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Why can't the supply chain keep up with organic bakery product demand? Understanding miller, distributor, and baker organic wheat quality perceptions and needs

RESEARCH ARTICLE

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Abstract

While the demand for organic wheat products in the U.S. is strong and continues to grow, organic wheat supply is actually decreasing in part due to grower challenges related to declining yields and quality. This study examines the perceptions, requirements, and needs of millers, distributors, and bakers surrounding organic wheat quality and supply. We also use ordered logit models to examine which factors and quality indicators influence organic wheat quality ratings alone and when compared to conventional wheat. Study data were collected in the winter of 2020/2021 through two online surveys. Results show that both bakers and millers/distributors rated wheat quality and consistent quality from suppliers as very important and that they consider protein quality and content as primary indicators of quality. However, they differ in their ratings of organic quality, as bakers perceive organic wheat to be of higher quality than conventional wheat and millers just the opposite. There was also disparity in their importance ratings for other wheat quality indicators. This study provides pertinent findings on the perceptions and needs of organic wheat buyers across the supply chain. Study findings will be especially informative to organic wheat growers, breeders, and researchers seeking to improve organic wheat quality and yields.

Keywords: grain marketing, organic, quality, supply chains, wheat
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1. Introduction

Demand for organic foods in the U.S. has grown steadily, outpacing growth in the overall food market. U.S. sales of organic foods reached $50.1 billion in 2019, representing a 4.6% increase over 2018 levels, while total food sales grew by 2.3% (OTA, 2020). Organic food sales are expected to increase even more due to the COVID-19 pandemic, which boosted consumer demand for healthy and clean foods that can be prepared at home (OTA, 2020). Demand for products from organic wheat – including bread, pasta, and flour – is also expected to increase, assuming the supply can keep up (OTA, 2020).

Organic wheat acreage represented 1.2% of all U.S. wheat acreage in 2019, increasing 34.8% between 2016 and 2019 (USDA NASS, 2020a,b). However, acreage growth alone is not enough to accommodate the growing demand for organic wheat due to the declining yields experienced by growers over time (Koory, 2018). The western U.S. states of Montana, Wyoming, Utah, and Colorado have consistently been among the top organic wheat producers in terms of acreage since 2010, accounting jointly for 54% of all U.S. organic wheat acreage in 2019 (USDA NASS, 2020a). But organic wheat growers in the arid U.S. West have faced challenges related to declining wheat yields and quality that threaten their ability to meet demand and maintain economic sustainability. Some growers have in fact transitioned out of organic wheat production, primarily due to pest management and resulting profitability concerns (Curtis and Quarnstrom, 2019). Given the significant contribution of western wheat growers to the domestic organic wheat supply and growing demand for organic products, it is important that growers can continue profitable organic wheat production while meeting the needs of organic wheat users.

This study assesses the perceptions and needs of organic wheat buyers, including millers, distributors, and bakers in terms of organic wheat and wheat flour quality. Previous studies have examined or summarized the technical parameters of wheat quality and their impacts on the quality of resulting flour and bakery products (e.g. Carson and Edwards, 2009; Graybosch *et al.*, 1996; Pagani *et al.*, 2014; Thanhaeuser *et al.*, 2014). Other studies have sought to examine the differences in quality between conventional and organic wheat, the implications for the processing quality of organic wheat, and ways to improve organic wheat quality (e.g. Kucek *et al.*, 2017; Mäder *et al.*, 2007; Mason *et al.*, 2007; Osman *et al.*, 2012; Park *et al.*, 2015; Rakszegi *et al.*, 2016). However, these studies do not evaluate the perceptions and needs of organic wheat users in terms of wheat quality and quantity. This study aims to fill this gap.

Specifically, we examine the importance of quality in organic wheat and organic wheat flour purchasing decisions, the important indicators of organic wheat/flour quality, and how the quality of organic wheat/flour compares to conventional. We also examine issues that current and potential organic wheat users encounter when meeting their quantity and quality needs and issues that prevent their use of organic wheat/flour. Study data were collected via online surveys of wheat millers, distributors, and bakers, primarily in the Western U.S.

Study results will be useful to organic wheat breeders and growers as they strive to provide high-quality organic wheat to users along the supply chain. Understanding and meeting buyers' quality standards is important and necessary for growers to command the best prices for their organic wheat (Born and Sullivan, 2005). The findings will also be useful to potential organic wheat growers, who may be unaware of buyer quality needs and perceive this as a barrier to starting organic wheat production. Finally, the findings may provide direction for future research focused on improving organic wheat quality.

2. Literature review

There is no single definition of quality – it can be viewed as excellence, a value, a conformation to specifications, or meeting and/or exceeding customers' expectations (Reeves and Bednar, 1994). Wheat has characteristics that can be used to objectively evaluate quality, depending on how wheat conforms to quality standards. The Federal Grain Inspection Service (FGIS) sets official U.S. standards for grains, including wheat, as well as methods and procedures for determining the grade for each wheat class. Grade-determining factors include

test weight, damaged kernels, foreign material, shrunken and broken kernels, total defects, and vitreous kernels, which are also known to affect milling yield (Carson and Edwards, 2009).

Other, non-grade factors such as moisture, protein content, ash content can also determine wheat quality; these can influence milling quality, flour technological quality, baking performance, and resulting end-product quality (Carson and Edwards, 2009; Pagani *et al.*, 2014). Understanding relationships between wheat and resulting products in different stages of the wheat chain (e.g. flour, dough, and final bakery product) is useful for identifying criteria that can predict quality. For example, protein content has been found to affect water-absorption capacity and loaf volume potential (Carson and Edwards, 2009; Graybosch *et al.*, 1996; Thanhaeuser *et al.*, 2014). Gluten index and rheological tests (e.g. farinograph, extensigraph, mixograph, and alveograph) predict dough strength, which is also strongly associated with protein quality, and these tests also determine whether flour is appropriate for a particular end product (Carson and Edwards, 2009). Overall, protein content and quality, dough strength properties, α-amylase activity, and degree of starch damage are important parameters affecting processing, baking, and end-product quality (Carson and Edwards, 2009).

