Changes in electrical energy requirements to operate an ice cream freezer as a function of sweeteners and gums

D. E. Smith, A. S. Bakshi, and S. A. Gay
Department of Food Science and Nutrition
University of Minnesota
1334 Eckles Avenue
St. Paul 55108

ABSTRACT

Changes in electrical energy required to operate a continuous freezer were monitored for various ice cream formulae. Ice cream formulae consisted of nine different combinations of sucrose, 36 DE corn syrup, and 42 high fructose corn syrup as well as two ratios of guar gum to locust bean gum. Within the same sweetening system, a mix high in locust bean gum tended to have a lower energy demand than mix with large amounts of guar gum. This was especially pronounced in mixes with 50% 42 high fructose corn syrup and/or 50% 36 DE corn syrup solids.

INTRODUCTION

When changing an ice cream formula, numerous factors need to be taken into account: cost of ingredients, effect on product quality, alterations in processing methods, and changes in electrical energy costs needed to process the product. The order listed is the one in which these items are usually considered, not necessarily because of importance, but because of the ease by which a comparison can be made between formulae. Cost analysis can be done quickly by calculating amount and cost of ingredients in one formula versus another. Alteration of product quality can usually at least be guessed from information available from the ingredient supplier. Methods to calculate the freezing point of the mix have been reported by Keeney (6) and Bradley and Smith (3). It is believed that the lower the freezing point of mix, the greater the tendency of the product to be icy, the more susceptible the product to heat shock and, thus, the more rapid the loss of quality. Cottrell et al. (4, 5) reported the effect on product quality of changes in stabilizer. Flow characteristics of three sweetener systems with five levels of whey substitution for nonfat dry milk solids were reported by Smith et al. (8). This information can be helpful in the calculation of pumping requirements for ice cream mix.

Assessment of changes in ingredients as they affect electrical energy required to process the ice cream mix is only rarely mentioned in the literature. It would be useful to know how ingredient substitution causes changes in the energy needed to run the freezer. Tracy and McGown (9) did show, in their 1934 work, how corn syrup solids altered the hardening rates of the products. No information is available on how energy required to run the freezer is affected by changes in ingredients.

The objective of this research was to determine if changes in sweeteners and/or stabilizers would result in changes in the electrical energy needed to move the product in a freezer.

MATERIALS AND METHODS

Mix Composition and Processing

Twenty-four 65-kg batches of ice cream were made containing nine combinations of three different sweeteners: sucrose, 36 DE corn syrup (36 DE CSS), and 42 high fructose corn syrup (42 HFCS), as listed in Table 1, and two different ratios (50:50 and 25:75) of a constant total amount of guar gum and locust bean gum. Mix 3 was produced seven times to determine variability in mix processing and data measuring procedures. The overall mix composition was as follows: milk fat, 10.2%; milk solids-nonfat, 10.0%; sweetener, 17%; carrageenan, .015%; guar and locust bean gum, .15%; emulsifier, .10%; water, 62.55%. Milk fat and total solids

Received July 13, 1984.
TABLE 1. Composition of mixes used to sweeten ice cream.

<table>
<thead>
<tr>
<th>Mix</th>
<th>% of Sweetener1</th>
<th>% of Sweetener1</th>
<th>% of Sweetener1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sucrose (1)</td>
<td>36 DE CSS (2)</td>
<td>42 HFCS (3)</td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>45</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>70</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>35</td>
<td>40</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>8</td>
<td>25</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>9</td>
<td>50</td>
<td>50</td>
<td>0</td>
</tr>
</tbody>
</table>

1 36 DE CSS = 36 DE corn syrup, 42 HFCS = 42 high fructose corn syrup.

of the mixes were determined by Mojonnier analysis (2) and Association of Official Analytical Chemists oven method (1), respectively.

After mixing the ingredients, each mix was pasteurized at 68.5°C for 30 min, homogenized (13,890 kPa first stage and 3550 kPa second stage) and cooled. Following approximately 3 h of storage, mixes were frozen to an overrun of 100% in a Cherry Burrell continuous freezer. Mix inlet temperature was 9.6 ± .9°C, and the freezer was adjusted to a draw temperature of −4.6 ± .3°C for each mix. Rate of processing mix through the freezer was 2.27 ± .1 kg/min.

Energy Determinations

The electrical energy required mechanically to operate the freezer was determined by a power meter wired into the electrical supply line to the freezer. A schematic diagram of the monitoring system is shown in Figure 1. Number of revolutions of the plate (one revolution equals 3 Wh) in the power meter were recorded by the revolution counter (modified calculator) attached to the power meter. For this study, time required for four revolutions of the plate was recorded as was the amount of product processed in that time. From these data, joules per 1000 kg of mix were calculated. The standard deviation for power demand was ±220 kJ/1000 kg of mix.

RESULTS AND DISCUSSION

In Figure 2 are presented the calculated electrical energy requirements in kilojoules/1000 kg of mix needed to move mixes through the freezer.

In comparing mixes with the same sweeteners, mix containing large amounts of locust bean gum relative to guar gum generally requires less energy to run the freezer (Figure 2). This finding can be explained from the work of Wallingford and Labuza (10), who reported that guar gum has about four times the water-binding capacity of locust bean gum. A greater water-binding capacity would tend to increase the effective radius of the molecule and cause a more viscous product. Increased viscosity...
would in turn result in a greater energy demand.

The tendency of high levels of locust bean gum to produce a lower energy demand is even more pronounced if only those mixes containing 50% 42 HFCS or 50% 36 DE CSS are considered. Among these mixes, differences between gum systems range from 1297 to 1374 kJ/1000 kg. A possible explanation is that higher 42 HFCS and 36 DE CSS alter the overall mix structure. This alteration affects the gums' behavior to the extent that differences in energy input become apparent. From acoustic data for sugar solutions (7) and previously published work on the effects of various sweeteners on the viscosity of ice cream mix (8), it is known that fructose and glucose “structure” aqueous systems more than sucrose. Increase in “structure” would be expected with higher 42 HFCS and 36 DE CSS, both of which contain large amounts of glucose and fructose. Increases in structure result from changes in the arrangement of water molecules around the sugar molecules. Such changes could result in differences in the extent of hydration of gums and, therefore, in energy required to run the freezer for various mixes.

In summary, alterations in the formulation of an ice cream mix can affect electrical energy required to run the freezer. In this study, substitution of locust bean gum for guar gum lowered energy requirements. The overall difference was intensified as 42 HFCS or 36 DE CSS in the mix were raised. The cause of these differences is complex but likely related to the percentage bound water in the mix as well as to changes in water structuring caused by the sweetener.

ACKNOWLEDGMENTS

This paper is Scientific Journal Series No. 14,033 from the University of Minnesota Agricultural Experiment Station. This work was supported in part by a grant from the Graduate School of the University of Minnesota and Minnesota Agricultural Experiment Station Project No. 18-82.

REFERENCES