OPTIMIZATION OF WHEAT AND FLOUR BLENDING FOR COST MINIMIZATION BY USING MATHEMATICAL MODELLING[1]

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Abstract: Flour producer produce flour by mixing different wheat having different quality characteristics grown in different region. The wheat grown under different environmental conditions may have variable quality characteristics. This variation occurs on the basis of region and time period. However, producer must blend the wheat having different quality characteristics to produce flour with constant/standard quality in order to satisfy customer. In addition, it is necessary to blend different flours and add additives in order to provide specific flours. Although blending of wheat and flour is an everyday process for the flour producer to produce desired quality flour, the blending process is usually far from the optimization. It depends on mainly the experience of the flour producer. In other words, this blending process is carried out by trial / error method. However, the optimization methods providing optimum blending for cost minimization exist. In this study, the flour mill located in Samsun have been investigated and based on the mill working conditions, a mathematical model was developed for the wheat and flour blending problem. An interface has been developed to solve the developed mathematical model using MS Excel Solver. When the desired wheat and flour properties are entered to the created interface, the solution will be found with the established model and the lowest cost mixing ratio will be obtained. As a result of this implementation, it has been observed that this approach reduces the company's costs by 5-10% per day.

Keywords: Blending, Flour production, Integer programming, Excel solver, Optimization

Jel Codes: *C00, C02*

1. INTRODUCTION

Flour, which is the main source of human nutrition, is obtained by grinding wheat grains. Flour with different quality properties is obtained by adding additives in the flour depending on the purpose of use (bread, dessert, etc.). The quality of the obtained flour varies depending on used the characteristics of the wheat and the additives (gluten,

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ascorbic acid, type-2 of enzyme mixture). Although the characteristics of additives added to flour are constant, the characteristics of wheat depend on both region and production season. It also has different characteristics within the region. However, the characteristics of the used flour must be constantly constant. For this reason, flour producers try to obtain flour by mixing wheat with different characteristics. Mixing wheat with each other is one of the standard processes daily in flour mills, but this process is far from optimal and entirely depends on the experience of the person in charge.

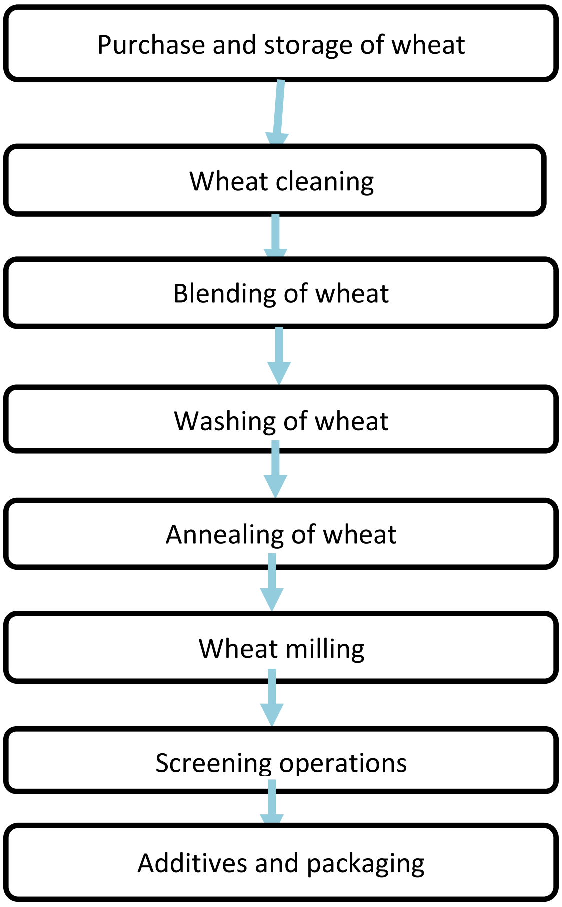
Flour production and consumption of flour products are continuous. However, wheat used in flour production is not available continuously and has different quality characteristics. It is necessary to mix (blend) the wheat continuously to obtain standard flour from wheat of different quality specifications. The price of wheat should also be considered when this process is carried out. Generally, high-quality wheat is more expensive, and low-quality wheat is cheaper. This situation also depends on the availability of wheat. Flour producers desire wheat input costs to be at minimum levels. By using the available data in this, a blending model should be established to minimize the total cost.

