td>1000</td>
</tr>
<tr>
<td>B&lt;sup&gt;c&lt;/sup&gt;</td>
<td>102</td>
<td>27</td>
<td>200</td>
</tr>
<tr>
<td>Available NH₄⁻N&lt;sup&gt;c&lt;/sup&gt;</td>
<td>9979</td>
<td>7548</td>
<td>6000</td>
</tr>
</tbody>
</table>

<sup>a</sup> Total nitrogen  
<sup>b</sup> in percent (dry matter basis)  
<sup>c</sup> ppm (dry matter basis)
### Table E1  Yield (t ha\(^{-1}\)) by site-year, variety and N treatment (kg ha\(^{-1}\))

<table>
<thead>
<tr>
<th>Variety</th>
<th>N (kg ha(^{-1}))</th>
<th>2010 La Conner</th>
<th>2010 Mount Vernon</th>
<th>2011 La Conner</th>
<th>2011 Mount Vernon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bauermeister</td>
<td>0</td>
<td>4.91 ± 0.33</td>
<td>4.51 ± 0.41</td>
<td>3.17 ± 0.34</td>
<td>0.13 ± 0.06</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>5.45 ± 0.25</td>
<td>4.58 ± 0.08</td>
<td>3.90 ± 0.29</td>
<td>0.24 ± 0.12</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>4.95 ± 0.36</td>
<td>5.04 ± 0.53</td>
<td>3.87 ± 0.07</td>
<td>0.29 ± 0.12</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>4.63 ± 0.31</td>
<td>4.39 ± 0.53</td>
<td>3.65 ± 0.10</td>
<td>0.20 ± 0.14</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>5.29 ± 0.37</td>
<td>4.68 ± 0.21</td>
<td>3.71 ± 0.32</td>
<td>0.21 ± 0.09</td>
</tr>
<tr>
<td>MDM</td>
<td>0</td>
<td>5.73 ± 0.24</td>
<td>4.94 ± 0.28</td>
<td>3.19 ± 0.35</td>
<td>0.38 ± 0.25</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>5.54 ± 0.19</td>
<td>4.68 ± 0.15</td>
<td>3.75 ± 0.29</td>
<td>0.47 ± 0.24</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>5.66 ± 0.28</td>
<td>4.65 ± 0.22</td>
<td>3.75 ± 0.34</td>
<td>0.50 ± 0.29</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>5.45 ± 0.28</td>
<td>4.24 ± 0.32</td>
<td>3.86 ± 0.35</td>
<td>0.30 ± 0.19</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>5.48 ± 0.19</td>
<td>4.89 ± 0.24</td>
<td>3.81 ± 0.15</td>
<td>0.35 ± 0.18</td>
</tr>
<tr>
<td>8022</td>
<td>0</td>
<td>7.04 ± 0.34</td>
<td>4.81 ± 0.41</td>
<td>5.21 ± 0.37</td>
<td>0.71 ± 0.45</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>7.26 ± 0.07</td>
<td>4.78 ± 0.47</td>
<td>4.62 ± 0.49</td>
<td>0.57 ± 0.26</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>7.26 ± 0.18</td>
<td>4.45 ± 0.37</td>
<td>4.89 ± 0.40</td>
<td>0.28 ± 0.06</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>7.10 ± 0.66</td>
<td>4.37 ± 0.53</td>
<td>5.04 ± 0.44</td>
<td>0.46 ± 0.33</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>6.92 ± 0.57</td>
<td>4.66 ± 0.38</td>
<td>4.89 ± 0.49</td>
<td>0.33 ± 0.22</td>
</tr>
</tbody>
</table>

Expressed as mean ± standard error
**Table E2** Test weight (kg hL\(^{-1}\)) by site-year, variety and N treatment (kg ha\(^{-1}\))

<table>
<thead>
<tr>
<th>Variety</th>
<th>N (kg ha(^{-1}))</th>
<th>2010</th>
<th>2011</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>La Conner</td>
<td>Mount Vernon</td>
<td>La Conner</td>
<td>Mount Vernon</td>
<td></td>
</tr>
<tr>
<td>Bauermeister</td>
<td>0</td>
<td>79.9 ± 0.8</td>
<td>85.7 ± 0.6</td>
<td>89.5 ± 0.5</td>
<td>74.0(^{†})</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>79.1 ± 1.4</td>
<td>86.2 ± 0.6</td>
<td>89.4 ± 0.4</td>
<td>74.7 ± 1.4</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>79.4 ± 1.2</td>
<td>85.3 ± 0.5</td>
<td>89.5 ± 1.4</td>
<td>72.1 ± 2.2</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>76.1 ± 1.8</td>
<td>85.8 ± 0.8</td>
<td>89.7 ± 0.6</td>
<td>74.5(^{†})</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>78.6 ± 2.3</td>
<td>86.5 ± 1.0</td>
<td>89.4 ± 0.7</td>
<td>71.2 ± 2.5</td>
</tr>
<tr>
<td>MDM</td>
<td>0</td>
<td>80.8 ± 0.4</td>
<td>86.2 ± 0.8</td>
<td>89.2 ± 0.7</td>
<td>75.6 ± 2.7</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>77.3 ± 1.6</td>
<td>84.1 ± 0.7</td>
<td>89.4 ± 0.8</td>
<td>77.5 ± 0.9</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>77.6 ± 3.4</td>
<td>85.4 ± 0.4</td>
<td>89.4 ± 0.1</td>
<td>79.8 ± 4.7</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>79.0 ± 1.4</td>
<td>84.2 ± 1.0</td>
<td>90.5 ± 0.5</td>
<td>74.7 ± 1.9</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>79.7 ± 2.9</td>
<td>84.6 ± 0.8</td>
<td>89.8 ± 0.5</td>
<td>77.7 ± 1.6</td>
</tr>
<tr>
<td>8022</td>
<td>0</td>
<td>89.0 ± 0.5</td>
<td>89.8 ± 0.6</td>
<td>92.0 ± 0.4</td>
<td>80.8 ± 2.6</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>88.8 ± 0.3</td>
<td>88.6 ± 0.6</td>
<td>91.9 ± 0.4</td>
<td>79.7 ± 1.7</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>88.8 ± 0.8</td>
<td>88.3 ± 0.8</td>
<td>92.5 ± 0.4</td>
<td>81.4 ± 2.0</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>87.1 ± 1.8</td>
<td>88.6 ± 0.8</td>
<td>92.9 ± 0.2</td>
<td>81.4 ± 2.2</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>84.5 ± 3.1</td>
<td>87.3 ± 1.1</td>
<td>94.3 ± 1.7</td>
<td>81.2 ± 3.2</td>
</tr>
</tbody>
</table>

Expressed as mean ± standard error

\(^{†}\) Standard error not available due to limitation on samples large enough for analysis

**Table E3** Test weight (kg hL\(^{-1}\)) by location variety combination for each year

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Year</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Conner</td>
<td>Bauermeister</td>
<td>78.6 c</td>
<td>89.5 e</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>78.9 c</td>
<td>89.6 e</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>87.7 a</td>
<td>92.7 d</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>81.7</td>
<td>90.5</td>
<td></td>
</tr>
<tr>
<td>Mount Vernon</td>
<td>Bauermeister</td>
<td>85.9 b</td>
<td>72.9 h</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>84.9 b</td>
<td>77.0 g</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>88.5 a</td>
<td>80.8 f</td>
<td></td>
</tr>
<tr>
<td></td>
<td>mean</td>
<td>86.4</td>
<td>89.1</td>
<td></td>
</tr>
</tbody>
</table>

Means that are not significantly different within year share a letter
### Table E4 Grain protein (%) by site-year, variety and N treatment (kg ha\(^{-1}\))

