Potential for Expansion of the Oklahoma Flour Milling Industry

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Abstract: A survey of wheat Oklahoma flour users suggests that there is currently an excess demand for flour in Oklahoma. While Oklahoma produces mostly hard red winter wheat, most Oklahoma bakers require predominantly soft wheat flour for their products and are currently receiving that flour from out-of-state suppliers. An economic engineering-based, mixed-integer programming model was used to determine the optimal number, size and location of additional flour mills in Oklahoma to capture this excess flour demand. The results suggest that additional mills are potentially justified, and the potential increases if Oklahoma soft wheat production increases.

Key terms: flour demand, end-user quality requirements, economic engineering, mixed-integer mathematical programming

Introduction

Wheat is one of the most important crops in Oklahoma, as it is planted on more agricultural land than any other commodity (Oklahoma Department of Agriculture). Besides being a major source of revenue to farmers, winter wheat also provides excellent winter pasture opportunities for cattle. The unique growing conditions of Oklahoma, Texas and parts of Kansas allow for most of the wheat planted for grain to also be grazed by cattle as winter pasture. Hard red winter (HRW) wheat dominates Oklahoma production, representing nearly 99% of the state's total wheat output each year.

Since 1992, Oklahoma wheat production has fluctuated from 168.2 to 93.1 million bushels (Oklahoma Department of Agriculture). Part of this fluctuation can be attributed to weather and growing conditions, while some is also due to the impacts of changes in government programs. Government programs are currently giving producers much lower incentives to plant and harvest program-supported crops like

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wheat. As a result, producers are considering more crop options, with
decision-making being based upon the relative prices and production
costs of various commodities. It is possible that the mix of crops
grown in Oklahoma will continue to change as farm programs phase out.

The current wheat milling industry in Oklahoma is comprised of
four (4) major firms, one in each of the following locations (Figure 2, north
to south “X’s”): Blackwell, Enid, Okeene and Shawnee. The four together
have a total capacity of about 31,400 hundred weight (cwt.) of flour per
day, which is equivalent to 942 million pounds of flour per year (Oklahoma
Department of Commerce). However, full utilization of this
capacity would handle less than 20% of the state’s total wheat produc-
tion. At least 80% of the wheat produced in Oklahoma is exported as
grain. To some people, the amount of wheat leaving Oklahoma as grain
appears to represent potential for expansion of the milling industry.

Generally, more urbanized and densely populated states have com-
parative advantages in flour milling over Great Plains states such as
Oklahoma due to the proximity to end-users (Harwood et al.). Several
changes in recent years could lessen these comparative advantages. For
example, there has been a general increase in population shares for the
South and West while those of the Northeast and North Central have
been declining (Myers). These changes in population demographics,
along with a migration of food processing companies, have increased
interest in developing additional flour mills in Oklahoma, thereby
identifying the need to evaluate the industry’s potential for expansion.

In addition to the changes in consumer demographics, numerous
changes in the nature of the demand for wheat products have taken
place. As with most foods in the U.S., more value is being added prior to
when consumers actually purchase the food products (Barkema et al.).
Away-from-home food consumption has grown at a faster rate than total
food consumption. The growth of restaurant chains and their demand
for products requiring little preparation time have created needs for
finished goods and frozen and refrigerated doughs for breads, pizza
crusts, and pastries that can be baked on site. These relatively higher-
valued products can be produced at centralized locations and shipped to
customers throughout a wide geographic area. Oklahoma has been able
to attract several firms that manufacture flour-based products for
regional and national distribution (Oklahoma Department of Agriculture).
As a result, it becomes more important and cost efficient to have
flour produced near processors rather than population centers.

Consumers are also purchasing bread and flour products for at-home
use that are more convenient and have higher values, as opposed to
purchasing flour and creating flour-based products in the home. Wheat
flour-based products of this nature include frozen foods that can be
quickly heated or baked, breads, and doughs that require only minimal
preparation prior to consumption. Ready-to-eat cookies and crackers are also among the rapidly growing flour-based products (Putnam et al.).

Objectives

An industry evaluation and expansion project was undertaken to increase the capacity to systematically evaluate food processing prospects in Oklahoma, primarily those prospects associated with increased flour milling. Sub-objectives were to:

1. Determine the quantity and quality characteristics of wheat flour needed by Oklahoma food processors and currently supplied by out-of-state firms;
2. Determine the costs of building processing facilities that could potentially meet this excess flour demand;
3. Identify optimal locations for flour milling expansion;
4. Determine the overall costs of wheat procurement, transportation from production points to potential milling sites, flour milling, and flour delivery to food processors; and
5. Evaluate conditions that would increase the probability of profitable wheat processing in Oklahoma (these could include alternative varieties, production methods, or growth of local and regional markets).