The aim of this study is to create a linear programming model that will mix the different quality wheat and provide the mixture with the minimum cost to get the flour in the desired quality. The linear programming model is widely used in the analysis of problems related to optimum distribution of resources. Linear programming is used both before and after systems are installed in the analysis and follow-up of the system (Bazaraa et al., 1990; Hillier and Lieberman, 1990; Ozturk, 1998; Taha, 2000). Studies on the wheat blend have been made predominantly in relation to obtaining the final flour. In these studies, the additives used when predominantly obtaining final flour were also investigated. (Sarkar, 1998) modeled the flour mixture for final users and (Hayta et al., 2001) analyzed the additives for the blends required for bread flour making. (Stefann, 2012) has developed a linear programming model that will minimize the total cost for flour obtained by adding additives. A similar approach was used in this study, in which local wheat mixtures were considered.

2. FLOUR PRODUCTION PROCESS

The flour production process is generally as given in Figure 1.

Figure 1. Process of Obtaining Flour from Wheat



The wheat which is delivered to the factory by the producers is firstly analyzed and checked for suitability. Suitable wheat is emptied into separate storage depending on its characteristics. First of all, wheat is divided into two main groups as hard wheat and soft wheat. Then the wheat to be added to the blending process is cleaned and separated from the foreign materials in it. The cleaned wheat is blended (mixed) so that the flour can be obtained as desired. Blended wheat is washed with water, then annealed for drying. For tempering, hard wheat is kept for about 18 hours and soft wheat for about 12 hours at 40-46 ° C. The annealed wheat is transferred to grinding process. Wheat is passed through the mills and sieves at different stages until the flour is obtained. Finally, the flour is obtained, packed and stored in the desired quantity by adding the additive in different amounts.

3. MATERIAL AND METHODS

In this study, the real data of a flour factory was used. However, information is not given about the company within the confidentiality principles of the company. Wheat, which is supplied from different regions in the plant, is used for flour production in this factory. The characteristics of these flours are given in Table 1.

Table 1. The Characteristics of Different Flours

Name of flours (S_{ij})	Humidity	Gluten	Gluten Index	Sedimentation	Delayed Sedimentation	Falling Number
Anadolu Ata	14,5	28,5	90	35	45	250
Anadolu Doğadan	14,5	25,5	70	35	45	250
Ekamaks	14,5	30,5	95	50	60	350
Hasattan Tam Buğday	14,5	25	60	20	30	250
Maksimus	14,5	28,5	70	30	40	250
Mavi Lüx	14,5	25,5	80	35	45	250
Pizzamiks	14,5	30,5	95	45	55	350
Plus 1	14,5	28,5	90	40	50	250
Plus 2	14,5	28,5	85	35	45	250
Plus 61	14,5	28,5	85	35	45	250
Plus Max	14,5	27,5	80	35	45	250
Plus Pide	14,5	27,5	80	35	45	250
Plus Tandır	14,5	26,5	75	25	35	250
Plusslim	14,5	30,5	90	40	50	350
Simimix	14,5	28,5	90	35	45	250

The minimum values specified in the wheat mixture are determined by the customer in the flour mixture. Therefore, constant change is the issue. There is a column to enter the minimum values in the interface created by considering this change.

3.1. Mathematical Model

Mathematical modeling of wheat blending problem occurs in three steps. In the first step, decision variables are defined. In the second step, the objective function of the problem is defined. In the third step, the constraints to achieve the desired goal are determined and these constraints are expressed as equality or inequality. These steps are also valid in the mathematical model for the mixture of flour.

3.1.1. Decision Variables

Decision variables refer to preferences. Two different decision variables are defined since there are two different models for this problem. Decision variables are the percentage of wheat in the mixture in silo and the percentage of flour in the mixture in silo.

Decision variables for wheat mixture;

X_i *: The percentage of wheat in the mixture in silo (%)*

i: 1,…,n (wheat variety)

Decision variables for flour mixture:

X_i *: The percentage of flour in the mixture in silo (%)*

i: 1,…,n (flour variety)

3.1.2. Objective Function

The objective function is the function that the decision maker wants to optimize (minimize or maximize). The aim is to minimize the cost of wheat and flour mixtures in the flour factory.

$$\min Z = X_1C_1+X_2C_2+X_3C_3+X_4C_4+X_5C_5+X_6X_6$$

Here;

c_i *: i^{th} unit price of wheat or flour (TL/ton)*

3.1.3. Constriants

The constraints of the model are the factors that prevent variables from being freely valued.