<table>
<thead>
<tr>
<th>Variety</th>
<th>N (kg ha(^{-1}))</th>
<th>La Conner</th>
<th>Mount Vernon</th>
<th>La Conner</th>
<th>Mount Vernon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bauermeister</td>
<td>0</td>
<td>9.52 ± 0.37</td>
<td>9.57 ± 0.18 c</td>
<td>8.40 ± 0.17 b</td>
<td>8.87 ± 0.23 b</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>9.30 ± 0.35</td>
<td>10.17 ± 0.22 bc</td>
<td>9.13 ± 0.21 ab</td>
<td>9.05 ± 0.23 b</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>9.65 ± 0.70</td>
<td>10.32 ± 0.16 b</td>
<td>9.18 ± 0.27 a</td>
<td>9.40 ± 0.20 ab</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>10.38 ± 0.28</td>
<td>11.48 ± 0.21 a</td>
<td>9.63 ± 0.21 a</td>
<td>9.43 ± 0.19 ab</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>10.35 ± 0.64</td>
<td>11.03 ± 0.30 a</td>
<td>9.38 ± 0.34 a</td>
<td>10.00 ± 0.21 a</td>
</tr>
<tr>
<td>MDM</td>
<td>0</td>
<td>9.00 ± 0.46</td>
<td>9.93 ± 0.29 c</td>
<td>8.95 ± 0.03</td>
<td>8.82 ± 0.15</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>9.45 ± 0.25</td>
<td>10.27 ± 0.29 bc</td>
<td>9.63 ± 0.45</td>
<td>9.27 ± 0.35</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>9.57 ± 0.46</td>
<td>9.98 ± 0.19 c</td>
<td>9.55 ± 0.44</td>
<td>9.43 ± 0.21</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>9.77 ± 0.54</td>
<td>11.05 ± 0.21 ab</td>
<td>9.30 ± 0.25</td>
<td>9.27 ± 0.17</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>9.72 ± 0.69</td>
<td>11.13 ± 0.38 a</td>
<td>9.92 ± 0.14</td>
<td>9.73 ± 0.23</td>
</tr>
<tr>
<td>8022</td>
<td>0</td>
<td>8.03 ± 0.52</td>
<td>9.65 ± 0.25 b</td>
<td>7.83 ± 0.12 b</td>
<td>8.20 ± 0.11 c</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>8.18 ± 0.58</td>
<td>10.57 ± 0.50 ab</td>
<td>7.85 ± 0.18 b</td>
<td>8.55 ± 0.12 bc</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>8.32 ± 0.46</td>
<td>10.35 ± 0.16 b</td>
<td>8.30 ± 0.11 ab</td>
<td>8.57 ± 0.11 b</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>9.00 ± 0.72</td>
<td>11.07 ± 0.18 a</td>
<td>8.50 ± 0.31 ab</td>
<td>9.07 ± 0.12 a</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>8.29 ± 0.68</td>
<td>11.07 ± 0.34 a</td>
<td>9.03 ± 0.45 a</td>
<td>9.13 ± 0.15 a</td>
</tr>
</tbody>
</table>

Expressed as mean ± standard error of the mean

Means that are not significantly different within a year location variety share a letter
Table E5  Flour extraction (g kg⁻¹) by site-year, variety and N treatment (kg ha⁻¹)

<table>
<thead>
<tr>
<th>Variety</th>
<th>N (kg ha⁻¹)</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>La Conner</td>
<td>Mount Vernon</td>
</tr>
<tr>
<td>Bauermeister</td>
<td>0</td>
<td>608 ± 11</td>
<td>644 ± 6</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>575 ± 29</td>
<td>618 ± 6</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>575 ± 37</td>
<td>610 ± 13</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>584 ± 8</td>
<td>611 ± 8</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>598 ± 5</td>
<td>625 ± 8</td>
</tr>
<tr>
<td>MDM</td>
<td>0</td>
<td>605 ± 9</td>
<td>617 ± 17</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>565 ± 37</td>
<td>610 ± 11</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>579 ± 7</td>
<td>643 ± 4</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>582 ± 13</td>
<td>600 ± 7</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>589 ± 12</td>
<td>623 ± 7</td>
</tr>
<tr>
<td>8022</td>
<td>0</td>
<td>604 ± 37</td>
<td>626 ± 6</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>619 ± 20</td>
<td>625 ± 12</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>636 ± 12</td>
<td>613 ± 4</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>631 ± 10</td>
<td>631 ± 4</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>634 ± 4</td>
<td>630 ± 7</td>
</tr>
</tbody>
</table>

Expressed as mean ± standard error
† Standard error not available due to limitation on samples large enough for analysis

Table E6  Flour extraction (g kg⁻¹) by location variety combination for each year

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Year</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2010</td>
<td>2011</td>
<td></td>
</tr>
<tr>
<td>La Conner</td>
<td>Bauermeister</td>
<td>588.0 b</td>
<td>600.2 ab</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>584.1 b</td>
<td>580.7 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>625.0 a</td>
<td>622.0 a</td>
<td></td>
</tr>
<tr>
<td>Mount Vernon</td>
<td>Bauermeister</td>
<td>625.0 a</td>
<td>622.0 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>621.6 a</td>
<td>534.8 c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>618.4 a</td>
<td>549.4 c</td>
<td></td>
</tr>
</tbody>
</table>

Means that are not significantly different within year share a letter
Multiple comparisons were conducted despite violation of normality assumption
### Table E7  Flour protein (%) by site-year, variety and N treatment (kg ha\(^{-1}\))

<table>
<thead>
<tr>
<th>Variety</th>
<th>N (kg ha(^{-1}))</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>La Conner</td>
<td>Mount Vernon</td>
</tr>
<tr>
<td>Bauermeister</td>
<td>0</td>
<td>8.92 ± 0.24</td>
<td>8.92 ± 0.22</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>8.54 ± 0.24</td>
<td>9.66 ± 0.43</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>8.6 ± 0.56</td>
<td>9.63 ± 0.27</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>9.50 ± 0.14</td>
<td>10.13 ± 0.42</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>9.48 ± 0.57</td>
<td>9.55 ± 0.50</td>
</tr>
<tr>
<td>MDM</td>
<td>0</td>
<td>8.08 ± 0.36</td>
<td>9.65 ± 0.30</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>8.34 ± 0.08</td>
<td>9.31 ± 0.28</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>8.23 ± 0.36</td>
<td>9.39 ± 0.58</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>8.77 ± 0.49</td>
<td>8.92 ± 0.10</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>8.62 ± 0.51</td>
<td>9.91 ± 0.16</td>
</tr>
<tr>
<td>8022</td>
<td>0</td>
<td>7.18 ± 0.43</td>
<td>9.74 ± 0.28</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>7.50 ± 0.63</td>
<td>9.40 ± 0.07</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>7.87 ± 0.54</td>
<td>9.25 ± 0.41</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>8.04 ± 0.6</td>
<td>9.76 ± 0.32</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>7.68 ± 0.55</td>
<td>9.46 ± 0.30</td>
</tr>
</tbody>
</table>

Expressed as mean ± standard error of the mean

\(^{†}\) Standard error not available due to limitation on samples large enough for analysis

### Table E8  Flour Protein (%) by location variety combination for each year

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Year</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Conner</td>
<td>Bauermeister</td>
<td>9.02 b</td>
<td>8.63 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>8.41 c</td>
<td>8.61 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>7.65 d</td>
<td>7.44 b</td>
<td></td>
</tr>
<tr>
<td>Mount Vernon</td>
<td>Bauermeister</td>
<td>9.57 a</td>
<td>8.70 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>9.44 ab</td>
<td>8.47 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>9.52 a</td>
<td>7.65 b</td>
<td></td>
</tr>
</tbody>
</table>

Means that are not significantly different within year share a letter
Table E9  Sedimentation volume (cc g\(^{-1}\)) by site-year, variety and N treatment (kg ha\(^{-1}\))

<table>
<thead>
<tr>
<th>Variety</th>
<th>N (kg ha(^{-1}))</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>La Conner</td>
<td>Mount Vernon</td>
<td>La Conner</td>
</tr>
<tr>
<td>Bauermeister</td>
<td>0</td>
<td>10.1 ± 0.4</td>
<td>10.5 ± 0.8 b</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>9.7 ± 0.5</td>
<td>12.5 ± 0.9 ab</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>9.8 ± 1.1</td>
<td>12.2 ± 0.6 ab</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>11.0 ± 0.3</td>
<td>13.5 ± 0.6 a</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>10.6 ± 0.7</td>
<td>10.9 ± 1.2 b</td>
</tr>
<tr>
<td>MDM</td>
<td>0</td>
<td>9.6 ± 0.5</td>
<td>12.6 ± 0.7</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>10.0 ± 0.3</td>
<td>12.3 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>10.0 ± 0.7</td>
<td>12.3 ± 1.1</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>10.6 ± 1.1</td>
<td>12.0 ± 0.3</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>9.9 ± 1.1</td>
<td>12.8 ± 0.4</td>
</tr>
<tr>
<td>8022</td>
<td>0</td>
<td>6.8 ± 0.9</td>
<td>13.2 ± 1.1</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>7.6 ± 0.8</td>
<td>12.4 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>7.6 ± 1.0</td>
<td>12.3 ± 0.3</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>8.3 ± 1.3</td>
<td>12.9 ± 0.4</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>7.4 ± 1.2</td>
<td>12.5 ± 0.6</td>
</tr>
</tbody>
</table>

Expressed as mean ± standard error of the mean
Means that are not significantly different within a year location variety share a letter
Table E10  Sedimentation volume adjusted to a 10% protein (cc g\(^{-1}\)) basis by site-year, variety and N treatment (kg ha\(^{-1}\))