Conceptual Framework

In a perfectly competitive market environment, prices differ by the costs of transfer among different levels of the marketing channel. These transfer costs constitute the value of form, place, time, and/or possession utilities created in the productive process of marketing (Kohls et al.). Thus, in considering the optimal distribution of expanded flour milling capacity, all costs associated with wheat and flour marketing (transportation, storage, processing, and transactions) must be taken into account wherever possible.

Much of economic theory seeks to explain economic phenomena that are assumed to exist in a spaceless world. With many problems this approach may be appropriate, but there also exist certain economic problems that require explicit consideration of the effects of space. Many of these situations exist in agriculture, where the production of commodities is often geographically distributed in patterns considerably different from the locations of final product consumption. Thus, the farm-to-retail price spreads for agricultural commodities include the costs of moving the farm commodity to processing locations and distributing the final products to consumer demand locations.
Location of Economic Activity

The plant location problem has been most successfully analyzed by mathematical programming techniques, which provide a logically consistent method for evaluating alternative economic scenarios and industry structures. The optimal plant location is determined at the unique point that minimizes total transportation and processing costs by balancing the locational pulls exerted by raw material inputs and markets. Empirically, the optimal number, size and location of agricultural processing plants can be approached in two ways: continuous space and discrete space optimization (French). The continuous space formulation assumes that commodity production and marketing activities are dispersed in a continuous manner. A major difficulty with this approach, however, is that supply density typically is not uniform and supply areas are not regular and continuous in space. Moreover, there are often limited numbers of realistic choices for efficient locations, and plant cost functions may not be independent of these locations.

An alternative to the continuous space approach, the discrete case groups supply sources and market territories into finite numbers of point locations and considers some predetermined set of potentially feasible plant locations. The discrete case is a special case of the more general continuous case, in which production occurs at specific discrete points on the plane and assembly costs include only the costs of moving product from these points to the plant. The commonly used static agricultural plant location models can be broadly categorized into a) linear programming and transshipment models; b) Stollsteimer location models; and c) mixed integer models (Faminow).

Mixed Integer Programming

A limitation of the transshipment and Stollsteimer models is that they ignore fixed charges associated with plant establishment and operation. The opening of a plant, however, will typically involve a considerable initial plant investment plus other fixed costs that are amortized over the life of the plant. Additional fixed costs associated with operating may also be incurred. Failure to consider these fixed costs may lead to research results that are of limited use to policy makers or industry (Faminow). Thompson and Thore formally present total capacity installation costs as:

\[ \gamma_j y_j + \delta_j \Delta X_j, \]  

(1)

where \( \gamma_j \) is the fixed-charge portion of capacity costs (all costs not associated with scale of operation of the activity), \( \delta_j \) is the slope of the linear portion of capacity expansion cost function, and \( y_j \in \{0,1\}, \forall j = 1, \ldots, n \) is a binary variable, equal to 0 if new capacity
\[ \Delta X_j = 0 \] and equal to 1 if \[ \Delta X_j > 0 \]. The cost schedule (1) has a discontinuity at the origin. If no new capacity is added, the cost is zero. If any positive amount of new capacity is added, the entire fixed charge must be paid (as well as variable costs).

**Methods and Procedures**

To accomplish the first sub-objective, a comprehensive, self-administered, mail survey of major Oklahoma flour users was conducted to provide an understanding of flour usage by flour quality and specification. All existing processors in Oklahoma were asked to give information about the type of flour used and their current sources of flour by flour type. The survey requested specific information on the quantity of flour used annually, the locations of flour suppliers, and flour specifications for each product manufactured. The questionnaire also asked each company to rate the importance of a list of characteristics that may affect their flour supplier decisions.

To accomplish the remaining sub-objectives, a wheat processing plant location model was developed to minimize total transportation, mill construction, and processing costs associated with replacing out-of-state flour with Oklahoma-milled flour. Wheat, flour, and mill feed shipments were used as choice variables in the model. Also, binary variables determined the viable locations for mill capacity addition or construction. The model is an economic engineering representation of a system incorporating wheat production, wheat shipping and milling, flour shipping, mill feed shipping, and flour usage.