The constraints required for the wheat mixture are:

- Humidity (%)

$$P_{11}X_1 + P_{21}X_2 + P_{31}X_3 + P_{41}X_4 + P_{51}X_5 + P_{61}X_6 \leq S_{i1}D$$

- Gluten (%)

$$P_{12}X_1 + P_{22}X_2 + P_{32}X_3 + P_{42}X_4 + P_{52}X_5 + P_{62}X_6 \geq S_{i2}D$$

- Gluten Index (%)

$$P_{13}X_1 + P_{23}X_2 + P_{33}X_3 + P_{43}X_4 + P_{53}X_5 + P_{63}X_6 \geq S_{i3}D$$

- Sedimentation (cc)

$$P_{14}X_1 + P_{24}X_2 + P_{34}X_3 + P_{44}X_4 + P_{54}X_5 + P_{64}X_6 \geq S_{i4}D$$

- Delayed sedimentation (cc)

$$P_{15}X_1 + P_{25}X_2 + P_{35}X_3 + P_{45}X_4 + P_{55}X_5 + P_{65}X_6 \geq S_{i5}D$$

- Falling Number (s)

$$P_{16}X_1 + P_{26}X_2 + P_{36}X_3 + P_{46}X_4 + P_{56}X_5 + P_{66}X_6 \geq S_{i6}D$$

- Quantity

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 = 100$$

- Positivity and Integer Constraint

$$X_1, X_2, X_3, X_4, X_5, X_6 \geq 0 \ and \ integer$$

The constraints required for the flour mixture are:

- Humidity (%)

$$P_{11}X_1 + P_{21}X_2 + P_{31}X_3 + P_{41}X_4 + P_{51}X_5 + P_{61}X_6 \leq S_1D$$

- Gluten (%)

$$P_{12}X_1 + P_{22}X_2 + P_{32}X_3 + P_{42}X_4 + P_{52}X_5 + P_{62}X_6 \geq S_2D$$

- Gluten Index (%)

$$P_{13}X_1 + P_{23}X_2 + P_{33}X_3 + P_{43}X_4 + P_{53}X_5 + P_{63}X_6 \geq S_3D$$

- Sedimentation (cc)

$$P_{14}X_1 + P_{24}X_2 + P_{34}X_3 + P_{44}X_4 + P_{54}X_5 + P_{64}X_6 \geq S_4D$$

- Delayed sedimentation (cc)

$$P_{15}X_1 + P_{25}X_2 + P_{35}X_3 + P_{45}X_4 + P_{55}X_5 + P_{65}X_6 \geq S_5D$$

- Falling Number (s)

$$P_{16}X_1 + P_{26}X_2 + P_{36}X_3 + P_{46}X_4 + P_{56}X_5 + P_{66}X_6 \geq S_6D$$

- Cinder (%)

$$P_{17}X_1 + P_{27}X_2 + P_{37}X_3 + P_{47}X_4 + P_{57}X_5 + P_{67}X_6 \geq S_7D$$

- Energy (BU)

$$P_{18}X_1 + P_{28}X_2 + P_{38}X_3 + P_{48}X_4 + P_{58}X_5 + P_{68}X_6 \geq S_8D$$

- Quantity

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 = 100$$

- Positivity and Integer Constraint

$$X_1, X_2, X_3, X_4, X_5, X_6 \geq 0 \ and \ integer$$

Here;

P_{ij} : i^{th} silo j^{th} value of the component

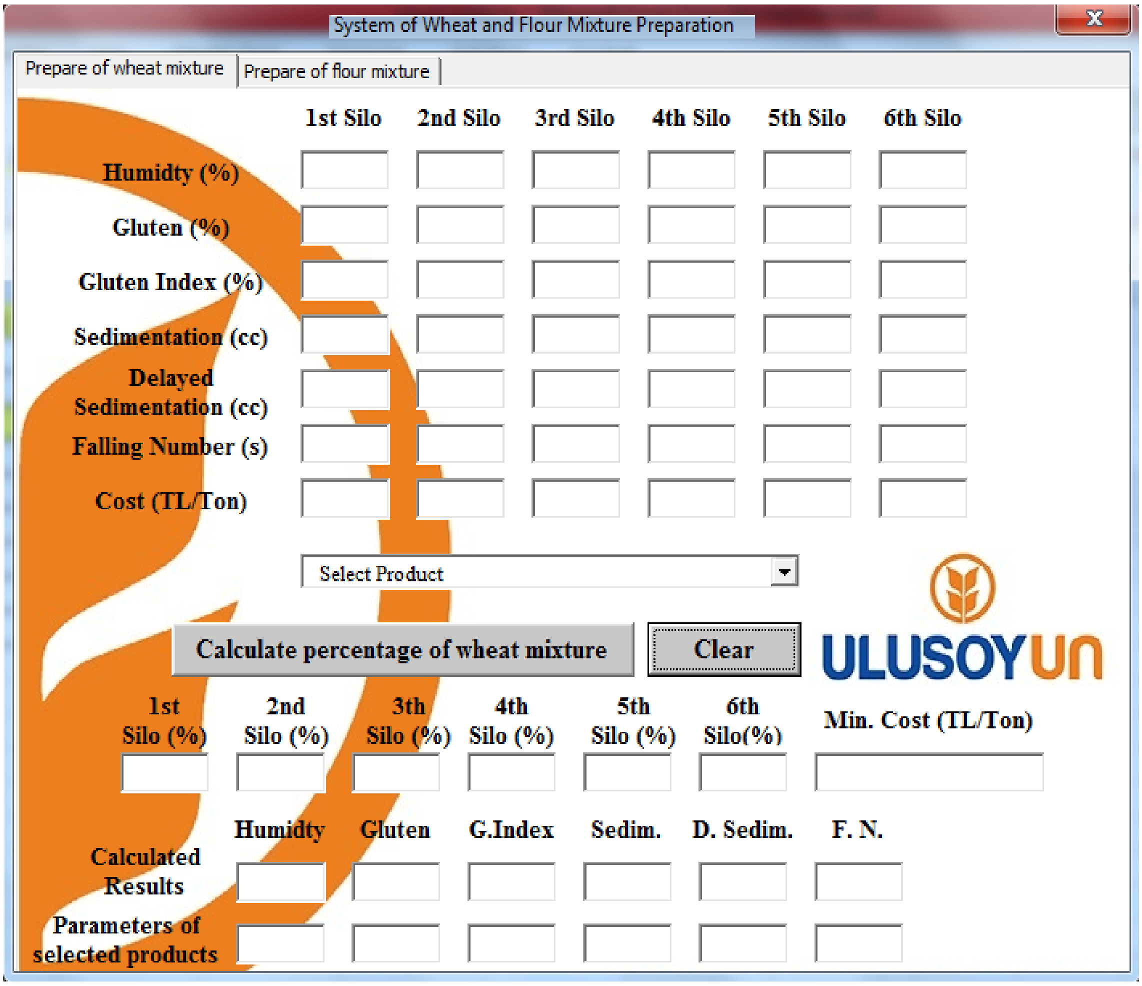
S_{ij} : i^{th} product j^{th} limit of value of the component

D : Quantity to mix

3.2. Problem Solution

The interface created by using Visual Basic in Microsoft Excel is an environment created to input user data and to see the results. It is foreseen that the users may be engineers, workers or foremen, and developed an easy-to-use interface in the sense that they are not experts in mathematical programming. The interface for the wheat mixture is as shown in Figure 2.

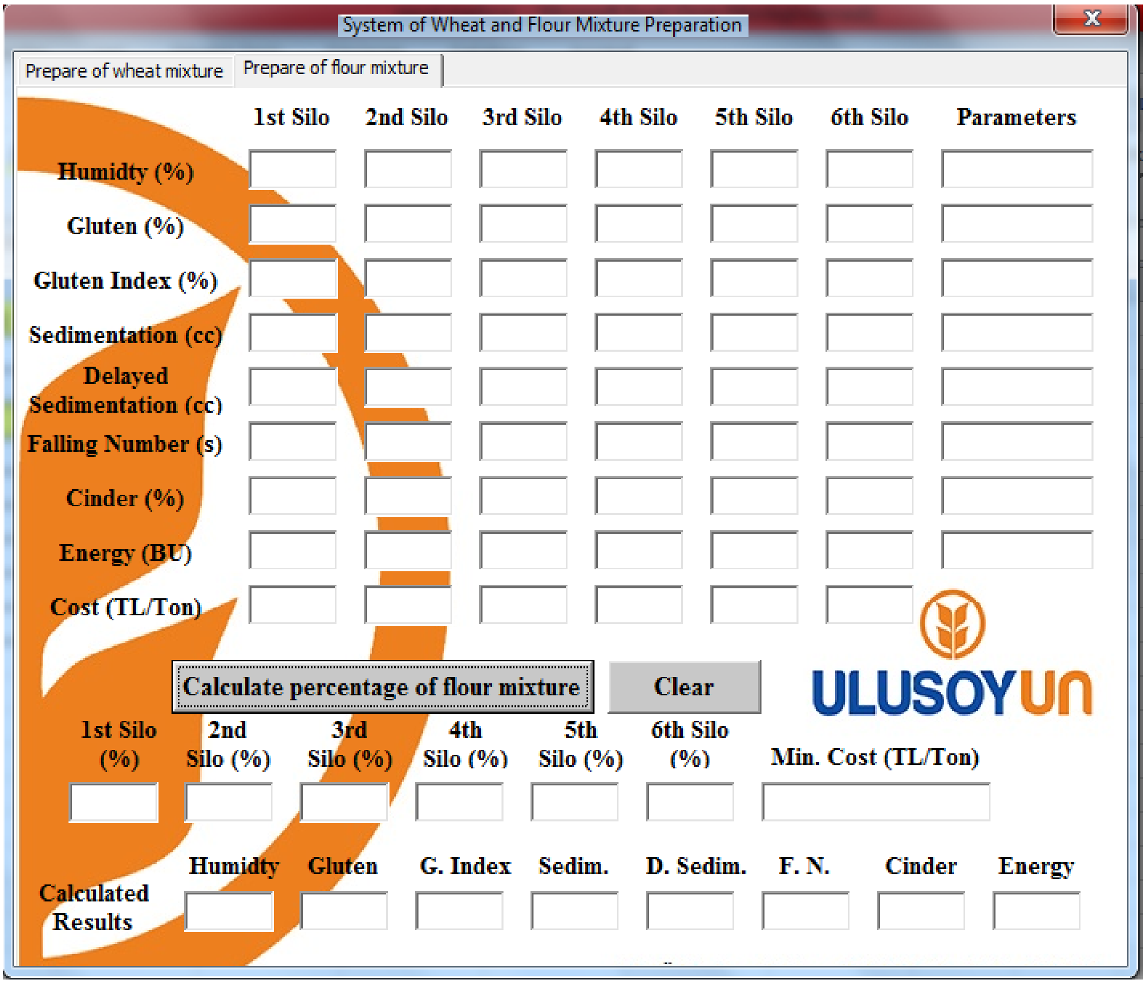
Figure 2: The Interface for the Wheat Mixture



At the interface shown in the Figure 2, the wheat parameters and the cost of the wheat are entered by the staff who will determine the mixing percentage. After selecting the product to be produced, the best mix percentages that provide the product values at the minimum cost will be included in the interface by clicking on the calculate percentage button. Mixing percentages are calculated using the Excel Solver. It is possible to make comparison by seeing calculated parameter values and product values in the interface. The interface for the flour mixture is as shown in Figure 3.

At the interface shown in the Figure 3, the flour parameters, desired parameter values of mixture result and the cost of the flour are entered by the staff who will determine the mixing percentage. After selecting the product to be produced, the best mix percentages that provide the product values at the minimum cost will be included in the interface by clicking on the calculate percentage button. Mixing percentages are calculated using the Excel Solver. It is possible to make comparison by seeing calculated parameter values and product values in the interface.

Figure 3. The Interface for the Flour Mixture



4. CONCLUSION

As it is known, the use of raw materials in the production sector leads to high costs in today's conditions. The extra profit will be provided if the minimization of excess raw material costs does not fall below the product values. It is the main goal to do these minimizations in order not to fall back from the competitive environment. This application is aimed to bring the lowest cost of raw material and flour mixture in the food sector.

The aim of the study is to show that mathematical optimization methods can be used to blend wheat for flour production. A very limited study has been done in the literature and in practice blending (blending wheat) is based on the experience of the operator instead of mathematical optimization methods. The study showed that the problem is a classic linear programming problem. However, the greatest challenge is to determine the parameters required for the study and to obtain sufficient information about these parameters. As soon as the parameters entering the system are determined, it will be possible to make more appropriate decisions according to changing conditions (price and wheat characteristics).

Also, it has been observed that this approach reduces the company's costs by 5-10% per day thanks to the created interface.

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