<table>
<thead>
<tr>
<th>Variety</th>
<th>N (kg ha(^{-1}))</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>La Conner</td>
<td>Mount Vernon</td>
<td>La Conner</td>
</tr>
<tr>
<td>Bauermeister 0</td>
<td>10.6 ± 0.3</td>
<td>10.9 ± 0.6</td>
<td>11.6 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>10.4 ± 0.1</td>
<td>12.2 ± 0.9</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>10.0 ± 0.5</td>
<td>11.8 ± 0.4</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>10.6 ± 0.3</td>
<td>11.8 ± 0.7</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>10.2 ± 0.3</td>
<td>9.9 ± 0.9</td>
</tr>
<tr>
<td>MDM</td>
<td>0</td>
<td>10.7 ± 0.3</td>
<td>12.7 ± 0.7</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>10.6 ± 0.4</td>
<td>12.0 ± 0.3</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>10.4 ± 0.4</td>
<td>12.3 ± 1.2</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>10.8 ± 0.6</td>
<td>10.8 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>10.2 ± 0.6</td>
<td>11.5 ± 0.5</td>
</tr>
<tr>
<td>8022</td>
<td>0</td>
<td>8.4 ± 0.6</td>
<td>13.7 ± 1.4</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>9.2 ± 0.4</td>
<td>11.8 ± 0.7</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>9.0 ± 0.7</td>
<td>11.9 ± 0.3</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>9.0 ± 0.8</td>
<td>11.6 ± 0.2</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>8.8 ± 0.8</td>
<td>11.3 ± 0.5</td>
</tr>
</tbody>
</table>

Expressed as mean ± standard error of the mean

Table E11  Sedimentation volume (cc g\(^{-1}\)) adjusted to a 10% protein basis by location variety combination for each year

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2010</td>
</tr>
<tr>
<td>La Conner</td>
<td>Bauermeister</td>
<td>10.4 b</td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>10.5 b</td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>8.9 c</td>
</tr>
<tr>
<td>Mount Vernon</td>
<td>Bauermeister</td>
<td>11.3 a</td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>11.9 a</td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>12.0 a</td>
</tr>
</tbody>
</table>

Means that are not significantly different within year share a letter
### Table E12  Ash content of flour (%) by site-year, variety and N treatment (kg ha\(^{-1}\))

<table>
<thead>
<tr>
<th>Variety</th>
<th>N (kg ha(^{-1}))</th>
<th>2010</th>
<th></th>
<th>2011</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>La Conner</td>
<td>Mount Vernon</td>
<td>La Conner</td>
<td>Mount Vernon</td>
</tr>
<tr>
<td>Bauermeister</td>
<td>0</td>
<td>0.63 ± 0.03</td>
<td>0.50 ± 0.00</td>
<td>0.50 ± 0.00</td>
<td>0.70 †</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>0.60 ± 0.04</td>
<td>0.50 ± 0.00</td>
<td>0.55 ± 0.03</td>
<td>0.63 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>0.60 ± 0.04</td>
<td>0.53 ± 0.03</td>
<td>0.55 ± 0.03</td>
<td>0.65 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>0.63 ± 0.03</td>
<td>0.53 ± 0.03</td>
<td>0.58 ± 0.03</td>
<td>0.70 †</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>0.63 ± 0.03</td>
<td>0.53 ± 0.03</td>
<td>0.60 ± 0.00</td>
<td>0.65 ± 0.05</td>
</tr>
<tr>
<td>MDM</td>
<td>0</td>
<td>0.53 ± 0.03</td>
<td>0.50 ± 0.00</td>
<td>0.50 ± 0.00</td>
<td>0.60 ± 0.00</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>0.53 ± 0.03</td>
<td>0.53 ± 0.03</td>
<td>0.53 ± 0.03</td>
<td>0.65 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>0.53 ± 0.03</td>
<td>0.53 ± 0.03</td>
<td>0.50 ± 0.00</td>
<td>0.60 ± 0.00</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>0.55 ± 0.03</td>
<td>0.53 ± 0.03</td>
<td>0.50 ± 0.00</td>
<td>0.60 ± 0.00</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>0.55 ± 0.03</td>
<td>0.50 ± 0.00</td>
<td>0.50 ± 0.03</td>
<td>0.60 ± 0.00</td>
</tr>
<tr>
<td>8022</td>
<td>0</td>
<td>0.45 ± 0.03</td>
<td>0.50 ± 0.04</td>
<td>0.50 ± 0.00</td>
<td>0.50 ± 0.00</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>0.43 ± 0.03</td>
<td>0.50 ± 0.00</td>
<td>0.50 ± 0.04</td>
<td>0.53 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>0.48 ± 0.03</td>
<td>0.48 ± 0.03</td>
<td>0.50 ± 0.00</td>
<td>0.57 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>0.45 ± 0.03</td>
<td>0.50 ± 0.00</td>
<td>0.50 ± 0.00</td>
<td>0.55 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>0.48 ± 0.03</td>
<td>0.53 ± 0.03</td>
<td>0.50 ± 0.00</td>
<td>0.50 †</td>
</tr>
</tbody>
</table>

Expressed as mean ± standard error of the mean

† Standard error not available due to limitation on samples large enough for analysis.

### Table E13  Ash content of flour (%) by location variety combination for each year

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Year</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>La Conner</td>
<td>Bauermeister</td>
<td>0.62 a</td>
<td>0.56 c</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>0.54 b</td>
<td>0.51 de</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>0.46 c</td>
<td>0.50 e</td>
<td></td>
</tr>
<tr>
<td>Mount Vernon</td>
<td>Bauermeister</td>
<td>0.46 c</td>
<td>0.50 e</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MDM</td>
<td>0.52 bc</td>
<td>0.66 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8022</td>
<td>0.50 a</td>
<td>0.61 b</td>
<td></td>
</tr>
</tbody>
</table>

Means that are not significantly different within year share a letter

Multiple comparisons were conducted despite violation of normality assumption
**Figure E1** Protein (mean and standard error) by variety for 2010 La Conner field trial

**Figure E2** Protein (mean and standard error) by variety for 2010 Mount Vernon field trial
Figure E3  Protein (mean and standard error) by variety for 2011 La Conner field trial

Figure E4  Protein (mean and standard error) by variety for 2011 Mount Vernon field trial
March 21, 2011

Dear baker or bakery owner,

There has been a revival of interest by bakers and growers in relying on increasing the use of wheat produced in our region and decreasing the import of wheat from great distances. However, there is a need for more information on the feasibility of connecting growers and bakers in western Washington. As part of a graduate research project for Washington State University, I am conducting a survey of commercial bakers in 19 counties of western WA.

We are requesting your help in this project. If you can spare approximately 30 minutes, I would like to ask you some questions about your flour use and your opinions about where the wheat/flour you use is grown. This survey should be filled out by the person who makes decisions about purchasing local supplies for the business. If the business consists of several storefronts or locations which purchase flour together, please have this filled out by the person who coordinates local supply purchasing.

You may be assured of complete confidentiality. The identification number on the back of the questionnaire is used for tracking purposes only. When we receive your completed questionnaire, we will take your name off our mailing list so that you will not receive duplicate materials. At no time will information about individual operations be released to any state, national, or other organization. To further ensure your privacy, all published results will be based on combined data from all survey respondents.

Please return the survey in the enclosed postage-paid envelope. If you’d like to be involved in evaluating wheat grown in western WA and/or receive the results of this survey, please email (khills@wsu.edu) or call (360-848-6129) Karen Hills. You may be contacted by phone in the near future and asked to answer a few additional questions.

Survey results will also be available during the winter of 2011 on the WSU Mount Vernon Plant Breeding website (http://plantbreeding.wsu.edu). Also, we would like to take this opportunity to inform you that there will be an artisan baking conference held in Mount Vernon in September 2011 (www.kneadingconferencewest.com) that may be of interest to you.

Your participation will help to guide the future of small grain systems in Western Washington and I appreciate you taking a few minutes out of your busy schedule to complete this survey.

Best Regards,

Karen Hills
Department of Crop & Soil Sciences
Washington State University Mount Vernon
Northwestern Washington Research and Extension Center
USE OF REGIONALLY PRODUCED WHEAT AND FLOUR
IN WESTERN WASHINGTON:
A SURVEY OF COMMERCIAL BAKERS

Please return the completed questionnaire in the enclosed envelope to:
Washington State University Mount Vernon
Northwest Washington Research and Extension Center
16650 State Route 536
Mount Vernon, WA 98273

Questions: Please contact Karen Hills (khills@wsu.edu or 360-848-6129)
Thank you for your participation. This survey should be filled out by the person who makes purchasing decisions for the business. Your answers will be kept confidential and will be used for informational purposes only. Please do not fill out the survey more than once.

**GENERAL INFORMATION**

**A1 Does your bakery purchase flour or wheat berries?**
- Yes $\rightarrow$ Please proceed to Question A2.
- No $\rightarrow$ Please return the questionnaire in the postage-paid envelope provided.

**A2 Does your bakery sell exclusively cakes, cupcakes, doughnuts or pies?**
- Yes $\rightarrow$ Please return the questionnaire in the postage-paid envelope provided.
- No $\rightarrow$ Please proceed to Question A3.