The mixed-integer programming model used was designed to minimize the combined costs of delivering wheat to milling sites, milling flour, and shipping flour and by-products to end users. The model is of the mixed integer variety because additional mill construction and capacity were allocated for only three discrete mill daily capacities (7,000, 4,900, and 3,000 cwt. of flour per day) based on the daily capacities of existing Oklahoma mills. All other variables in the model were assumed to be continuous.

Industry accounting data are often nonexistent, unreliable, or difficult to obtain (French). In accordance with Flores et al., this study uses an economic engineering approach to estimate and compare transportation, processing, and other costs associated with building and operating flour mills of different sizes. The economic engineering technique uses engineering coefficients for input-output relationships and applies relevant input costs and cost allocations to estimate total cost and revenue for plants of different sizes or types (Allen et al.).

All the cost and throughput data associated with mill construction and operation were obtained from the Flores et al. Mill Management
Economic Model (MMEM) and then adapted to the current study. Because the MMEM was based on one mill size (7000 cwt.), these data were also adjusted to meet the requirements of the other two mill sizes used in the current study. To account for inflation, cost data were updated to current prices using the US GDP deflator, 1995 base year.

Data on flour volume, quality, and type preferences were obtained through a survey of commercial food processing companies in Oklahoma. Another survey of Oklahoma shippers provided data on transportation rates. Average wheat production levels were computed using data from Oklahoma Agricultural Statistics publications for the period 1990-96 (Oklahoma Department of Agriculture). Therefore, the central components of the wheat processing plant location model include the Mill Management Economic Model (MMEM), results from the flour use survey, wheat production data by county, transportation costs from the phone survey of wheat and flour shippers, flour and wheat price data from the *Millling and Baking News*, wheat price data from Oklahoma Agricultural Statistics and mill feed prices (Figure 1).

**Figure 1. Flour Usage and Milling Potential Project Flow Chart.**
The primary use of the MMEM in this study was to produce estimates of the construction and operating costs of the three sizes of mills allowed to operate in the mixed-integer mathematical programming model. In addition to considering new mill locations based on the volume of local flour use, the model also considered expansion of the existing Oklahoma flour mills at estimated fixed costs less than those charged to new facilities. The model allowed existing mills to expand capacity or additional locations to build any one of the three mill sizes as long as the total costs associated with milling and wheat/flour/mill feed flows were minimized. Interstate trade was incorporated into the model by including out-of-state sources for each type of wheat and flour, based upon information obtained from Oklahoma bakers and millers.

Major Results and Implications

Survey Results

Forty-six commercial baking companies were surveyed, including all large bakers (over 10,000 cwt. annual flour usage) and many small (less than 1,000 cwt. annual flour usage) family-owned businesses. Through the mailings and follow-up telephone calls, information was received from 19 of the 46 companies (41% response rate). Respondents included all of the state’s large bakers and a few of the smaller businesses. However, many of the non-responding small businesses stated in telephone calls that their operations were too small to warrant inclusion in this study. Based upon the flour utilization estimates of the large bakers and the sizes of the non-responding small businesses, the survey captured well over 90% of the flour usage by Oklahoma bakers.

Although Oklahoma mainly produces HRW wheat, most food processors produce soft flour-based products. Cookies, for example, are the most commonly produced food items, produced in one form or another by approximately 24 percent of the respondents. In Figure 2, flour proportions by type of product are shown. The flour blends for each product indicate the divergence between the primary type of wheat produced in the state (HRW) and the predominantly soft red winter (SRW) wheat used by Oklahoma food processors (Figure 3).

Most of the commonly produced products have very high soft flour content. On aggregate, cookies from Oklahoma bakers are made almost solely of soft wheat flour. Quantitative data obtained from respondents also indicated that, out of about 2,830,000 cwt. total annual flour use, roughly 68% is soft wheat flour. Virtually all of this flour is purchased from out-of-state mills. Carthage, Missouri, was identified as a major source of soft wheat flour.
Figure 2. Main wheat producing counties and new flour mill distribution (Version I).

Figure 3. Counties transferring to 100% SRW production and suggested new flour mills (Version II).
These findings indicate the need to understand flour demand patterns when assessing milling potential as opposed to emphasizing the current wheat production of the state. Production of HRW wheat does not create a milling opportunity for wheat in Oklahoma. Use of SRW wheat flour may, however, create a potential milling opportunity in Oklahoma.