Evaluating wheat quality and its processing quality is conditional on the intended use or end product, which also determines suitable wheat classes. Specialty breads require flour with higher protein content than pastries and cakes; thus, hard wheat classes with higher protein content are more suitable for breadmaking (Carson and Edwards, 2009; Park *et al.*, 2015). In addition to wheat class or genotype, quality characteristics also depend on environmental conditions (e.g. soil type and climate conditions during the growing season) and whether conventional or organic production methods were used (Carcea *et al.*, 2006; Gooding *et al.*, 1993; Graybosch *et al.*, 1996; Pagani *et al.*, 2014; Rakszegi *et al.*, 2016).

Research on quality differences between conventional and organic wheat (and their implications for milling, baking, and end-product quality) has focused mainly on breadmaking potential and thus protein content. Studies conducted in the UK (Gooding *et al.*, 1993), Italy (Carcea *et al.*, 2006) and Northwestern Europe (Osman *et al.*, 2012) found that organic wheat contains less protein, which negatively affects loaf volume and baking quality. Other studies, conducted in Canada (Mason *et al.*, 2007) and Central Europe (Mäder *et al.*, 2007), found no significant differences in protein content between organic and conventional wheat, concluding that overall breadmaking and end-product quality of wheat is comparable across the two production systems. More specifically, Mäder *et al.* (2007) found no differences in milling properties, starch quality, rheological properties of the dough, and baking quality due to the organic production method, although milling and baking properties are highly dependent on protein and starch contents and protein content was somewhat higher in conventional wheat. However, the impact of organic production methods on protein content and other quality traits also depends on environmental conditions (Rakszegi *et al.*, 2016), which can explain the differences in findings across studies. In the U.S., Park *et al.* (2015) examined functional and nutritional characteristics of organic and conventional wheat grown in Washington and Montana. The authors concluded that the end-user quality was associated more with soil fertility and resulting protein levels than with the production system itself and emphasized the need to focus on fertility management.

Hills *et al.* (2013) identified quality and its consistency as the two most important factors for bakers in Washington when purchasing regionally produced flour. Bakers rated the importance of specific technical parameters of flour quality relatively low (except protein), and the authors noted that bakers may not be concerned about them due to their inability to verify them; they may rely on millers instead to make these quality judgments. It is possible that bakers using organic flour pay more attention to quality parameters as they may be more concerned about some aspects of quality. However, Gallardo *et al.* (2009) found that Mexican millers were willing to pay more for improvement of selected wheat quality characteristics, including test weight, protein content, falling number, and dough strength/extensibility, but they were not particularly sensitive to the variability of these attributes. The risk associated with inconsistent quality for wheat users could be mitigated by specifying higher protein content, varieties, locations, or functional traits in a contract but at higher costs (Wilson and Dahl, 2008).

In summary, quality appears to be very important for wheat and wheat flour users (Hills *et al.*, 2013). The literature provides some evidence that organic production may have negative impacts on some wheat quality aspects – including protein content, which influences processing quality – but the impacts depend on regional or environmental conditions (e.g. Osman *et al.*, 2012; Rakszegi *et al.*, 2016). Further, the difference in organic wheat quality relative to conventional wheat quality appears to matter more for breadmaking than for other bakery products (Park *et al.*, 2015), and quality evaluation of a given organic wheat class depends on the end product (Kucek *et al.*, 2017). This study complements past literature, which focused on laboratory testing to measure organic wheat quality, by examining the actual perceptions of organic wheat users in different stages of the supply chain (distributors, processors/millers, and bakers). We examine how study respondents perceive organic wheat/flour quality compared to conventional wheat/flour quality, the characteristics associated with higher perceived quality, and, thus, where organic wheat growers and breeders may need to make improvements.

3. Data collection and sample description

Data for the study were collected through two online surveys administered from December 2020 to February 2021. A directory of bakers, millers, and distributors was compiled using online searches, which included professional association member directories and lists of businesses, with a focus on those located in the Western U.S. Bakers, wheat millers, and distributors were contacted either via email or phone to inform them about the study, its purpose, and to provide the link to the online survey. Several professional associations also disseminated the survey to their members. The two surveys – one for bakeries and one for millers/distributors – were developed based on the literature review and consultation with industry representatives. The questions in both surveys were similar, to allow us to compare responses across users where applicable. We asked questions regarding practices and experience related to the use of organic wheat/flour, importance of wheat characteristics (including quality) when deciding to purchase organic wheat/flour, important indicators of organic wheat/flour quality, comparison of organic and conventional wheat/flour in terms of quality indicators and overall quality, hurdles to securing organic wheat/flour of desired quality and quantity, reasons for not using organic wheat/flour, and basic business characteristics.

In total, 45 bakeries and 25 millers/distributors responded to the respective surveys. The low number of responses was expected due to the relatively small pool of subjects, especially for millers, that could be surveyed. The number of responses is comparable to those in similar studies of grain buyers and bakeries (e.g. Hills *et al.*, 2013; Torres *et al.*, 2020). Baker respondents are located primarily in the Western U.S. (93%), particularly California (20%), Colorado (18%), Oregon (16%), Utah (9%), and Washington (9%). All millers/distributor respondents are in the Western U.S., including Montana (25%), Washington (25%), Utah (21%), Oregon (17%), and California (13%), with some operating in multiple states. Table 1 reports selected respondent characteristics for bakeries and millers/distributors.

Most of the bakeries that use organic wheat in our sample are artisan bakeries selling directly to consumers (57%), and most sell through a store (54%). They vary in size in terms of employee count, years in business, and monthly gross sales. Bakeries that have not used organic flour are mostly privately owned wholesale bakeries (50%), many selling to restaurants and cafes (50%). They also tend to be larger in terms of employee count (50% over 20 employees), have been in business longer (63% over 20 years), and have larger monthly gross sales (63% report $70,000 or more) compared to bakeries using organic flour.

More than half (56%) of respondents in the miller/distributor group are wheat millers. More than half of respondents in this group sell wheat/flour to wholesalers/distributors (56%), and other markets selected by a majority of respondents handling organic wheat include traditional bakeries (63%), artisan bakeries (56%), and food processors (56%). Establishments handling organic wheat tend to be larger in terms of employee count than those that have not handled organic wheat. Regardless of organic wheat handling experience, respondents are largely represented by businesses that have been involved in wheat sales/processing for more than 20 years, with monthly gross sales from all operations above $5 million selected most frequently.