**A3 In what county is your bakery located?**

**A4 What is your role in the bakery?** *(Please check all that apply.)*
- Owner
- Head baker
- Assistant baker
- Other *(Please describe: _________________________________)*
**FLOUR USE**

**B1** How many pounds (lbs) of each of the following products do you estimate that your business uses per month (from all sources)? What is the protein content (%) of each type of flour (if known)?

<table>
<thead>
<tr>
<th>Type</th>
<th>Pounds (lbs) used per month</th>
<th>Protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>White bread flour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole wheat bread flour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White pastry flour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whole wheat pastry flour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cracked grains</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheat berries</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Other (Please explain:    |                            |             |)

**B2** From how many suppliers do you purchase flour?

☐ 1 □ 2 □ 3 □ 4 or more

**B3** How often do you order flour? __________________

**B4** How often do you receive shipments of flour? __________

**B5** How large is a typical shipment of flour (in lbs)? __________
B6 Do you mill any of your own flour?

☐ Yes → What type of mill do you have?

__________________________

What is the capacity (lbs/hr) of your mill?

_______ lbs/hour

How many pounds (lbs) of flour do you mill per month?

_______ lbs/month

Do you buy wheat berries directly from a farmer/grower?

☐ Yes  ☐ No

Do you mill flour for other bakeries?

☐ Yes  ☐ No

☐ No → Please proceed to Question C1.
ORIGIN OF FLOUR

C1 Are you currently purchasing any Washington-grown wheat berries and/or flour?

☐ Yes → How many pounds (lbs) of Washington-grown wheat berries and flour do you purchase per month? (Please enter a zero if you make no purchases.) _______ lbs/month of wheat berries _______ lbs/month of flour

Is the WA-grown wheat/fLOUR you purchase certified organic?
☐ yes ☐ no ☐ don’t know

Where in WA was the wheat grown?
☐ eastern WA ☐ western WA ☐ don’t know

How much more do you pay for WA-grown wheat berries or flour than for comparable products from wheat grown elsewhere?

☐ No → Do you know where the wheat in your flour was grown or milled?

☐ Yes (Please provide location.)

Grown: ________________ Milled: ________________

☐ No

☐ Don’t know → Please proceed to Question C2.
C2 In relation to purchasing flour/wheat for your bakery, how would you define "local"? (*Please use the box below for your answer.*)

C3 Do you have any interest in purchasing flour made from wheat grown in Washington west of the Cascades?

☐ Yes ☐ No ☐ Don't know

*Please explain your answer in the box below.*

C4 How important is it to you where the wheat in the products at your bakery is grown? (*Please circle a number ranging from 1= "Not Important" to 5= "Very Important.")

<table>
<thead>
<tr>
<th>Not Important</th>
<th>Very Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
C5 In your opinion, how important is it to your customers where the wheat in the products they purchase from your bakery is grown? (Please circle a number ranging from 1= "Not Important" to 5= "Very Important.")

<table>
<thead>
<tr>
<th>Not Important</th>
<th>Very Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

C6 In your opinion, are your customers willing to pay a price premium for products they buy from your bakery made with wheat grown in Washington?

☐ Yes  ☐ No  ☐ Don't know

C7 In your opinion, are your customers willing to pay a price premium for products they buy from your bakery made with wheat grown in western Washington?

☐ Yes  ☐ No  ☐ Don't know

C8 In your opinion, what are the greatest barriers to purchasing wheat grown in your region? (Please use the box below for your answer.)
**CONCERNS AND PREFERENCES**

**D1** How important would the following factors be in future purchases of regionally produced flour for your bakery? *(For each factor, one per line, please circle a number ranging from 1= "Not Important" to 5= "Very Important.")*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Not Important ▼</th>
<th>Very Important ▼</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliable supply</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Trusted brand name</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Quality of flour</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Consistency of flour quality between shipments</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Nutritional value</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Price</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Where the wheat was grown</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Where the flour was milled</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Fineness of grind</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Carried by preferred (or current) supplier</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Certified organic</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Flavor</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
**D1 continued**

How important would the following factors be in future purchases of regionally produced flour for your bakery? (*For each factor, one per line, please circle a number ranging from 1=“Not Important” to 5=“Very Important.”*)

<table>
<thead>
<tr>
<th></th>
<th>Not Important ▼</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technical specifications</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Personal relationship with grower</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other (Please explain:__________)</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**D2** How important would the following technical specifications be in the future purchase of regionally produced flour for your bakery? (*One each line, please circle a number ranging from 1=“Not Important” to 5=“Very Important.”*)

<table>
<thead>
<tr>
<th></th>
<th>Not Important ▼</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Falling number</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Protein</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ash</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Farinograph</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Other (Please explain:__________)</strong></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**D3** If wheat/flour grown in *western Washington* was available at an acceptable price, how many pounds (lbs) of this wheat/flour would you use in your production process per month? *(Please enter a zero if you would not use the wheat/flour listed.)*

________ lbs/month of white bread flour
________ lbs/month of white pastry flour
________ lbs/month of whole wheat flour
________ lbs/month of whole wheat pastry flour
________ lbs/month of cracked grain
________ lbs/month of wheat berries
________ lbs/month of other flours *(specify type: ____________)*

**D4** Please use the space below to provide your comments or concerns regarding the use of wheat/flour grown in *western Washington* in the products at your bakery.
BUSINESS INFORMATION

E1 In how many total locations does your business operate?

☑ Only one location ☐ 2-10 locations
☑ 10 or more locations ☑ Other (please explain: ________________)

E2 Is your bakery part of a franchise or chain?

☑ Yes → Which best describes your bakery?

☐ Franchise ☐ Chain
☐ Other (please explain: ________________)

☑ No → Please proceed to Question E3.

E3 How many full time employees work in the bakery? (If the business includes other aspects, please just include those who work with the bakery part of the business.)

☐ 4 or fewer ☐ 5-10 ☐ 10-20
☐ 20-50 ☐ 50 or more

E4 Which best describes the geographic range in which products from your bakery are distributed?

☑ Within my county ☑ Within neighboring counties ☑ Within Washington
☑ Within the Pacific Northwest ☐ Nationally
☐ Other (please explain: ________________

☐ Other (please explain: ________________

10
**E5** Which of these sales strategies do you use? *(Please check all that apply.)*

- Wholesale
- Retail
- Café/Restaurant
- Other *(please explain:________________________)*

**E6** What percentage of your sales are direct-to-consumer sales?

- None
- Less than 25%
- 25–75%
- 75% or more

**E7** Which products are made at your bakery? Please do not include products made elsewhere and sold at your business. *(Please check all that apply.)*

- Bread
- Pastries
- Cakes/cupcakes
- Pie
- Doughnuts
- Pizza
- Cookies
- Other *(please list:________________________)*

**E8** What percentage of your sales are from bread?

- None
- Less than 25%
- 25–75%
- 75% or more

*Thank you for your participation! Please return the questionnaire in the postage-paid envelope.*
Appendix G: Alaska wheat breeding project

The goal of this project was to cross Ingal (hard red spring wheat from Alaska with shattering problems) with three other early-maturing varieties in order to try to achieve a hard red spring with early maturity that does not shatter for growing in Alaska. The parent lines used for the crosses during the summer of 2011 are described below.

‘Ingal’ is an early maturing, semi-dwarf, stiff-strawed, red-glumed, red-kerneled, awned, hard red spring wheat released in 1981 by the USDA plant breeding program at the Palmer Research and Extension Center of the University of Alaska Fairbanks Agricultural and Forestry Experiment Station. It was selected from a cross between a variety developed in Alaska, ‘Gasser,’ and ‘Morin No. 16’ from the USDA World Wheat Collection. Seed kernels of Ingal are smaller than average, requiring care in planting and harvest. Ingal is prone to head shatter if adverse weather conditions such as heavy rains or high winds persist at harvest. Ingal is satisfactory for milling and baking.

‘Roblin’ was developed at the Agriculture Canada Research Station in Winnipeg. It was released in 1987. It is named after a town in Manitoba. In Manitoba, yield of Roblin was equal to Neepawa and slightly more than the other check cultivars. In Manitoba it has been earlier maturing, more resistant to lodging and shorter than any of the checks. It is resistant to shattering.

‘AC Intrepid’ (AC = Ag Canada) is an early maturing, midtall, stiff-strawed, red-glumed, red-kerneled, awned, hard red spring wheat released in 1997 by the plant breeding program of Agriculture Canada in Swift Current, Alberta. Yields are higher than Ingal but with lighter test weights. AC Intrepid is more susceptible to loose smut fungal attacks compared with Ingal. AC Intrepid is satisfactory for milling and baking.

‘CDC Bounty’ (CDC Crop Development Centre, Lacome, Alberta, Canada) is an early maturing, mid-tall, stiff-strawed, red-glumed, red-kerneled, awned, hard red spring wheat released in 1999 by the plant breeding program at the University of Saskatchewan in Saskatoon. Yields and test weights are higher than Ingal. CDC Bounty is more resistant to loose smut fungal attacks compared with Ingal. CDC Bounty is satisfactory for milling and baking.