All respondents indicated that the levels of moisture, protein, and ash in the flour they purchased were important quality considerations. The acceptable ranges of these attributes were very small for individual firms, but across all respondents these factors ranged from 12.5-14% for moisture content, 8.5-14% for protein, and 0.48-1.60% for ash. Other factors such as sieve analyses, gluten content, spread factors, and new-to-old crop wheat ratios, were also listed by different bakers.

As part of the survey, various service factors of flour suppliers were also given importance ratings by the survey respondents. Ratings were determined by way of a Likert scale, with 1 representing “Not Important,” 6 representing “Very Important” and 2-5 representing varying levels of importance. “Consistency of flour quality” and “freshness of flour” were recognized by all respondents as being “Very Important.” Likewise, “ability to produce desired quality” and “price level” were deemed especially important, with 87% and 75% of the respondents (respectively) valuing these attributes with a 6.

Respondents also were given the opportunity to make additional comments regarding factors important to their baking activities. Some of the comments received included:

1. A need for training of flour-based food manufacturers in new product development and marketing; and
2. A need to develop winter wheat varieties that give baking characteristics like hard red spring wheat: high protein levels which are generally used in frozen dough to give at least 120 days frozen shelf life.

These results also indicate the importance of understanding flour demand patterns when assessing milling potential as opposed to emphasizing only the wheat production side of the industry.

**Mathematical Programming Model Results**

Two versions of the mathematical programming model were run. In Version I, wheat production in Oklahoma was restricted to HRW wheat, the type of wheat currently grown in the state. As shown in Figure 2, while wheat is grown in nearly every county of the state, the main wheat producing regions are in Western and North Central Oklahoma. In Version II of the model, the model was allowed to ship either HRW or
SRW wheat from each production region by assuming that any portion of each county's wheat production could be transferred from HRW to SRW wheat. Version II was performed to determine if the increased production of SRW wheat in Oklahoma would greatly change the results from Version I. In both versions, all flour shipments from out-of-state mills were replaced with Oklahoma-milled flour.

The Version I results suggest that Oklahoma could expand current milling capacity by about 23% to serve the needs of existing flour users in Oklahoma. The best locations for any new wheat milling operations (Poteau and Chickasha) would be as shown in Figure 2, producing primarily soft wheat flour. These suggested locations coincide with flour needs of the largest Oklahoma baker, located near the eastern border of the state (Poteau), or the baking establishments in or south of the Oklahoma City metropolitan area (Chickasha). Furthermore, the model suggests constructing two different sizes of mills, one medium-sized mill operating at 80% capacity in Poteau and one small mill operating at full three-shift capacity in Chickasha (Table 1). Compared to the current situation, the results suggest that the cost of flour to end-users could be reduced by $1.66 per cwt. of flour (holding wheat prices constant). It is anticipated that competitive pressures would cause these savings to be shared by the miller, the wheat producer, and the flour end-user. That is, competitive pressures would tend to cause both flour prices to fall slightly and wheat prices to increase slightly, which would also put pressure on the millers' margins.

Experience suggests that the data may be overestimating the costs of transportation relative to the costs of mills, and judgement suggests that one mill operating with three shifts might be more realistic. The model was restricted to one location, and the results suggested one large mill operating at near full capacity (98.6%) in Chickasha, still providing 100% of both HRW and SRW wheat flour to all demand points. While this may seem contradictory to the unrestricted Version I model, which suggested a larger mill in Poteau than in Chickasha, this suggestion is the result of the transportation differences and the flour demand points. The suggested Chickasha mill, while not close to the state's largest baker in Poteau, is close to the state's second largest baker and several bakers in Central and South Central Oklahoma (Oklahoma City, Norman, Lawton, and Marietta). This one mill would provide hard, soft, and hard-and-soft flour blends to baking establishments in these two areas of the state, while also providing hard and soft wheat flour to Eastern and Northeastern Oklahoma. Additionally, placing a mill in Chickasha provides the transportation advantage of being near the larger HRW wheat production regions of the state.

The one-mill solution generated about 94% of the savings found in the two-mill solution. Because Oklahoma produces very little soft
Table 1. Optimal Flour Mill Locations, Mill Sizes, and Flour Shipments (cwt., by wheat/flour type) to Demand Points.

<table>
<thead>
<tr>
<th>Demand Points</th>
<th>Optimal Mill Locations (Version I)</th>
<th>Optimal Mill Locations (Version II)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poteau (Medium)</td>
<td>Chickasha (Small)</td>
</tr>
<tr>
<td></td>
<td>HRW</td>
<td>SRW</td>
</tr>
<tr>
<td>Tulsa</td>
<td>18,327</td>
<td>141,240</td>
</tr>
<tr>
<td>Oklahoma City</td>
<td>62,400</td>
<td>2,500</td>
</tr>
<tr>
<td>Lawton</td>
<td>25,391</td>
<td>337,340</td>
</tr>
<tr>
<td>Norman</td>
<td>50,000</td>
<td></td>
</tr>
<tr>
<td>Marietta</td>
<td>1,150,000</td>
<td>214,000</td>
</tr>
<tr>
<td>Vinita</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poteau</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Flour Shipments</td>
<td>1,218,327</td>
<td>936,000</td>
</tr>
<tr>
<td>Total Annual Capacity</td>
<td>1,529,800</td>
<td>936,000</td>
</tr>
<tr>
<td>Percent Capacity Used</td>
<td>80%</td>
<td>100%</td>
</tr>
</tbody>
</table>
wheat, 2.6 million bushels of soft wheat needed by the end-users would have to be shipped into Oklahoma and then processed. Thus, while out-of-state flour purchases would cease, Oklahoma would need to ship in SRW wheat each year from out-of-state sources to use in the mills.

Because the volume of additional wheat milled in Version I is roughly 1.5% of the current total wheat production, one would anticipate little upward wheat price pressure created by the additional milling. It is possible, though, that some producers willing to produce specific varieties and qualities of wheat for a mill could receive a premium. The potential decrease in the cost of flour to end-users should provide sufficient motivation for consideration of milling investment in Oklahoma.

In Version II, the 2.6 million bushels of soft wheat needed to meet the flour needs of existing Oklahoma processors were “allowed” to be grown in Oklahoma. These results suggest that SRW wheat would replace HRW wheat in the Southeastern quadrant of Oklahoma. Figure 3 shows the counties that the model included as SRW wheat producing regions when allowed to choose the least cost production/processing/shipping pattern. Figure 3 also depicts the least cost locations of the three small mills suggested by the Version II solution: Catoosa (Arkansas River port in Northeastern Oklahoma), Poteau (near the Oklahoma/Arkansas border), and Ardmore (South Central Oklahoma).

This solution is contingent on SRW wheat varieties having equivalent yields of both grain and pastures or that sufficient discounts or premiums are paid for SRW wheat. Some areas of Oklahoma currently have producers planting SRW wheat, but only for its superior winter forage production. Virtually none of those soft wheat acres are harvested for grain.

Version II suggests that, given additional milling capacity and SRW wheat production in Eastern Oklahoma, the cost of flour delivered to mills could be reduced by $2.82/cwt. (holding wheat prices constant). Again, competitive pressures would cause the savings to be shared by the wheat producers, flour millers, and end users. The increase in processing would represent less than 3.3% of a normal Oklahoma crop and therefore would not be expected to cause considerable upward wheat price pressure. However, it is possible that wheat prices could be increased for producers with the quality and variety needed by the mills.

As with the Version I model, the Version II model was restricted to suggest one mill. Once again, the addition of one large mill to the state is probably more realistic than the addition of three small mills. As with the Version I findings, the model suggested the addition of one large mill operating at 98.6% capacity. Also, the one-mill solution was slightly less cost efficient than the three-mill solution. However, the suggested location for the one large mill was in Catoosa, not Chickasha. The
difference is due to the change in location advantages resulting from increased SRW wheat production in Eastern Oklahoma. As with the one-mill solution from Version I, this large mill would mill both HRW and SRW wheat, meeting 100% of the flour needs at all demand points.

Conclusions and Implications

The survey of wheat flour users in Oklahoma suggests that an excess demand for flour exists in Oklahoma. Most processors in Oklahoma require soft or soft-and-hard wheat flour blends for manufacturing their products, especially cookies and crackers. These flour needs are currently being met by out-of-state suppliers.

The plant location modeling results suggest that there is potential for expanding wheat milling in Oklahoma by as much as 23% if acceptable SRW wheat flour is produced in the state. Milling industry growth could come in the forms of expanded existing mills or new mills specifically designed to meet the needs of end-users. Expanded milling becomes even more likely if growth continues in Oklahoma’s value-added wheat products industry and if SRW wheat becomes more readily available from sources in Oklahoma. Clearly, the results suggest that vertical market linkages are crucial in determining whether additional milling capacity in Oklahoma is feasible. Any individual or group considering a new milling venture will want to pursue quantity- and quality-based contracts with interested end-users prior to initiating investment in milling operations.

References