Table 1. Sample characteristics of respondent wheat users.

	Bakeries, n=45			Millers/distributors, n=25		
Attribute	**Category**	**Organic n=37[a]**	**No organic n=8[a]**	**Category**	**Organic n=16[a]**	**No organic n=9[a]**
Business type	Retail, artisan	21; 57%	2; 25%	Miller	10; 63%	4; 44%
	Retail, café/store	3; 8%	1; 13%	Distributor, wholesaler	4; 25%	4; 44%
	Retail, grocery/chain	2; 5%	0; 0%	Other (grain co-op)	2; 13%	1; 11%
	Wholesale, private	8; 22%	4; 50%			
	Wholesale, chain	0; 0%	1; 13%			
	Other	3; 8%	0; 0%			
Main markets/ customer type	Restaurants/cafes	18; 49%	4; 50%	Wholesalers	9; 56%	5; 56%
	Grocery stores	14; 38%	3; 38%	Traditional bakeries	10; 63%	4; 44%
	Consumers in store	20; 54%	1; 13%	Artisan bakeries	9; 56%	3; 33%
	Consumers at farmers' market	17; 46%	2; 25%	Food processors	9; 56%	2; 22%
				Livestock producers	6; 38%	3; 33%
	Consumers in café	13; 35%	2; 25%	Other	12; 75%	3; 33%
Employee count	1-2 employees	12; 34%	1; 13%	1-10 employees	3; 20%	3; 33%
	3-5 employees	2; 6%	1; 13%	11-30 employees	3; 20%	5; 56%
	6-10 employees	6; 17%	2; 25%	31-60 employees	2; 13%	1; 11%
	11-20 employees	4; 11%	0; 0%	61-100 employees	2; 13%	0; 0%
	>20 employees	11; 31%	4; 50%	>100 employees	5; 33%	0; 0%
Years in business[b]	5 years or less	11; 31%	3; 38%	5 years or less	1; 7%	0; 0%
	6-10 years	9; 25%	0; 0%	6-10 years	0; 0%	0; 0%
	11-20 years	8; 22%	0; 0%	11-20 years	0; 0%	0; 0%
	>20 years	8; 22%	5; 63%	>20 years	14; 93%	9; 100%
Estimated monthly gross sales[c]	<$10,000	8; 24%	0; 0%	<$1 million	3; 23%	0; 0%
	$10,000-30,000	6; 18%	2; 25%	$1-2 million	1; 8%	1; 13%
	$30,000-50,000	3; 9%	0; 0%	$2-3 million	2; 15%	0; 0%
	$50,000-70,000	2; 6%	1; 13%	$3-4 million	1; 8%	1; 13%
	>$70,000	15; 44%	5; 63%	$4-5 million	1; 8%	2; 25%
				>$5 million	5; 38%	4; 50%

[a] Sum of responses per category may not add up to total number of survey responses due to missing responses.

[b] Considering only the wheat sales/processing business of millers/distributors.

[c] Considering all grain operations for millers/distributors.

Table 2 reports specifics of the business related to organic wheat/flour use among respondents who have experience with organic wheat/flour. Overall, most bakeries indicated that they use or have used organic whole wheat bread flour (86%), followed by organic white bread flour (70%) and organic all-purpose flour (49%), but organic white bread flour is used most often by 49% of surveyed bakeries. The vast majority of bakeries source organic wheat flour from millers (67%) and distributors, wholesalers, and brokers (64%); they utilize 1-2 suppliers (73%); and they have used organic wheat flour for 5 years or less (54%). Among millers/distributors, many respondents indicated that they handle hard red winter (88%), soft white (75%), hard red spring (69%), and hard white (63%) organic wheat classes. Organic hard red winter and hard red spring classes are each handled in 38% of businesses. The vast majority of millers/distributors source organic wheat from wheat growers directly (94%) and utilize 1-20 suppliers (69%).

Table 2. Specifics related to organic wheat/flour handling or use.

Characteristic	Bakeries, n=37[a]		Millers/distributors, n=16[a]	
	Category	n; %	Category	n; %
Organic wheat class or flour type handled or used regularly/monthly[b]	White, bread	26; 70%	Hard red winter	14; 88%
	White cake/pastry	9; 24%	Hard red spring	11; 69%
	Whole wheat, bread	32; 86%	Soft red winter	3; 19%
	Whole wheat, cake/pastry	8; 22%	Soft white	12; 75%
	All purpose	18; 49%	Hard white	10; 63%
			Durum	4; 25%
Organic wheat class or flour type handled or used most	White, bread	18; 49%	Hard red winter	6; 38%
	White, cake/pastry	1; 3%	Hard red spring	6; 38%
	Whole wheat, bread	8; 22%	Soft red winter	0; 0%
	Whole wheat, cake/pastry	0; 0%	Soft white	2; 13%
	All purpose	3; 8%	Hard white	1; 6%
	Other	3; 8%	Durum	0; 0%
	All/many	4; 11%	All/many	1; 6%
Organic wheat or flour source[b]	Own milling facility	4; 11%	Own fields/farm[c]	1; 6%
	Millers	24; 67%	Wheat growers[c]	15; 94%
	Distributors, wholesalers	23; 64%	Grain elevators	8; 50%
			Distributors, u.s.	7; 44%
			Distributors, imported	3; 19%
Number of regular suppliers of organic wheat or flour	None (mill ourselves)	3; 8%	None (own field/farm)	1; 6%
	1-2 suppliers	27; 73%	1-20 suppliers	11; 69%
	3-4 suppliers	6; 16%	21-50 suppliers	0; 0%
	5-8 suppliers	1; 3%	51-100 suppliers	2; 13%
	>8 suppliers	0; 0%	101-200 suppliers	2; 13%
Years handling or using organic wheat or flour	1-2 years	6; 16%	1-2 years	2; 13%
	3-5 years	14; 38%	3-5 years	3; 20%
	6-10 years	6; 16%	6-10 years	3; 20%
	11-20 years	7; 19%	11-20 years	1; 7%
	>20 years	4; 11%	>20 years	6; 40%

[a] Sum of responses per category may not add up to total number of survey responses due to missing responses.