Crosses

Initial crosses were made on June 5, 16, and 18 2011. Ingal was a parent in each of the crosses. The later crosses were more successful than the earlier ones, probably due to a learning curve. Here was my inventory of the seeds resulting from the crosses:
Ingal crossed with:

Bounty: 47 seeds from 5 crosses
Intrepid: 43 seeds from 6 crosses
Roblin: 44 seeds from 5 crosses

The wheat heads were cut from the plants on July 18 due to issues with powdery mildew and aphids in the greenhouse and continued to dry at room temperature. On August 25, I planted the F1 seeds, along with the parents (for comparison) to increase the populations. I am taking notes on variations in maturity dates and shattering while growing out the F1 plants. Since the wheat will continue to segregate, all F2 seeds will be kept from the F1 generation, and will be threshed and sent to our Alaska collaborators for field planting in Spring 2012 and evaluation during Summer 2012.

F1 seeds were planted in the greenhouse on August 25, 2011 and were harvested on December 15, 2011. The mean and standard deviation for days from planting to heading for each set of F1 plants are listed below:

Ingal x Intrepid: 48.0 (sd =3.4)
Ingal x Bounty: 54.8 (sd=2.9)
Ingal x Roblyn: 49.3 (sd=3.7)

I planted the parent lines on the same day using the original seed.

Days to heading for the parent lines ranged from 66 (Ingal) to 70 (Roblin)

These plants were significantly less vigorous than F1 seeds and were also later to head. This could have been due to the age of the seed.

**Table G1 F2 seed from Alaska crosses**

<table>
<thead>
<tr>
<th>Cross</th>
<th>Total F2 seed</th>
<th>Sent to UAF February 2012</th>
<th>To be planted in Mt. Vernon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingal x Intrepid</td>
<td>31.9 g</td>
<td>22.3 g</td>
<td>9.6 g</td>
</tr>
<tr>
<td>Ingal x Roblin</td>
<td>35.1 g</td>
<td>27.0 g</td>
<td>8.1 g</td>
</tr>
<tr>
<td>Ingal x Bounty</td>
<td>30.1 g</td>
<td>24.0 g</td>
<td>6.1 g</td>
</tr>
</tbody>
</table>

**F2s and parent lines**
Seed was hand planted in short rows on 5/9/12 at the Northwestern Washington Research and Extension Center in Mount Vernon, WA. It was harvested by hand and threshed using a stationary thresher on 9/6/12. Neither the parent lines nor the crosses were affected as severely with stripe rust this year as last year, possibly due to later planting required by the wet field conditions. Crosses segregated by plant height and awn length. All of the crosses had the same heading date as the earliest parent (Ingal). Shattering is of interest for this study, but due to field conditions, no shattering was observed on either the crosses or the parent lines. The amount harvested is not necessarily indicative of yield potential, as there was not enough seed to extrapolate yield.

Table G2 2012 Field data from F2 crosses and parent lines grown in Mount Vernon WA

<table>
<thead>
<tr>
<th>Plot</th>
<th>Heading Date</th>
<th>Plant Height</th>
<th>Other Notes</th>
<th>Amount Harvested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bounty</td>
<td>July 7 (59)</td>
<td>42</td>
<td></td>
<td>257.5</td>
</tr>
<tr>
<td>Ingal</td>
<td>July 2 (54)</td>
<td>28</td>
<td>Straw is darker than others</td>
<td>110.6</td>
</tr>
<tr>
<td>Intrepid</td>
<td>July 5 (57)</td>
<td>39</td>
<td></td>
<td>188.3</td>
</tr>
<tr>
<td>Roblin</td>
<td>July 4 (56)</td>
<td>38</td>
<td>Variation in awns</td>
<td>135.6</td>
</tr>
<tr>
<td>Ingal/Roblin</td>
<td>July 2 (54)</td>
<td>33</td>
<td>Shortest cross</td>
<td>129.6</td>
</tr>
<tr>
<td>Ingal/Intrepid</td>
<td>July 2 (54)</td>
<td>35</td>
<td>Most biomass of crosses</td>
<td>161.8</td>
</tr>
<tr>
<td>Ingal/Bounty</td>
<td>July 2 (54)</td>
<td>35</td>
<td>Stems seem spindly</td>
<td>154.3</td>
</tr>
</tbody>
</table>

F2 seed was also planted in Fairbanks Alaska by collaborators Dr. Mingchu Zhang and Bob VanVeldhuizen and results are shown in Table G3. All the named varieties were planted using an ALMACO cone seeder in plots 30 feet long and 6 ft wide with 6 planted rows approximately 6 inches apart. There were three replications in a randomized complete block design. The F2 selections were planted with a V-belt one row seeder. Each selection had enough seed to plant one row 30 feet long. The three selections were planted next to each other one foot apart. Everything was planted into ground that was fallow the previous year with no additional
nutrients applied this year. Soil tests showed that there were sufficient plant nutrients already present to produce successful yields. Weed control was through the use of a hoe during the summer.

Harvest for the named varieties was done with a Wintersteiger plot combine. Harvest for the F2 selections was done by hand with a pair of garden shears (whole plant). The harvested crop was forced air dried with warm air for two weeks until a constant dry weight was reached of 14 percent moisture in the grain. The F2 selections were then threshed using a stationary Vogel thresher. All grain was then run through a Clipper M2-B seed cleaner, weighed for total yields and a subsample taken for test weight measurement.

F3 seed will be grown in 2013 to continue building up seed. The location of future work will be decided with input from our Alaska collaborators.
Table G3  2012 Field data F2 crosses and parent lines grown in Fairbanks AK

<table>
<thead>
<tr>
<th>Variety Name</th>
<th>Emergence Date</th>
<th>Heading Date</th>
<th>Maturity Date</th>
<th>Maturity GDD&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Height (cm)</th>
<th>Lodging (%)</th>
<th>Loss (%)</th>
<th>Yield (kg/plot)</th>
<th>Yield (bu/a)</th>
<th>Test wt. (lbs/bu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRS wheat Ingal</td>
<td>23-May</td>
<td>24-Jun</td>
<td>27-Jul</td>
<td>1074.9</td>
<td>70</td>
<td>0</td>
<td>10</td>
<td>4.69</td>
<td>43</td>
<td>62</td>
</tr>
<tr>
<td>CDC Bounty</td>
<td>23-May</td>
<td>30-Jun</td>
<td>8-Aug</td>
<td>1238.8</td>
<td>85</td>
<td>0</td>
<td>5</td>
<td>5.57</td>
<td>51</td>
<td>62</td>
</tr>
<tr>
<td>AC Intrepid</td>
<td>23-May</td>
<td>29-Jun</td>
<td>5-Aug</td>
<td>1207.0</td>
<td>91</td>
<td>0</td>
<td>5</td>
<td>5.87</td>
<td>54</td>
<td>62</td>
</tr>
<tr>
<td>Roblin</td>
<td>23-May</td>
<td>27-Jun</td>
<td>6-Aug</td>
<td>1219.7</td>
<td>86</td>
<td>0</td>
<td>5</td>
<td>6.00</td>
<td>55</td>
<td>62</td>
</tr>
<tr>
<td>Ingal x Roblin</td>
<td>23-May</td>
<td>24-Jun</td>
<td>5-Aug</td>
<td>1199.2</td>
<td>81</td>
<td>0</td>
<td>15</td>
<td>1.46</td>
<td>77</td>
<td>62</td>
</tr>
<tr>
<td>Ingal x AC Intrepid</td>
<td>23-May</td>
<td>25-Jun</td>
<td>5-Aug</td>
<td>1199.2</td>
<td>89</td>
<td>0</td>
<td>15</td>
<td>1.60</td>
<td>84</td>
<td>62</td>
</tr>
<tr>
<td>Ingal x CDC Bounty</td>
<td>23-May</td>
<td>24-Jun</td>
<td>5-Aug</td>
<td>1199.2</td>
<td>85</td>
<td>0</td>
<td>15</td>
<td>1.66</td>
<td>87</td>
<td>62</td>
</tr>
</tbody>
</table>

All were planted on May 15 and harvested on August 23

<sup>b</sup> Growing Degree Days were calculated with a base of 32 F, then converted to degrees C
**Figure G1** 3 rows on R are the 3 F2 crosses (from L to R: Ingal/Roblin, Ingal/Intrepid, Ingal/Bounty) on July 10, 2012
Figure G2  Ingal/Roblin F2 (2J11AK01)  
July 24, 2012

Figure G3  Ingal/Bounty F2 (2J11AK03)  
July 24, 2012

Figure G4  Ingal/Intrepid F2 (2J11AK02)  
July 24, 2012

Figure G5  Intrepid (Ingal on L)  
July 24, 2012
Appendix H: Home baking summary

Report on Use of Locally Grown Whole Wheat by Home Bakers

Karen Hills (khills@wsu.edu)

WSU-Mount Vernon

On October 4, 2010 eleven people met who had participated in the “Decentralized baking group” to discuss results and share baked goods. There were also several more people who participated, but were unable to attend. The goal of the group was to give a home baker’s perspective on use of local whole wheat flour. Four different types of flour were distributed: white whole wheat (10 and 12 percent protein) and red whole wheat (10 and 12 percent protein). For most baking purposes, especially for yeast breads, high protein is desirable. The flour had been ground using a stone mill so had larger flakes of bran than are present in most commercial whole wheat flour. At the end of this report, there is a copy of the questionnaire that was given to the participants. Each participant’s comments are summarized below.

