Applying A Genetic Algorithms Programming to Natural Cheese Products

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Abstract: - Model integrates cheese manufacturing has attracted considerable in recent years. Most modifications of Genetic Algorithms (GA) for solving optimization problems are to find some mathematical support to the GA. This paper applies genetic algorithms to achieve the parameters of the processed cheese products. The genetic algorithms are very suitable for searching discrete, noisy, multimodal and complex space. The economic evaluation of standaized milk for cheese making is given and the objective is to make the profit of the natural cheese. As recognized, exploitation of the optimization based on Genetic Algorithms gives advanced results.

Key-Words: Genetic Algorithms, Natural Cheese, Process, Optimization, Economic, Profit

1 Introduction
Cheese is one of the main products from milk in the dairy industry. Cheese manufacturing is essentially a Process of concentrating the protein(casein) and fats contained in milk by complicated microbial and biochemical reactions (Smith, 1996). The main steps in cheese manufacturing are: (1) the acidification of milk by the microbial conversion of lactose to lactic acid by lactic acid bacteria, (2) the coagulation of casein and fats by the combination of proteolysis using chymosin (rennet) and the acidication, (3) the dehydration and shaping of the coagulated casein and fats(curd), and additionally (4) maturing of the dehydrated curd as required [1].

Controlling the manufacture of these products for overall organization objective can lead to manufacturing efficiencies and to increased profitability for the organization [1, 9-11].

2 Genetic Algorithms
Genetic Algorithms (GA) is computationally simple and independent of any assumption about search space. GA is very suitable for searching discrete, noisy, multimodal and complex space. GA differ from other search or optimization algorithms. First, the algorithms work with a coding of the parameter set, not the parameters themselves. Binary coding is normally used and has been suggested to be optimal in certain cases. Secondly, the algorithms search from the population of points, climbing many picks in parallel, and therefore have a reduced chance of converging to optima. Thirdly, the algorithms only require object function values to guide their search, but they have no need for derivative or other auxiliary information. Finally, these differences contributed to a genetic algorithms’ robustness and resulting advantage over other more commonly used techniques [2-8].

3 Developing Model
An integrated process cheese manufacturing system combines two components: the conversion of raw materials into the output products of cheese, whey cream, and separated whey and the allocation of these intermediate products with other ingredients to achieve the pasteurized process cheese food product. In the example developed here, Table 1 lists some of the input resources that could be used in the manufacture of natural cheese. We will assume that Cheddar cheese is to be manufactured and some or all of it will be processed.
The Cheddar cheese is to be made with a fat on a dry basis (FDB) of 53.5%. This is accomplished by regulating the casein to fat ratio to be 0.6925. Moisture of the cheese is assumed to remain at 37%.

Table 1. Several input resources available for use in the manufacture of natural cheddar cheese.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Amount available</th>
<th>Fat %</th>
<th>Casein %</th>
<th>Cost/ pound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silo 1</td>
<td>300,000</td>
<td>3.55</td>
<td>2.44</td>
<td>0.1178</td>
</tr>
<tr>
<td>Silo 2</td>
<td>300,000</td>
<td>3.57</td>
<td>2.49</td>
<td>0.1181</td>
</tr>
<tr>
<td>NDM</td>
<td>As needed</td>
<td>1.00</td>
<td>28.00</td>
<td>0.79</td>
</tr>
<tr>
<td>Cream</td>
<td>As needed</td>
<td>45.0</td>
<td>1.39</td>
<td>0.80</td>
</tr>
<tr>
<td>Condense milk</td>
<td>As needed</td>
<td>0.37</td>
<td>9.20</td>
<td>0.228</td>
</tr>
<tr>
<td>Skim milk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The values used in the cheese yield formula are 1.09 salt solids retention factor, 93% fat retention, and 96% casein retention. It is assumed that the fat content of whey cream removed is 45%.

Whey fat is recovered at a rate of 100%. All of the raw milk is used for cheese production. The purchasable quantities of nonmilk resources is assumed to be immeasurable. Potential inputs for process cheese manufacture are listed in Table 2.