[b] Respondents could select multiple options, so percentages do not add up to 100%.

[c] 'Own fields/farm' means the miller/distributor grows their own wheat and thus can control the process, while 'wheat growers' means the miller/distributor buys wheat from wheat growers directly and does not control the process.

4. Results and discussion

4.1 Ratings, characteristics, and indicators of organic wheat/flour quality

Respondents were asked to rate the overall quality of organic and conventional wheat/flour on a scale from 1 = 'very low quality' to 5 = 'very high quality.' Results in Table 3 show that bakeries rate organic flour quality higher than they rate conventional flour, while millers/distributors rate organic wheat as lower in quality compared to conventional wheat; both differences are statistically significant. Bakeries also rate the quality of organic flour significantly higher than millers/distributors rate the quality of organic wheat, while the opposite is found for quality of conventional wheat/flour. Overall, it appears that the bakeries in our sample are content with the quality of organic flour, while millers/distributors may require some improvements in wheat quality.

To assess the importance of wheat/flour quality as well as other factors when making organic wheat/flour purchasing decisions, bakeries and millers/distributors were asked to rank the importance of various factors on a scale from 1 = 'not at all important' to 5 = 'extremely important.' The mean levels of importance for each factor were calculated and ordered from most to least important by group. The difference in importance among factors by group was also tested, where applicable.

Results in Table 4 show that wheat quality and consistent wheat quality between shipments are the two most important factors for surveyed millers/distributors. Bakeries in our sample view organic flour quality and its consistency equally as important as millers/distributors, but they view attributes of the final baked product, baking properties, and flour freshness as even more important. Price is among the top three factors for millers/distributors, while it is the least important factor for bakeries; the difference in importance is significant. Bakeries view wheat origin and services provided by suppliers as significantly more important compared to millers/distributors. And as expected, they view the attributes of the final baked product and baking properties as most important.

Table 3. Organic and conventional wheat/flour quality ratings.[a]

	Bakeries (B)	**Millers/distributors (MD)**	***P*-value, H0: B=MD[b]**
Organic wheat/flour quality (OQ)	4.26 (35)	3.50 (16)	0.005
Conventional wheat/flour quality (CQ)	3.69 (32)	4.44 (16)	0.004
P-value, H0: OQ=CQ[c]	0.015	0.006	

[a] Reported values represent average quality rating, where 1 = 'very low quality' and 5 = 'very high quality.' Numbers of observations are in parentheses.

[b] Two-sample Wilcoxon rank-sum (Mann-Whitney) test of the difference in means between bakeries and millers/distributors.

[c] Wilcoxon signed-rank test of difference in means between organic and conventional wheat/flour quality rating.

Table 4. Importance of factors when making organic wheat/flour purchase decisions.

Bakeries			**Millers/distributors**		
Factor	**Mean[a,b]**	**St. dev.[c]**	**Factor**	**Mean[a,b]**	**St. dev.[c]**
Final baked product	4.65***	0.63	Wheat quality	4.07[ns]	0.62
Baking properties	4.41***	0.69	Consistent wheat quality	3.93[ns]	1.03
Flour freshness	4.38	0.76	Price	3.86*	0.77
Flour quality	4.19[ns]	0.94	Customer feedback	3.85	0.90
Consistent flour quality	4.19[ns]	0.88	Relationship with supplier	3.77[ns]	0.83
Flour origin	4.08	0.86	On-time delivery	3.54[ns]	1.13
Relationship with supplier	3.95[ns]	1.05	Baking properties	3.38***	1.26
Wheat origin	3.95**	1.03	Final baked product	3.38***	1.19
Resulting dough quality	3.94[ns]	1.15	Resulting flour quality	3.29	1.44
Consumer demand	3.92	1.09	Resulting dough quality	3.23[ns]	1.42
On-time delivery	3.70[ns]	1.18	Wheat origin	3.00**	1.08
Supplier services	3.70**	1.00	Supplier services	2.86**	1.10
Price	3.27*	1.19			

[a] Mean values represent average importance of a factor on a scale from 1 = 'not at all important' to 5 = 'extremely important.' Where applicable, difference of importance between bakeries and millers/distributors was tested.

[b] ***, **, * represent significant difference at the 0.01, 0.05, and 0.1 level, respectively; [ns] means the difference in importance is not significant at the 0.1 level for factors, where the differences were tested.

[c] St. dev. = standard deviation.

Next, we examine in more detail which wheat/flour characteristics are important indicators of organic wheat/flour quality among surveyed bakeries and millers/distributors and whether survey respondents perceive organic wheat/flour to be inferior to conventional. Table 5 reports the proportions of respondents who view the characteristic as important and, among those who view the characteristic as important, the proportion of those who view organic wheat/flour as inferior to conventional wheat/flour. In each group, the characteristics are ordered based on the proportion of those who view them as important, from most to least. Most respondents in both groups view protein quality and protein content as important, and their views of other characteristics are similar across both groups. Millers/distributors are significantly more likely to perceive organic wheat as inferior to conventional in terms of protein content and protein quality. More than half of millers/distributors also view moisture content, test weight, dockage, wheat defects, and contamination with other wheat classes as important, and the majority of those respondents perceive organic wheat to be inferior in terms of dockage and wheat defects. Nutritional content, water absorption, flour texture, and ash content are viewed as important indicators by 50% or more of bakeries, and only 10% or less of these bakeries perceive organic flour to be inferior. However, two bakers mentioned in a comment that water absorption specifically tends to be more variable for organic flour than conventional flour, and more consistency is desired.

With regards to the other characteristics examined, a higher percentage of surveyed bakeries than millers/distributors view ash content, alveograph test, wet gluten test, flour color, and extensigraph test values as

Table 5. Important indicators of organic wheat/flour quality.[a,b]

Bakeries			**Millers/distributors**		
Flour quality characteristic	**Important**	**Organic inferior**	**Wheat quality characteristic**	**Important**	**Organic inferior**
Protein quality	73%^{ns}	11%*	moisture content	81%	15%
Protein content	68%^{ns}	8%*	test weight/1000-kernel	75%	42%
Nutritional content	62%	4%	protein content	75%^{ns}	33%*
Water absorption[c,d]	59%	9%	protein quality	69%^{ns}	36%*
Flour texture	57%	10%	dockage	63%	80%
Ash content	51%***	0%	wheat defects	63%	60%
Alveograph	49%***	11%^{ns}	other wheat classes mixed	50%	25%
Dough stability time[c]	46%	12%	farinograph	44%	29%
Wet gluten test	46%***	6%^{ns}	flour falling number	38%^{ns}	0%^{ns}
Dough peak time[c,d]	43%	19%	microbial contamination	25%	0%
Mixing tolerance index[c,d]	41%	7%	single kernel description	19%	33%
Flour color	41%**	0%	ash/mineral content	13%***	0%
Extensigraph	38%**	14%^{ns}	mixograph	13%	0%
Flour falling number	38%^{ns}	7%^{ns}	wet gluten test	6%***	0%^{ns}
Viscosity/flour starch[e]	24%^{ns}	11%^{ns}	flour color	6%**	0%
			alveograph	6%***	0%^{ns}
			extensigraph	6%**	0%^{ns}
			amylograph	6%^{ns}	0%^{ns}

[a] Where applicable, difference of importance between bakeries and millers/distributors was tested. Percentages in the 'important' columns represent the proportion of those who viewed the characteristic as important indicator of quality. Percentages in the 'organic inferior' category represent the proportion of those who indicated that organic wheat/flour is inferior to conventional among those who viewed the characteristic as important.

[b] ***, **, * represent significant difference at the 0.01, 0.05, and 0.1 level, respectively; ^{ns} means the difference is not significant at the 0.1 level, where tested.

[c,d,e] Indicates that the characteristic is reported in farinograph, mixograph, and amylograph test results, respectively.

important indicators of quality.[1] But the shares of those who view organic wheat/flour as inferior in terms of these characteristics are small (at most 14% for extensigraph among bakeries) and not statistically different across groups. The share of respondents in both groups who view the flour falling number and amylograph test as important are also similar.

Wheat and wheat flour are closely related products, differing in the level of processing. Wheat is an input for wheat flour, and flour is an input for bakery products. Thus, wheat quality is expected to influence the quality of flour and resulting bakery products, as discussed in the literature review. However, we find that bakeries and millers/distributors differ in terms of the characteristics they view as important indicators of organic wheat/flour quality. Naturally, bakeries purchasing processed wheat flour would not be concerned about certain characteristics of raw wheat (e.g. test weight, dockage, and wheat defects) that concern millers and distributors, since they affect yield of resulting flour. But millers/distributors might be concerned about some technological properties of flour, which is used by bakeries in the next stage and is made from the wheat they handle.

Among the quality characteristics that could potentially be of interest and evaluated by both groups, only protein quality and content are viewed as important indicators of both organic wheat and flour quality by most. Fewer millers/distributors than bakeries view some flour tests (wet gluten test, alveograph, extensigraph) and flour properties (color, ash content) as important wheat quality indicators, which suggests that they may not examine these characteristics for the resulting flour. In fact, one respondent from the group of bakeries mentioned in a comment that millers tend to rely on one testing method, but several methods (including alveograph, farinograph, wet gluten test, and flour falling number) are also important. Compared to bakeries, millers/distributors appear to be more critical of organic wheat in terms of the quality indicators they view as important, which is in line with their overall lower rating of organic wheat quality compared to conventional wheat quality (Table 1). Despite these issues, it appears that they are successful in supplying high-quality organic wheat/flour to bakeries. However, one respondent commented that the organic label distorts expectations among some wheat buyers, who tend to believe that raw organic wheat should be cleaner, more beautiful, and without any defects compared to conventional wheat. This might explain why organic wheat buyers are more critical of organic wheat quality than are bakeries, which use processed wheat flour. Also, the sample of bakeries and millers/distributors in this study may not be representative of the entire industry.

4.2 Indicators of organic wheat/flour quality

Next, we examine indicators of organic wheat/flour quality ratings alone and compared to conventional wheat/flour quality ratings. We estimated ordered logit models (Train, 2009) using factors evaluated by both bakeries and millers/distributors as regressors to allow us to pool responses from both groups. The same models were estimated using only the bakery data. Ordered logit models were used because the outcome variables are categorical in nature, with more than two levels, and the order of the categories is meaningful. Due to sample size concerns, we estimated additional models using the penalized maximum likelihood estimation (PMLE) method, which reduces both variance and bias in small samples and substantially improves logit estimates (Kessels *et al.*, 2019; Rainey and McCaskey, 2021). Since PMLE models require the organic quality rating be collapsed into a binary variable, information is lost; thus, the PMLE model results were not included here, as the results were essentially the same as those from the ordered logit models.

Table 6 reports the results of eight ordered logit models, estimated using two datasets (pooled data and bakery data only) and two sets of regressors (factors considered when purchasing organic wheat/flour and organic

[1] The alveograph and extensigraph tests measure gluten strength of dough and dough extensibility (U.S. Wheat Associates, 2020). Additional tests are considered important and were included in the surveys, following discussions with industry representatives, including farinograph, mixograph, and amylograph tests. Farinograph tests describe the mixing properties of the dough, which include peak time, stability, and water absorption (U.S. Wheat Associates, 2020). Peak time and stability indicate gluten strength and dough properties, while water absorption determines the quantity of dough that is produced. Mixograph tests measure the resistance of dough to mixing with pins and provides indices of peak time, peak height, and mixing tolerance (Pagani *et al.*, 2014). Amylograph tests measure viscosity, flour starch properties, and enzyme (α-amylase) activity (U.S. Wheat Associates, 2020).

Table 6. Ordered logit model results.[a,b]

Regressor group	Regressors	Organic quality rating[c]		Organic quality rating compared to conventional[d]	
		Pooled responses	Bakeries only	Pooled responses	Bakeries only
Importance of factors when purchasing organic wheat/ flour	Final baked product	0.07	0.31	1.00	0.91
	Baking properties	0.05	0.42	-0.89	-5.18*
	Flour/wheat quality	-0.41	-0.31	0.44	3.14
	Consistent flour/wheat quality	0.70	-0.32	-1.40*	-2.02
	Relationship with supplier	-0.19	-1.63**	0.96	1.30
	Wheat origin	1.01*	2.19**	-0.54	n/a[e]
	Resulting dough quality	-0.51	-0.96*	0.26	0.59
	On-time delivery	-0.57	-0.65	-0.64	0.37
	Supplier services	0.47	1.31**	0.36	-0.11
	Price	-0.46	-0.30	-0.11	-0.46
	Bread wheat/flour type[f]	0.16	-0.87	0.47	5.75
	Bakery	0.80		1.99	
	Organic quality rating			3.39***	7.66**
	No. of obs.	47	34	45	32
	Prob. > chi^2	0.114	0.074	0.000	0.000
Important organic wheat/flour quality indicators	Protein quality	1.40	2.08*	0.93	2.04
	Protein content	-1.65*	-1.14	-0.59	-1.40
	Ash content	-0.73	-2.79*	-0.48	1.59
	Alveograph	-0.48	-0.52	0.44	-0.16
	Wet gluten test	1.58	1.84	-0.62	-0.49
	Flour color	0.35	-0.37	0.17	0.18
	Flour falling number	0.38	2.07	1.39	-0.75
	Extensigraph	-2.85**	-4.54***	0.03	1.09
	Amylograph	1.83	2.52*	-1.06	-1.18
	Bread wheat/flour type[f]	-1.44	-3.42**	0.52	2.21
	Bakery	2.15***		2.55**	
	Organic quality rating			2.52***	3.32***
	No. of obs.	51	35	48	32
	Prob. > chi^2	0.060	0.249	0.000	0.005

[a] Values represent β coefficient estimates. Multicollinearity issues were tested using variance inflation factors (VIF), confirming VIF<5 for each regressor. Models using one regressor at a time yielded similar results.

[b] ***, **, * denote significance at 0.01, 0.05, 0.1 level, respectively.

[c] Ordered logit models with the organic wheat/flour quality rating as the dependent variable, ranged from 1 = 'very low quality' to 5 = 'very high quality.'

[d] Ordered logit models with the comparison of the organic and conventional wheat/flour quality rating as the dependent variable, where 0 = organic quality ranking lower than conventional, 1 = organic quality ranking same as conventional, and 2 = organic quality ranking higher than conventional.

[e] Estimate not available. The variable was excluded due to a high correlation with 'relationship with supplier' (ρ=0.79), which caused estimation errors. Similar results were obtained after excluding 'relationship with supplier'.

[f] Dummy variable = 1 if respondent handles mostly bread wheat/flour type, 0 otherwise.

wheat/flour quality indicators) for two outcome variables (the organic quality rating and the organic quality rating compared to conventional). Coefficient estimates for each model are reported by order of importance for each factor/indicator from most to least important for bakeries. Models also include a dummy variable equal to 1 if the respondent primarily handles wheat/flour suitable for breadmaking and 0 otherwise. This will account for the potential differences in perceived quality across different wheat classes or flour types (i.e. different wheat/flour uses).

First, results based on the pooled responses show that when users place a higher importance on organic wheat origin, their ratings of organic wheat/flour quality are also higher. The β coefficient estimates can be interpreted in terms of odds ratios, calculated as e^{β}. For example, if the importance placed on organic wheat origin increases by 1 unit, from 4 = 'very important' to 5 = 'extremely important,' then the odds of respondents rating organic wheat/flour quality as 5 = 'very high quality' compared to 4 = 'high quality' or lower are 2.74 ($\approx e^{1.01}$) times higher. Also, if consistent quality is more important, then respondents are less likely to rate organic wheat/flour quality higher than conventional quality. The insignificant coefficient estimate for 'bakery' means that when the examined factors are accounted for, the difference in quality ratings between bakeries and millers/distributors is not significant.

When examining the results of the pooled responses, the remaining factors do not significantly affect organic wheat ratings or its rating in comparison to conventional wheat/flour. This may imply that these factors affect quality ratings for bakeries and millers/distributors differently. Indeed, estimates of the same models using only the bakery responses reveal some differences. Placing a high importance on supplier relationships and dough quality negatively affects organic flour quality ratings. Also, placing a high importance on baking properties negatively impacts bakery organic flour quality ratings compared to conventional.

The results of the pooled responses (Table 6) further show that those who view protein content, and extensigraph test values as important indicators of organic wheat/flour quality are less likely to assign higher quality ratings to organic wheat/flour. However, the importance of each examined organic wheat/flour quality indicator does not have a significant effect on the organic quality rating relative to conventional quality, which could be again due to the differences in effects of the regressors between bakeries and millers/distributors. However, the odds of a higher organic wheat/flour quality rating alone and relative to conventional wheat/flour are higher for bakeries than for millers/distributors. Significant coefficients for bakeries mean that other, unaccounted-for indicators (in addition to those examined in the regressions) could explain the difference in the quality ratings between bakeries and millers/distributors. Estimating the same models using only the bakery responses reveals differences in the impacts of the examined indicators on the ratings between bakeries and millers/distributors. In addition to the importance of extensigraph test values, the importance of ash content and use of bread flour type are associated with lower organic wheat quality ratings among bakeries.

In summary, we find that bakeries and millers/distributors in our sample rate the quality of organic (and conventional) wheat/flour differently, and they differ somewhat in what they perceive to be important factors when purchasing organic wheat/flour as well as which characteristics indicate organic wheat/flour quality, where comparable. However, it appears that these differences in perception do not explain the divergent quality ratings of bakeries and millers/distributors. An exception is the importance of wheat origin, protein content, and extensigraph test values, which were found to significantly impact organic wheat quality ratings when responses from bakeries and millers/distributors were pooled. Improvements in protein content (selected as an important indicator of quality by two-thirds of the bakeries and millers/distributors) and extensigraph test values may improve perceptions of organic wheat/flour quality.

In addition, improved consistency of organic wheat/flour quality, viewed by both groups as highly important when purchasing organic wheat/flour, may contribute to a more favorable view of organic wheat/flour quality when compared to conventional wheat/flour. Considering bakeries alone, findings also suggest that there may be a need for closer relationships with suppliers as well as improvements in dough quality, ash content, and – particularly – baking properties, which are ranked as the second-most important factor and are related

to a lag of organic flour quality behind conventional flour. Bakeries that primarily use bread-type flour tend to rate organic wheat flour quality lower, suggesting that the breadmaking quality of organic wheat flour may need to improve.

4.3 Past experiences and requirements related to organic wheat/flour

Bakeries and millers/distributors were also asked to indicate their agreement with some statements regarding their experiences and needs related to organic wheat/flour, on a scale from 1 = 'strongly disagree' to 5 = 'strongly agree.' Table 7 reports mean values for each statement, the share of those who disagreed (1 = 'strongly disagree' or 2 = 'somewhat disagree') with the statement, and the share of those who agreed (4 = 'somewhat agree' or 5 = 'strongly agree'). Six statements were similar for both groups, and the difference of responses between the groups was tested.

Results in Table 7 reinforce our finding that surveyed millers/distributors are less satisfied than surveyed bakeries with the quality of organic wheat/flour. Millers/distributors are significantly more likely than bakeries to agree that suppliers sometimes provide lower-quality organic wheat than agreed upon, although they are also significantly more likely to agree that they know their quality needs related to organic wheat and communicate them clearly to their suppliers. However, two-thirds agree that millers can enhance organic flour quality, which may explain the significant difference in perceptions of organic wheat/flour quality between the groups. They also tend to be more likely than bakeries to agree that they need organic wheat of higher quality than their suppliers can currently provide, although the difference is not significant. Over half (57%) of millers/distributors also agree that organic wheat quality varies by supplier and region of origin.

Overall, both bakeries and millers/distributors tend to disagree about the difficulty of working with organic wheat/flour compared to conventional such that it would require them to adjust their processes, although bakeries are significantly more likely to agree with the statement. Both bakeries and millers/distributors tend to agree equally that consumers display strong demand for organic flour from bakeries and for healthier/organic bakery products. Only 20% of bakeries and 14% of millers/distributors agree that their business

Table 7. Experience and needs related to organic wheat/flour.[a]

	Bakeries			Millers/distributors		
Statement	**Mean[b]**	**Disagree[c]**	**Agree[c]**	**Mean[b]**	**Disagree[c]**	**Agree[c]**
Demand (organic flour/products) is strong	3.97[ns]	14%	76%	3.69	8%	54%
Quality needs known and communicated clearly	3.81**	11%	61%	4.43	0%	86%
Can manipulate quality of organic product	3.29	11%	46%			
Organic product quality similar to conventional	3.25	31%	47%			
Need to adjust some processes for organic	2.61*	53%	31%	1.69	85%	8%
Need higher quality organic wheat/flour	2.54[ns]	49%	23%	3.21	36%	43%
Need more organic wheat/flour	2.20*	69%	20%	2.79	29%	14%
Organic wheat/flour quality sometimes lower	2.11***	69%	11%	3.43	7%	36%
Organic wheat quality varies by supplier/grower				3.79	0%	57%
Organic wheat quality varies by origin/region				3.57	21%	57%
Organic flour quality similar to conventional				3.53	27%	47%
Millers can enhance organic flour quality				3.43	29%	64%

[a] ***, **, * represent significant difference at the 0.01, 0.05, and 0.1 level, respectively; [ns] means the difference is not significant at the 0.1 level, where tested.

[b] Mean values represent average agreement with the statement on a scale from 1 = 'strongly disagree' to 5 = 'strongly agree.' Where applicable, difference of responses between bakeries and millers/distributors was tested.

[c] Percentages represent share of respondents who disagreed and those who agreed with the statement.

needs more organic wheat/flour than their suppliers can provide, indicating that there is not a severe shortage of organic wheat/flour at this time.

4.4 Hurdles to securing organic wheat/flour

Hurdles that prevent respondents from securing desired quality or quantity of organic wheat/flour were also examined. Respondents could indicate whether potential issue is a hurdle or not, where 1 = 'not a hurdle,' 2 = 'somewhat a hurdle,' and 3 = 'definitely a hurdle.' Table 8 reports mean values and percentages of those who viewed listed issues as hurdles to some extent (choosing 2 or 3). A large percentage (80%) of millers/distributors feel that there are not enough organic wheat growers. Cost/price of organic wheat/flour is viewed as a hurdle to some extent most frequently by both bakeries (61%) and millers/distributors (70%), and there is no difference between both groups. Further, 50% of millers/distributors view lack of interaction with suppliers as a hurdle to some extent, and remaining issues are viewed as hurdles by fewer than 50% of respondents in both groups.

Overall, a larger share of millers/distributors than of bakeries tends to view these issues as hurdles, but the differences are not statistically significant. It appears that the main issue for millers/distributors is quality rather than lack of supply of organic wheat: 14% indicated that they need more organic wheat/flour, while 43% need organic wheat of higher quality (Table 7). The price of organic wheat as a hurdle might indicate that they cannot afford organic wheat of higher quality. However, one respondent also commented that the smaller volumes available in the organic wheat market compared to those of the conventional wheat market is a hurdle that eventually affects the quality by limiting blending opportunities and ability to maintain blending consistency.

Until now, presented findings were based on responses from bakeries and millers/distributors, which handle organic wheat/flour currently or did so in the past. Respondents who have never handled organic wheat/flour were asked about the issues that prevent them from doing so. Among bakeries, price is a major issue (6 out of 8 respondents), as it was among bakeries who have experience with organic wheat flour. Other selected issues include concerns related to supply, consumer demand, difficulty complying with USDA organic standards, and concerns related to final bakery product (2 out of 8 respondents for each); one bakery indicated concern regarding organic flour quality. Among millers/distributors, those who have never handled organic wheat are most concerned about the demand for organic wheat/flour (5 out of 9 respondents), despite the fact that more than half of those who currently use organic wheat agree that demand is strong (Table 7).

Table 8. Hurdles to securing desired organic wheat/flour quality or quantity.