Overall summary:

The themes that were repeated in this group are that participants liked the flavor, but some had trouble with rising and dryness. Most people noticed that the whole wheat flour needs more moisture than is called for in a recipe using standard all-purpose flour. Most people had more success baking with the whole wheat flour when it was mixed half and half with white flour rather than using it 100 percent. There was only one all-out flop and that was a chocolate chip recipe where the cookies spread excessively. Home bakers will have the most success when they follow a recipe that calls for whole wheat flour. There was a discussion about how to best market this type of flour in a way that would best highlight its strengths and avoid baking flops. Suggestions that were voiced included: guiding customers toward appropriate recipes, a contest or collection of local recipes from customers, creating a brochure about the product (separate from the recipes), and offering samples of baked goods made using the product.
Zucchini bread & pumpkin bread – 11 loaves

Used 10% red WW. Blended 1 to 1 with Bob’s Red Mill unbleached white plus oatmeal, wheat bran, and flaxmeal.

Rate from 1 to 5 how much you agree with each of the following statements:

The flour:

- was easy to work with
- was not too sticky
- rose well

was difficult to work with
was extremely sticky
didn’t rise well
Comments: Very nice quality – not too ‘gritty’- finished bread had good texture, moisture and ease of slicing.

12% red wheat \(\rightarrow\) **Empanadas w/ Tempeh**

10% white wheat \(\rightarrow\) **Linzer pie w/ anise blackberry filling**

The flour:

- was easy to work with \(1\) \(2\) \(3\) \(4\) \(5\) was difficult to work with
- was not too sticky \(1\) \(2\) \(3\) \(4\) \(5\) was extremely sticky
- rose well \(1\) \(2\) \(3\) \(4\) \(5\) didn’t rise well

My final product:

- was moist \(1\) \(2\) \(3\) \(4\) \(5\) was dry
- was not too dense \(1\) \(2\) \(3\) \(4\) \(5\) was too dense
- had good flavor \(1\) \(2\) \(3\) \(4\) \(5\) had a disagreeable flavor
- had a good texture \(1\) \(2\) \(3\) \(4\) \(5\) had a disagreeable texture

Comments: Labor intensive flour for both kinds. From the sifting to the kneading, the flour requires a lot of manipulation to generate the equivalent form & texture of the recipe. Interestingly, the white wheat flour didn’t react well to eggs. It turned into a paste that required a lot of extra flour to bring back the consistency. The flour is very aromatic in its original form. A unique comment of the red flour is that the final product had a texture of a corn flour type product. Baking times also differed from traditional flour for both types of flour.

**Bread**

I used 12% protein red wheat flour

I blended the red whole wheat flour with grocery store unbleached white flour. I used 40% whole wheat and 60% white flour.

I baked a whole wheat bread recipe from the James Beard bread cookbook. The recipe had 1 tablespoon brown sugar, no fat, 1/2 cup dry milk and one potato mashed along with the extra potato cooking water.

The flour:

- was easy to work with \(1\) \(2\) \(3\) \(4\) \(5\) was difficult to work with
- was not too sticky \(1\) \(2\) \(3\) \(4\) \(5\) was extremely sticky
rose well 1 2 3 4 5 didn’t rise well

My final product:

was moist 1 2 3 4 5 was dry
was not too dense 1 2 3 4 5 was too dense
had good flavor 1 2 3 4 5 had a disagreeable flavor
had a good texture 1 2 3 4 5 had a disagreeable texture

Excellent bread texture, slices thin with no crumbling. This recipe started with a sponge and had 2 risings. This recipe turned out better than my normal bread, partly because I was trying to be good and follow directions and measurements. The 2 loaves I baked had a much better texture than the bread I normally bake. I liked the little dark flecks of bran in the flour, it looks appealingly wholesome. I often have a problem with my bread crumbling when I use a lot of whole grain additions and these loaves can be fairly thinly sliced for toast or sandwiches.

Cookies

10% protein red wheat

Blended 1 to 1 with bleached white flour

The flour:

was easy to work with 1 2 3 4 5 was difficult to work with
was not too sticky 1 2 3 4 5 was extremely sticky
rose well 1 2 3 4 5 didn’t rise well

Banana Chocolate Tea Bread

10% protein white wheat

Blended 1:1 with all-purpose white flour

My final product:

was moist 1 2 3 4 5 was dry
was not too dense 1 2 3 4 5 was too dense
had good flavor 1 2 3 4 5 had a disagreeable flavor
had a good texture 1 2 3 4 5 had a disagreeable texture
**Pecan Pear Muffins** (from Cheeseboard Bakery Cookbook)

The flour: all 10% protein white whole wheat

- was easy to work with 1 2 3 4 5
- was not too sticky 1 2 3 4 5
- rose well 1 2 3 4 5

was difficult to work with
was extremely sticky
didn’t rise well

My final product: added a little milk to each batter to compensate for anticipated dryness

- was moist 1 2 3 4 5
- was not too dense 1 2 3 4 5
- had good flavor 1 2 3 4 5
- had a good texture 1 2 3 4 5

was dry
was too dense
had a disagreeable flavor
had a disagreeable texture

Comments: I really like the idea of working whole wheat flour into recipes like these muffins – that already have some strong flavor / texture components (i.e. Pecans, dried pears, tangy buttermilk). This flour wouldn’t work for a cake-type muffin, but worked for this recipe. When using the whole wheat flour the batter needed to be mixed a touch more. 

A (All whole wheat flour) A little more crumbly and rose a little less than

B (50% whole wheat + 50% all purpose) Rose a little better. More like the traditional (all-purpose flour) version
Comments: I really like the idea of working whole wheat flour into recipes like these muffins – that already have some strong flavor / texture components (i.e. Pecans, dried pears, tangy buttermilk). This flour wouldn’t work for a cake-type muffin, but worked for this recipe. When using the whole wheat flour the batter needed to be mixed a touch more.

A (All whole wheat flour) A little more crumbly and rose a little less than

B (50% whole wheat + 50% all purpose) Rose a little better. More like the traditional (all-purpose flour) version

---

**Zucchini Bread**

12% protein white wheat

Blended 1 to 1 with white flour

The flour:

was easy to work with1 2 3 4 5 was difficult to work with
was not too sticky 1 2 3 4 5 was extremely sticky
rose well 1 2 3 4 5 didn’t rise well

My final product:

was moist 1 2 3 4 5 was dry
was not too dense 1 2 3 4 5 was too dense
had good flavor 1 2 3 4 5 had a disagreeable flavor
had a good texture 1 2 3 4 5 had a disagreeable texture

My bread was a little dryer than usual. It also had a grainy texture, but good flavor.

---

Our standard **bread** recipe is this:

2.4 cups all-purpose white, 1 cup whole wheat (here we substituted your flour), ¼ cup gluten, ¼ cup corn flour, 1 tsp salt, 2 tsp dry yeast, 1 Tbsp oil, 1 Tbsp sugar. I use the breadmaker.
Used 12% red for bread substituting 1 cup of 12% red for our normal mix of whole wheat flour. Result was that loaf in breadmaker rose 15% more than usual and did not collapse at the end of rising. Bread seemed too fluffy and was hard to slice.

Red 10% in **pancakes**, used only red 10% flour and Joy of Cooking recipe. Pancakes do not hold together in the pan when flipping. Gritty when cooked. Rises normally.

White 10% in **waffles**, using the pancake mix recipe and taking ½ of the 10% white flour and ½ regular pastry flour. Waffle held together well, a little gritty but overall the best combination of flours so far.

½ cup of Red 12%, 3 cups pastry and rest as usual in bread mix.

Used 12% white in bread and that seemed to rise quite vigorously but taste is good.

---

**Baking powder biscuits**

Tried using 100% whole wheat in recipe, but the kids didn’t like it. When used 1 cup white : ¾ cup whole wheat the result was better. Also used it 50% in chocolate chip cookies and liked the results.