Table 2. Several input resources available for use in the manufacture of process cheese.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Fat %</th>
<th>Moisture %</th>
<th>Cost/ pound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cheese</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Determined by LP</td>
<td>37.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Whey protein concentrate</td>
<td>3.5</td>
<td>1.5</td>
<td>0.4825</td>
</tr>
<tr>
<td>Emulsifiers</td>
<td>0</td>
<td>0</td>
<td>0.535</td>
</tr>
<tr>
<td>Fat</td>
<td>83.0</td>
<td>17.0</td>
<td>1.53</td>
</tr>
<tr>
<td>Whey cream</td>
<td>45.0</td>
<td>55.0</td>
<td>0.78</td>
</tr>
<tr>
<td>Water</td>
<td>0</td>
<td>100.0</td>
<td>0.01</td>
</tr>
</tbody>
</table>

All of the manufactured cheese is either sold or processed. It is possible to divide the manufactured cheese, i.e., one-third can be sold and two-thirds processed or half sold and half processed. The value of the output products (cheese, whey cream, and separated whey) and the resources used for process cheese manufacture are related to the value of the final process cheese product. The end product is pasteurized process block cheese valued at a block wholesale price of $1.50/lb.

3.1 Decision Variables

The decision variables for the natural cheese manufacture are identified with the resources that may be used and the amount of cream that can be removed from a milk resource during a standardization [1]. Other variables are the direct inputs to the process cheese food.

3.2 Constraints

In the model presented here in the casein: fat ratio of the cheese milk is 0.6925. A summing up of contraints for this model could be found in Table 3. Studies have shown relationships between the casein: fat ratio in milk, manufacturing conditions, and the resulting FDB, moisture in the nonfatty substance (MNFS), and fat and moisture percentage in the cheese (20, 22). The greater control is needed when range is superior allowed during the manufacturing operation to maintain a consistent quality product. The general format for the constraint is:

\[
\frac{\text{Casein percentage of standardized milk}}{\text{fat percentage of standardized milk}} = 0.6925
\]

This ratio was chosen to establish the FDB of the natural cheese at 53.5%, which is the FDB of unstandardized milk in this example. Other ratios could be calculated from cheese yield formula:

\[
FDB = \frac{FR(F)}{[FR(F) + CR(C)]SR}
\]

where: \(FR = \text{fat retention percentage divided by 100, } F = \text{fat percentage of standardized milk, } CR = \text{casein retention percentage divided by 100, } C = \text{casein percentage of standardized milk, and } SR = \text{salt solids retention factor.}

The determination of final form of this constraint is considering all additions and subtractions separately from the cheese milk of casein and fat. (We may remove cream from the batch, for instance.)

The result for this case is:

Table 3. Constraints for the model.

1) \[0.0002x_1 + 0.0002x_2 + 0.2977x_3 + 0.2974x_4 + 0.2731x_5 + 0.0894x_6 - 0.2977x_7 \geq 0\]

\text{casein to fat ratio constraint}
Constraint 2. $x_1 = 300,000$ and $x_2 = 300,000$

Constraint 3. Use all milk constraints

Constraint 4. $0.0789x_1 - x_3 \geq 0$ and $0.0793x_2 - x_4 \geq 0$

These two constraints limit the amount of cream that could be removed from the two milk resources.

Constraint 5. There must be a constraint to maintain the amount of cheese removed is:

$0.078x_1 \geq x_3,$

and rearranged:

$0.078x_1 - x_3 \geq 0.$

Constraint 6. The whey cream by-product resulting from the cheese manufacture is:

$WF = \frac{(F - FR(F)) \times WFR}{WF}$

where: $WF = \text{fat percentage of whey cream divided by 100,}$

Constraint 7. There must be a constraint to maintain the certain amount of cheese is the rocess cheese blend. The total process cheese batch is represented by $P$, where:

$P = M + B1 = B3 + B5 + y3 + y4 + y5 + y6.$

The same format would be used for constraining the casein:fat ratio between two limiting values. The optimum casein:fat ratio is that which maximizes the net return of the processed cheese product. A manufacturer might test several different casein:fat ratios to ascertain the impact different fat cheese have on the final processed product.
Constraint 8. It is assumed that the process cheese batch size is known and constant. Thus $P = \text{batch size of process cheese blend}$.

Constraint 9. The amount and type of emulsifiers used for processing must be incorporated into the program in a similar manner as that done for cheese (Constraint 7).

Constraint 10. WPC is a supplement to the raw cheese and is generally accepted for its lower cost and the improved sensory qualities it could impart to the final process cheese food product. Because sensory qualities can be adversely affected by too much WPC, limits must be set (24). Management and experience play a major role in deciding the quantity to be used. In this example, WPC is limited to less than or equal to 10% of the total batch, where $y_4$ is pounds of WPC.

$$y_4 \leq 0.10P$$

Constraint 11. The moisture in the process cheese product must be constrained to comply with the equal standards of identity and the characteristics of the product as set by management. Because moisture adds to the yield of the product with next to no cost, the LP model will add as much moisture as it is allowed by the constraints. Therefore, only an upper limit constraint is needed. To ensure the final product has less than or equal to the legal moisture of 43% requires the following constraint:

$$0y_3 + .15y_4 + .17y_5 + 1.0y_6 + .55z_1 + .37B_1 + .36B_3 + .35B_5 + .37M \leq .43P.$$  

Constraint 12. Another constraint is necessary to ensure the fat content of the process cheese food meets the standard of identity for the specific product. Pasteurized process cheese foods must contain at least 23% fat. An extra 1% is added for a safety margin. The general inequality is:

pounds fat in process cheese $\geq .24$ (total process cheese batch).