	Bakeries			**Millers/distributors**		
	Mean[a]	Somewhat a hurdle[b]	Definitely a hurdle[b]	Mean[a]	Somewhat a hurdle[b]	Definitely a hurdle[b]
Not enough organic wheat growers				1.90	70%	10%
Cost/price of organic wheat/flour	1.81[ns]	42%	19%	1.90	50%	20%
Difficulty finding suppliers	1.49[ns]	31%	9%	1.50	30%	10%
Lack of interaction with suppliers	1.48[ns]	18%	15%	1.50	50%	0%
Complexity of handling	1.36[ns]	18%	9%	1.40	40%	0%
Suppliers do not understand needs	1.31[ns]	19%	6%	1.60	40%	10%
Suppliers unable to verify needs	1.30[ns]	24%	3%	1.60	40%	10%
Contamination during handling	1.09[ns]	9%	0%	1.10	10%	0%

[a] Mean values represent average perception whether an issue is a hurdle on a scale from 1 = 'not a hurdle' to 3 = 'definitely a hurdle.' Where applicable, difference of responses between bakeries and millers/distributors was tested. [ns] means that the difference is not significant at the 0.1 level.

[b] Percentages represent share of respondents who thought an issue is somewhat a hurdle and definitely a hurdle.

Two out of 9 respondents are also concerned about organic wheat quality, issues related to segregation of organic and conventional wheat, and organic wheat supply. One respondent is concerned about the price of organic wheat, compliance with USDA standards, and organic wheat flour quality.

5. Conclusions

Previous literature has examined the technical attributes of wheat quality and how they impact milling and baking quality, how organic wheat differs from conventional wheat in terms of quality, and the implications for organic wheat processing quality. This study adds to the conversation by examining the actual perceptions and needs of wheat buyers across the supply chain in terms of organic wheat quality and the quality of resulting organic bakery products.

Study results show that millers/distributors may view organic wheat as inferior to conventional wheat, indicating the need to improve some aspects of wheat quality. On the other hand, surveyed bakeries find organic flour to be of higher quality than conventional flour. This suggests that millers may be able to manage the quality of the resulting organic wheat flour and process possibly lower-quality organic wheat into higher-quality organic flour. This also suggests that there is sufficient interaction and communication between millers and bakeries and that millers are able to accommodate bakery quality requirements. However, the lower quality ranking of organic wheat in its raw form may also be due to some undesirable characteristics related to physical appearance, which are eliminated during processing (e.g. dockage and wheat defects) and not exclusively due to the characteristics that influence baking quality and end product, which matter to bakers. Also, as noted by one respondent, the organic label seems to increase expectations among some buyers about the physical appearance of organic wheat compared to conventional wheat. Thus, there may be a need to educate wheat buyers about how organic production can and cannot affect physical properties of wheat so that expectations can be adjusted.

Millers/distributors and bakeries differ somewhat in what they perceive to be the most important factors when purchasing organic wheat/flour and indicators of organic wheat/flour quality (where comparable), but some similarities are found too. For example, surveyed millers/distributors view wheat quality and consistency of wheat quality as the two most important factors when purchasing organic wheat; bakeries view them as similarly important. This is comparable with Hills *et al.* (2013), who found that flour quality and consistency of flour quality are the most important factors among bakers in Washington when purchasing regionally produced flour. In Torres *et al.* (2020), organic grain buyers viewed quality as the most important factor to build and maintain relationships with grain suppliers. But bakeries in our sample view attributes of the final baked product, baking properties, and flour freshness as even more important factors than quality and its consistency when purchasing organic flour. However, some bakeries in our study emphasized the importance of quality consistency and lack thereof in final comments, mentioning that quality tends to decline toward the end of the marketing year. One respondent pointed out that consistency issues regarding organic wheat/flour quality are possibly associated with the smaller volume of organic wheat in the market, which limits blending opportunities for organic flour and thus reduces the ability to maintain consistent quality.

Further, the majority of respondents in both groups view protein content and quality as important indicators of organic wheat/flour quality, in line with past literature (Carson and Edwards, 2009; Graybosch *et al.*, 1996; Thanhaeuser *et al.*, 2014). Compared to bakeries, a higher percentage of millers/distributors in our sample perceive organic wheat to be inferior in terms of protein content and quality.

Findings suggest that many of the factors considered when purchasing organic wheat/flour and indicators of organic wheat/flour quality do not explain the variation in quality ratings for organic wheat or the comparison with conventional wheat. Considering the factors and indicators which did negatively impact ratings, improvements in protein content, extensigraph values, and quality consistency may be desirable. For bakeries, there also appears to be a need for better relationships with suppliers and improvements in dough quality, ash content, baking properties, and overall breadmaking quality.

While study findings provide insights into bakery and miller needs and perceptions of organic wheat/flour quality, this study has several limitations. First, the sample size available for the analysis is small; caution should therefore be exercised when interpreting the results. Specifically, the sample size may lead to understated variable significance and the results may not be generalizable or reflect the views of the entire industry. Further, the results suggest that other factors not accounted for in the analysis affect organic wheat/flour quality rating and the differences in quality ratings between millers/distributors and bakeries. For example, we did not examine the effect of the region where the organic wheat – which the respondents have used either in raw or processed form – was grown. This is a limitation since past literature has found that differences in soil type and weather conditions, which vary greatly across regions, also affect wheat quality. However, millers tend to source wheat from multiple suppliers, which would make it difficult to account for wheat origin in the regression models applied in this study. Another limitation is that many respondents handle multiple classes/types of organic wheat/flour, which likely vary in quality, and thus their overall quality rating condenses their experience across multiple classes/types. To alleviate this issue, the impact on ratings for those who handle mostly the class/type of organic wheat flour used for breadmaking was isolated, which confirmed that wheat/flour class/type affects quality ratings significantly. One respondent also noted that wheat breeders are focused too much on the agronomic aspects of wheat varieties and they should consider the nutritional aspects more.

In conclusion, the results of this study suggest that there is a need to reduce organic wheat and wheat flour prices without compromising quality. Cost/price is reported to be a major hurdle to securing organic wheat/flour, as Hills *et al.* (2013) also found for other types of differentiated wheat, such as regionally produced wheat. Price reduction would likely increase baker interest in organic wheat flour, assuming stable quality. However, since organic wheat product demand is currently strong (Atchley, 2021; OTA, 2020), it is unlikely that organic wheat prices will decrease anytime soon. Future research may examine whether final consumers are willing to absorb higher prices for organic wheat flour, as well as what factors increase their willingness to pay for products made from organic wheat. A few bakers mentioned consumer unwillingness to pay more for organic bakery products and – possibly related – a lack of understanding of organic labels as reasons for not using organic flour. These bakers hesitate to pass the higher organic flour costs on to consumers for those reasons.

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