---

**Chocolate Chip Cookies**

12% protein red wheat

Blended this flour 1:1 with oat flour

The flour:

- was easy to work with 1 2 3 4 5
- was difficult to work with
- was not too sticky 1 2 3 4 5
- was extremely sticky
- rose well 1 2 3 4 5
- didn’t rise well

My final product:

- was moist 1 2 3 4 5
- was dry
- was not too dense 1 2 3 4 5
- was too dense
- had good flavor 1 2 3 4 5
- had a disagreeable flavor
- had a good texture 1 2 3 4 5
- had a disagreeable texture

Comments: This is my new chocolate chip cookie recipe! The result is just what I like in a cookie: crumbly, nutty, not bready or greasy.
Pumpkin Bread

12% protein white wheat mixed 1:1 with all-purpose flour

The flour:

- was easy to work with
- was not too sticky
- rose well

My final product:

- was moist
- was not too dense
- had good flavor
- had a good texture

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- was difficult to work with
- was extremely sticky
- didn’t rise well
- was dry
- was too dense
- had a disagreeable flavor
- had a disagreeable texture
Questionnaire given to participants:

The goal of this project is to get qualitative feedback from home bakers on the performance of local whole wheat flour in their home kitchens, with recipes they use. We have four different flours available for the group to use, all of which are whole wheat flours ground on a stone mill. We are suggesting that anyone baking bread use the 12% flour and anyone making cookies, muffins or quick breads use the 10% flour.

Because whole grain flour can go stale or rancid, please store it in the refrigerator or freezer until use. It is recommended that you blend in up to 50% white all-purpose flour if you are not used to baking with 100% whole wheat (it can be tricky). If you are using it 100%, it’s best to use in recipes calling for whole wheat flour, as it tends to act differently than white flour.

For those who are interested, will be having an informal lunch discussion of our experiences baking with Western WA wheat on Monday October 4 at NWREC. Feel free to bring a lunch and results of any weekend baking to share.

Thank you for your input!

Which type(s) of flour did you try?

____ 12% protein red wheat (bread)
____12% protein white wheat (bread)
____10% protein red wheat (cookies, muffins, quick breads)
____ 10% protein white wheat (cookies, muffins, quick breads)

Did you blend with white flour?

If so, what kind? What was the ratio of whole wheat to white?

What did you make with your flour?

Rate from 1 to 5 how much you agree with each of the following statements:

The flour:

was easy to work with 1 2 3 4 5 was difficult to work with

was not too sticky 1 2 3 4 5 was extremely sticky
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Appendix I: Rural Connections article

Rebuilding the Grain Chain
Stories from the Coastal Pacific Northwest

BY KAREN HILLS, ANDREW CORBIN, AND STEPHEN JONES

Karen Hills is a Ph.D. candidate at Washington State University. She worked at the Northwestern Washington Research and Extension Center in Mount Vernon, Washington.

Andrew Corbin is in Agriculture and Natural Resources Faculty at Washington State University Extension in Snohomish County in Everett, Washington.

Stephen Jones is director of Washington State University, Northwestern Washington Research and Extension Center in Mount Vernon, Washington and a professor of Crop Science.

Oregon State University barley breeder Dr. Pat Hayes, stands in a field of barley with farmer Wilbur Ringel of Snohomish, Washington. The barley grown in the field is from a variety called 'Hills', developed by Hayes to be well adapted to conditions in the Coastal Pacific Northwest. Photo credit: Elizabeth Dyck
Imagine it—biting into a pretzel made with wheat grown in your own community and following that with a sip of cool beer made from barley grown and malted nearby.

Unless you are talented enough to perform all of the steps involved in production, processing, baking, malting, and brewing, the search for this experience could turn into a long quest.
Though the “locavore” movement is alive and well in many parts of the U.S., it has focused primarily on fresh produce, meat, eggs, and dairy and has overlooked the grains that are an important staple in human diets. One reason for this is the massive amount of consolidation through the supply chain in global grain markets. In fact, five major companies now control 80 percent of the global grain trade (Pugh & McLaughlin, 2007). The consolidation in processing is such that even in a major wheat-growing state, like Kansas, it can be difficult to source local flour (Henning, 2011).

The alternative to the current dominant industrial system is that of decentralized independent production, processing, and distribution networks. The creation of such networks has the potential to generate income for processors, improve farm profitability, reconnect communities with their agricultural heritage, and recapture the idea of grain as a healthy “food from somewhere” rather than as an interchangeable commodity. Costs of staple grain would reflect the true cost of production, not the volatile swings characteristic of grain prices decided in Minneapolis, Kansas City, or Chicago.

Is this vision of localizing grain growing and production just a utopian dream? Not according to the food system pioneers working on independent yet parallel fronts in places like Vancouver Island, British Columbia; Mount Vernon, Washington; Athens, Ohio; and Asheville, North Carolina (Hanus, 2010; Hergesheimer & Wittman, 2011; Appalachian Staple Food Cooperative; Wolfe 2011). None of these places are commonly associated with modern-day grain production, yet each has a legacy of small-scale grain growing now being rediscovered, one field at a time.

The coastal Pacific Northwest is one of several U.S. regions working to reclaim their grain heritage. Its initial success suggests that this local movement could serve as a useful case study for others considering similar efforts. Communities in the coastal Pacific Northwest from Northern California through British Columbia (areas west of the Cascade Mountains) are interested in reviving the infrastructure necessary for drying, storing, and processing small grains in order to meet growing consumer demand.

In the Skagit Valley in Northwest Washington, wheat and barley are typically grown in rotation with higher value crops for their rotational benefits, but the harvested grain is sold for minimal return on the commodity market. Meanwhile, end users such as bakers, millers, maltsters, brewers, and livestock producers are sourcing small grains and grain legumes from as far away as Saskatchewan. The potential exists for a locally integrated small grain system in this region, creating shorter supply chains with the ability to preserve information about who produced the grain and where it was grown.

**Infrastructure**

The infrastructure required to support the processing of grains in the coastal Pacific Northwest existed in the past, but has been lost over time due to the consolidation of agricultural production and processing. The proximity of agricultural land to urban populations
in this region poses a paradox of opportunities and challenges as the region attempts to balance farmland preservation, urban development, and the sustainable management of natural resources.

Residents of the coastal Pacific Northwest care about their food supply, support local agriculture, and are interested in how to replace the infrastructure needed to maintain a local grain system. Farmers have a need for grains as a rotation crop to break disease cycles and improve soil quality. There are a variety of possibilities for end uses for local grain, with those commanding a higher price, such as flour, being the most attractive to farmers. However, it is critical that there are also outlets for grain that does not meet the strict quality standards for flour. For this reason, a robust local grain system must also include brewing, distilling, and feed for livestock.

These end uses require some common infrastructure. Agricultural production equipment such as grain drills for planting and combines for harvest, are already prevalent in areas where wheat is grown for commodity markets. Facilities for cleaning and storing seed to keep grain dry and pest-free will also be required.

Grain processing equipment varies by grain type and its intended use. Producing wheat for human consumption provides the greatest possible return to farmers. There are several steps involved in the processing of grain. Food uses of barley, oats, and spelt require seed hulls be removed with dehulling equipment. Wheat is free threshing, meaning the hull detaches during harvest. A hammer, stone, or roller mill is needed to process grain into flour. Each of these types of mills can provide whole grain flour. However, producing the white flour used most commonly by commercial bakers requires more sophisticated roller mills that sift out the bran and further reduce particle size.

"The potential exists for a locally integrated small grain system in this region, creating shorter supply chains with the ability to preserve information about who produced the grain and where it was grown."
“Breeding for wheat and barley varieties adapted to the coastal Pacific Northwest is occurring at Washington State University Mt. Vernon and at Oregon State University, which will give coastal grain growers better-adapted varieties.”

It’s Not Just Wheat

Though wheat is the most commonly consumed grain in American diets (USDA, 2003), there are other grains worthy of consideration in local grain systems. Malt is the highest value use for a barley crop. Malted barley is sprouted in a controlled way, which causes a spike in enzyme activity needed for the fermentation process. While most microbreweries use malt produced on a huge scale for national markets, there has been increasing interest from microbreweries in sourcing locally grown and malted barley. When barley or wheat doesn’t meet the quality standards necessary for malt or flour, respectively, due to weather conditions or other factors that can decrease crop quality, these grains can be used in distilleries.

Washington has seen a rise in micro-distilleries due to a passage of a 2008 law creating a craft-distilleries license (Allison, 2009). The law requires that 51 percent of ingredients used by craft distilleries be sourced from in state. In areas like western Washington with animal integrated agriculture, cereal grain can be used to meet local demand for an energy ingredient in livestock feed. Processing for this use generally involves cracking the grain by using a hammer mill for easier digestibility.

Once the processing infrastructure and marketing networks exist for wheat and barley, expanding the infrastructure for other types of grains like rye, oats, triticale, niche heritage grains, and dry beans would be relatively simple. Variety and crop choice will vary depending on regional environments, but the ambitious farmer can find many locally adapted varieties if sourced outside of the standard routes. Breeding for wheat and barley varieties adapted to the coastal Pacific Northwest is occurring at Washington State University Mt. Vernon and at Oregon State University, which will give coastal grain growers better-adapted varieties.

Supporters of this relocalized grain system are not proposing that every county, or every region be completely self-sufficient in grain. However, with some strategic investments in infrastructure in consultation with end users, a significant portion of grain purchased for use in baked goods, beer, distilled beverages, and livestock feed could be sourced locally, keeping dollars in the local economy.

Stories from the Coastal Northwest

This work is going on in many areas of the coastal Pacific Northwest. In Eugene, Oregon, Tom Hunton recently opened Camas Country Mills in response to a demand for local flour and grain (Dietz, 2011). In the same region, the Southern Willamette Valley Bean and Grain project, a collaboration of growers and community organizations, began formally meeting in 2008 building on previous work to increase local production for local consumption. Further north, in Corvallis, Oregon, Dr. Pat Hayes and Dr. Andrew Ross of Oregon State University are working to boost the consumption of locally grown barley. Hayes has been involved with a new mini-malter designed by students to test small batches of malting barley (Foyston, 2010). Ross has been working hard on developing ways to incorporate healthy doses of barley into delicious baked goods, such as breads and pretzels.

Continue north from the Willamette Valley past Seattle to Mt. Vernon, Washington, where researchers are looking into production strategies for growing organic bread wheat in Western Washington. Preliminary data shows that in the climate of Western Washington it is possible to achieve the protein levels in wheat required by craft bakeries (Hills, in preparation).

George DePasquale (2010), the owner and head baker at a large Seattle bakery said about the bread he made from flour grown in Mt. Vernon: “It had the best flavor I’ve tasted in my 33 years of baking.”
Preparations are underway for the first Kneading Conference West, a meeting of artisan bakers, millers, farmers, and grain enthuasiasts to be held September 15-17, 2011. Across the border in Canada there are now ideas being tested for marketing grains. The Urban Grains CSA began supplying grains to the Vancouver, British Columbia, market in 2008 (www.urbangrains.ca) using the same Community Supported Agriculture model now commonly used by diversified vegetable producers. A Victoria, British Columbia, brewery has created a beer with all ingredients grown within 24 miles (Kloster, 2010). Intrepid agronomists in Alaska have even developed a locally adapted hullless barley variety, Sunshine, featured in the November 2009 issue of Rural Connections (Tarnai, 2009).

Moving Beyond a Niche Market

One objection often raised about purchasing local grain is the potential high cost. This is a valid concern when the flour from the western part of Washington is commonly sold in 1-2 lb. bags for $4-6. However, if production and processing were increased even moderately, the economy of scale would drive the cost down substantially. And many local bakers are interested. A survey of 70 commercial bakers in Western Washington found those interested in sourcing flour locally represent 3.5 million lbs. of flour annually (Hills et al., 2011). The three issues most frequently cited as concerns by commercial bakers were cost, availability, and suppliers. Each of these concerns could be addressed by a moderate increase in the scale of production and processing.

We're at the point where it is cheaper for bakers in Kansas to import wheat from Montana to bake a loaf of bread, not by chance, but through a coordinated effort to build infrastructure for an agricultural system based on exports and industrial scale processing. Regional efforts to restore infrastructure for local grain systems on a scale matching local markets could provide opportunities for economic development, improved access to healthy whole grains, and preservation of the working agricultural landscape. Farmers, entrepreneurs, and researchers are working hard to make locally-produced pretzels and beer a reality.*

References

Appalachian Slate Food Cooperative. ask.foodcooperative.com
The Southern Willamette Valley Bread and Grain Project. mndc.oregonstate.edu/beansandgrains.html

*Recommended Reading:
Plant Breeding
plantbreeding.wsu.edu
Barley World
barleyworld.org
Kneading Conference West
kneadingconferencewest.com
Appendix J: Bread Bakers Guild of America article

**Grain & Milling**

**Local Grain Production in the Skagit Valley**

By Karen Hills and Stephen Jones, Washington State University

The Skagit Valley of western Washington state is more commonly known for its tulip fields and red raspberry production than its wheat fields, but there is a movement brewing here towards local grain production for local use as food, feed and malt. The area, which is located about 60 miles north of the Seattle metropolitan area, is home to a diverse array of agricultural enterprises, with 60 fresh-market and processing crops grown on approximately 80,000 acres.

Wheat and barley are not new crops in the area, but until recently they were grown primarily to add organic matter back into the soil after crops that involve heavy cultivation, and to break disease cycles between other crops. Growers typically produce 15,000 acres of wheat per year and sell it through a local grain elevator, where it gets loaded into semis or rail cars and shipped to Portland, OR, to join the commodity supply chain of Washington wheat, over 90% of which is exported.

Meanwhile, bakers, distillers, brewers and livestock feed buyers purchase small grains brought in from further afield – sometimes from as far away as the Midwest or the Canadian provinces. Because the wheat supply chain is so highly centralized, it has become next to impossible to source local grains in many areas of the country.

A team of growers, researchers and end-users of grain are seeking to close the loop in this system by bringing back some of the infrastructure and supply chains that have disappeared during the last 50 years. The Skagit Valley offers an ideal place to “relocalize” grain supply chains because of its diversity of agricultural operations and end users, existing small grain production and access to markets along the populated Interstate 5 corridor. This effort has received the attention of local producers who use wheat and barley in rotation with bulks and organic vegetables, and these producers have been participating in on-farm trials to optimize variety selection and management practices.

The level of interest in local grain production and use was made apparent at the inaugural Kneading Conference West held in September of 2011 in Mount Vernon, Washington, at Washington State University (WSU) Northwestern Washington Research and Extension Center. The meeting (sponsored in part by The Bread Bakers Guild of America), attracted 250 artisan bakers, millers, farmers and grain enthusiasts from 12 states and three Canadian provinces. Talks and workshops were given on diverse topics such as the art of baking pizza in a wood-fired oven, baking with fresh milled local grains, malting barley, and growing small grains. WP Kemper supplied a spiral mixer and four deck oven for a commercial baker track. The conference sold out over a month in advance, and over 50 people were put on a list for the 2012 event.

The general interest in grains in the region has been further strengthened by the relocation of Fairhaven Organic Flour Mill to nearby Burlington, providing a vital missing link in the supply chain for organic whole grain flour production.

Barley for food, feed and malt has been of major interest of producers in the area as well. Oregon State University food science professor, Dr. Andrew Ross, teamed with Seattle baker, Leslie Mackia, at the Kneading Conference West to demonstrate the potential for incorporating barley flour into wheat bread for a unique flavor and as a source of dietary fiber. In 2011 Skagit Valley Malting, a new business, began work on a pilot malt which will add value to our local grains through malting. The entrepreneurs at the helm have one unit up and running and are poised to market not just malt but also 1,000 pound malting units, a scale that will allow for malting of local grains for craft brewers.

**LEFT:** Oregon State University barley breeder discusses barley varieties at a grower field day. **RIGHT:** Barley heads drying down.
However desirable the high value uses of grain are (baking and malting), it is an important risk management strategy for farmers to have an outlet for grain that may not meet the high standards for those uses. Enter distilling and livestock feed. Forty craft distillery licenses have been approved by the state of Washington since 2006, with another 15 pending, most of which are located in western Washington. The state law licensing these distilleries requires that at least half of the raw materials used in the distilling process must be grown in Washington.

With the rising cost of feed, especially organic feed, livestock producers are also looking for feed sources. Many of them adopted a model of cheap feed and cheap transportation which led to an overreliance on out-of-state feed stocks. This model is not working as it once did.

Western Washington is home to innovative bakers who are advancing the local grain movement. Scott Mangold is a craft baker and owner of the Breadfarm in Bow, Washington. Mangold is partnering with WSU researchers to test bake with flours from locally grown wheat, evaluating aspects such as fermentation tolerance, proofing time, and flavor. Flavor is being rediscovered as an important component of wheat. George DePasquale, the owner and head baker at a large Seattle bakery, said about the bread he made from flour grown in Mount Vernon, “It had the best flavor I’ve tasted in my 33 years of baking.”

At the WSU Research and Extension Center in Mount Vernon, researchers are working with local growers to breed wheat from a variety of market classes to find the ones most adapted to the local area. Farmers are primarily growing a variety from the 1980s, which is the last time that agricultural researchers really paid attention to wheat in this area. There are better varieties available now that are adapted to this area. This year we are including even more grains in variety trials, including over 6,000 small plot trials of varieties of wheat, barley, oats and triticale (a rye/wheat hybrid) totaling about 8 acres. In addition, WSU is in the process of setting up a quality testing laboratory for craft bakers that will continue to facilitate communication between growers and bakers.

Regional efforts to restore infrastructure for local grain systems on a scale matching local markets could provide opportunities for economic development, improved access to healthy whole grains, and preservation of the working agricultural landscape.

This is a movement that is gaining momentum both in the Skagit Valley and in other parts of the United States and is generating excitement in growers, bakers and consumers alike. Grains are coming full circle.