Constraint 13. A constraint on the allowable solids content of the raw milk used for cheese making has been included in this model [labeled (*)]. This has been done for several reasons. If milk concentrated by reverse osmosis or ultrafiltration is used, it is necessary to set a limit on the solids content of the cheese milk. Using reverse osmosis, Barbano and Bynum (1, 7) have shown that at about a 15% reduction in volume (about 14.17% solids content), the increased lactose of the cheese may become the limiting factor in producing a good quality aged Cheddar cheese. They also go on to say that a low moisture barrel cheese used within 60 d may tolerate a reduction in volume of greater than 15%.

Constraint 14. Finally, there are several constraints that must establish the acceptable age blends used in the processed cheese product. These age blends may be set as absolute or given as a range. For example, an absolute age blend could consist of 60% 1-mo-old cheese, 30% 3-mo-old cheese, and 10% 5-mo-old cheese. Alternately, an acceptable range could be 50 to 60% 1-mo-old cheese, 20 to 35% 3-mo-old cheese, and 15 to 20% 5-mo-old cheese. The advantage of a range of values is that it allows some flexibility in the program depending on cost, availability, grade of cheese, etc.

Thus, the 1-mo-old cheese, $M$ and $B_1$, could be greater than 50% but less than 60% of the total cheese used in processing.

Rewritten:

$$M + B_1 \geq .5 (M + B_1 + B_3 + B_5)$$

$$M + B_1 \leq .6 (M + B_1 + B_3 + B_5)$$

Likewise,

$$B_3 \geq .2 (M + B_1 + B_3 + B_5)$$

$$B_3 \leq .35 (M + B_1 + B_3 + B_5)$$

and

$$B_5 \geq .15 (M + B_1 + B_3 + B_5)$$

$$B_5 \leq .20 (M + B_1 + B_3 + B_5).$$

3.3 Objective function

The objective function is to maximize the net returns of a pasteurized process cheese product. Net return is defined as the difference between revenue and cost.

2.3.1 Net Process Cheese Profit. The process cheese batch is represented by the following equation:

$$M + B_1 + B_3 + B_5 + Y_3 + Y_4 + Y_5 + Y_6 + Z_1$$

If the selling price of block process cheese is $1.50/lb. the expression gives the revenue from its sale:

$$1.50 (M + B_1 + B_3 + B_5 + Y_3 + Y_4 + Y_5 + Y_6 + Z_1)$$

The ingredient costs for the processing materials are just their purchase prices. Whey cream produced from the Cheddar cheese manufacturing
process has a "cost" value calculated from its foregone fat revenue. If whey cream fat is valued at $1.73/lb and 45% of the cream is fat, then:

$1.73/lb. fat * .45 fat in cream = $.78 (value of fat/lb, cream)

The expression representing the cost of the processing ingredients is:

$.535y3 + .4825y4 + 1.535y5 + .01y6 + .78zl.

The direct labor and overhead cost estimate is based on total pounds of process cheese produced. It is necessary to include these costs because process cheese production and natural cheese production are separate operations requiring different equipment, facilities, and labor. The inclusion of the labor and overhead estimate is written as:

$.35 (M + B1 + B3 + B5 + Y3 + Y4 + Y5 + Y6 + Z1).

Combined, this part of the objective function is written as:

1.15M + 1.15B1 + 1.15B3 + 1.15B5 + .615y3 + .6675y4 - .38y5 + 1.14y6 + .37zl.

2.3.2 Cost to Manufacture Natural Cheese. The cost to produce Cheddar cheese was not included directly in the profit from processed cheese to allow for the option of selling the manufactured cheese or processing it. There are the ingredients costs to consider as well as the direct labor and overhead that go into the manufacturing operation. The sweet cream represented by x3 and x4 have positive "costs" since any cream removed and sold is revenue (18). The sweet cream fat is valued at

$1.82/lb with 45% fat in the cream.

$1.82/lb fat * .45 fat in cream = $.82 (value of fat/lb cream)

Direct labor and overhead costs are calculated on the total pounds of natural cheese produced, whether sold or processed.

.11278x1 + .1181x2 - .8x3 - .8x4 - .79x5 + .228x6 + .82x7 + .25 (M+ S).

2.3.3 Cost to Buy Natural Cheese. Cost values are based on the estimated cost to buy Cheddar cheese of varying ages:

1.51B1 + 1.55B3 + 1.59B5.

2.3.4 Revenue from Natural Cheese (and Whey Cream).

1.49S + .78z2

Note that the sold cheese [S] value is $.02 less than the 1-mo-old cheese that could be purchased. It is assumed that it costs more to buy than is gained through sale of similar products. The objective function to be maximized is a combination of all four components:

-.1178x1 - .1181x2 + .8x3 + .8x4 - .79x5 - .228x6 - .82x7 + .615y4 + .6675y4 - .38y5 + 1.14y6 + .37zl + 1.24S + .9M - .36B1 - .4B3 - .45B5.

4. Results

Results of applying genetic algorithms to the model described are presented in Tables 4. There are several underlying assumptions common to the scenario. First is that all raw milk resources are used in their entirety to make natural Cheddar cheese. A second assumption is that there is no waste. Third, the process cheese batch size is known and constant. Fourth, all ingredients are of known quality and composition and there is no problem with availability. Fifth, marginal revenue and costs are not applicable over the stated batch sizes. The optimum input resources to maximize the profits of the process cheese manufacturing operation, their amounts and some costs are listed in Table 4.

Genetic Algorithms gives an economic evaluation of standardizing milk for cheese making. The objective is to maximize the profit of the natural cheese. The constantly changing economic environment regularly influences the optimal solution to the model. A small change in the cost of an input resource can dramatically change the optimal solution. An important question is how sensitive the solution is to these changes. It is important to know how close the unused decision variables (those held a value 0) came to be included in the optimal solution. If using a resource corresponding to a decision variable is obviously not profitable, then little extra effort is needed to accurately estimate its cost. Conversely, if a small
change in a decision variable results in a new optimal solution, that decision variable and the constraints limiting its use should be analyzed.

Table 4. The optimum formulation and profit potential that results from modeling the natural cheese operation.

<table>
<thead>
<tr>
<th>Natural cheese input resources</th>
<th>GA Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>x1 = Silo 1 milk</td>
<td>300,000</td>
</tr>
<tr>
<td>x2 = Silo 2 milk</td>
<td>300,000</td>
</tr>
<tr>
<td>x3 = Remove cream</td>
<td>0</td>
</tr>
<tr>
<td>x4 = Remove cream</td>
<td>0</td>
</tr>
<tr>
<td>x5 = NDM</td>
<td>0</td>
</tr>
<tr>
<td>x6 = Condition skin</td>
<td>0</td>
</tr>
<tr>
<td>x7 = Cream</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Process cheese input resources</th>
<th>GA Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>y3 = Emulsifier</td>
<td>3,000</td>
</tr>
<tr>
<td>y4 = WPC</td>
<td>9,382</td>
</tr>
<tr>
<td>y5 = Fat</td>
<td>329</td>
</tr>
<tr>
<td>y6 = Water</td>
<td>17,288</td>
</tr>
<tr>
<td>z1 = Whey cream used</td>
<td>0</td>
</tr>
<tr>
<td>z2 = Whey cream sold</td>
<td>3,322</td>
</tr>
<tr>
<td>M = Manufacturing cheese</td>
<td>58,935</td>
</tr>
<tr>
<td>S = Cheese sold</td>
<td>16,935</td>
</tr>
<tr>
<td>B1 = Purchased cheese, 1 mo.</td>
<td>0</td>
</tr>
<tr>
<td>B2 = Purchase cheese, 3 mo.</td>
<td>17,500</td>
</tr>
<tr>
<td>B3 = Purchase cheese, 5 mo.</td>
<td>10,500</td>
</tr>
<tr>
<td>Total processed batch size, lb</td>
<td>100,000</td>
</tr>
<tr>
<td>Cheddar cheese yield, lb</td>
<td>58,935</td>
</tr>
<tr>
<td>Total Cheddar cheese cost</td>
<td>$ 85,522</td>
</tr>
<tr>
<td>Cost/lb Cheddar cheese</td>
<td>$ 1.4511</td>
</tr>
<tr>
<td>Objective function value</td>
<td>$ 4,365</td>
</tr>
</tbody>
</table>

5. Conclusion

The model is a guideline to assist in decision making. Its assumptions and solutions must be regularly tested as economic and manufacturing conditions change. Human judgment is needed to evaluate the proposed solution and adjust it to the specific situation.

This paper illustrates the genetic algorithms to estimate parameters of the natural cheese process. The obtained parameters from genetic algorithms are investigated. GAs efficiently exploit past information to explore new regions of the decision space with a high probability of finding improved performance.

References: