THE RELIABILITY OF SEVERAL FORMULAS FOR THE CALCULATION OF WEIGHT PER GALLON OF ICE CREAM MIXES OF VARYING COMPOSITIONS

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By

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INTRODUCTION

Today the ice cream industry is faced with regulations governing the weight of packaged ice cream. The weight of total food solids and total milk solids of packaged ice cream have also become included in many regulations. Such regulations were unknown to pioneers of the ice cream industry.

Act Number 208 (1951) recently passed by the Sixty-sixth Legislature of the State of Michigan controls the commercial production, packaging, and sale of ice cream and related products in this state. This act placed a minimum weight of four and five-tenths pounds per gallon on packaged ice cream. It also required a minimum of 12 per cent milk fat; total food solids in the proportion of not less than one and six-tenths pounds per gallon; and total milk solids in the proportion of not less than nine-tenths pounds per gallon of the finished product. Regulations such as these have limited the percentage of overrun which may be incorporated into the finished product. Thus, the weight per gallon of a mix must be obtained in order to calculate the maximum overrun which will permit ice cream manufacturers to produce an ice cream that will meet legal requirements.

Ice cream is a product of variable composition. Unlike milk, the composition of ice cream is subject to the whims and fancies of the manufacturer as well as of the consumer. Since ice cream is heterogeneous, one would expect the weight per gallon of mixes to vary depending upon the percentage of the mix constituents. This variation is due to differences in specific gravity or weight per unit volume of the ingredients used in the mix.

Numerous investigators have determined the specific gravity and weight per gallon of the ingredients commonly used in the preparation of mixes, but there is a lack of knowledge concerning the specific gravity and weight per gallon of mixes of varying compositions.

It was the purpose of this study to determine, if possible, the specific gravity and actual weight per gallon of numerous mixes of varying compositions by analytical methods. Then it was sought to determine the reliability of proposed formulas which have been reported in the literature for calculating the specific gravity and weight per gallon of any mix for which the composition is known. It was hoped that these findings will be of value to the commercial ice cream manufacturer in the processing of ice cream to meet various regulations which are now in effect.

REVIEW OF LITERATURE

Regulations Governing Standards for Ice Cream

Standards governing the composition of commercially-produced ice cream first appeared in the literature during the years 1915 to 1919. Fisk (1919) listed the standards for dairy products which were in effect in each state at this time. Many states were found to have no standards whatsoever for ice cream.

Federal and state standards in effect in 1924 for milk, butter, and ice cream are listed by Dahle (1927). Most states had a standard for the minimum butterfat content of ice cream which varied from seven to 14 per cent. In some instances there were regulations concerning the minimum percentages of total solids and total milk solids of the ice cream.

State standards for ice cream compiled by Sommer (1938) show that all states had limitations for the minimum butterfat content. The number of states with a minimum percentage of total solids or milk solids content for ice cream at this time had increased to 10, including Michigan which required a minimum of one and six-tenths pounds of total food solids per gallon of finished ice cream. In four states there were regulations necessitating a minimum weight of four and twenty-five hundredths pounds per gallon; three states with a minimum weight of four and five-tenths pounds per gallon; and one state with a minimum weight of four and seventy-five hundredths pounds per gallon.

Ice cream standards for 1941, as reported by Turnbow, Tracy and Raffetto (1947), placed an increased emphasis on weight per gallon requirements. Only nine states were reported with a requirement of one and six-tenths pounds of total food solids per gallon; but, 12 states had a weight per gallon requirement of four and five-tenths pounds per gallon; three states had a requirement of four and twenty-five hundredths pounds per gallon; and one state had a requirement of four and seventy-five hundredths pounds per gallon.

In Michigan, Act Number 208 (1951) was recently passed by the Sixty-sixth Legislature. This act, which became effective September 28, 1951, regulates the commercial production, packaging, and sale of ice cream and related products in this state. A minimum weight of four and five-tenths pounds per gallon is placed on packaged ice cream. This legislation still retains the minimum milk fat content of 12 per cent for plain ice cream, total food solids in the proportion of not less than one and six-tenths pounds per gallon and total milk solids in the proportion of not less than nine-tenths pounds per gallon of the finished product. In the past the only regulations governing the weight of packaged ice cream in this state were the above requirements for total food solids and total milk solids. Thus, this new act will affect the percentage of overrun permitted for ice cream in a new way. Now the maximum percentage of overrun permitted in ice cream will be dependent upon the weight of the mix per gallon rather than the total food solids and total milk solids content of the mix.

Measurement of Overrun

Mechanical methods for measuring overrun reported by Turnbow, *et al*. (1947) include small candy scales and overrun scales such as the Mojonnier, De Raef, Torsion, and Toledo.

In order to determine the amount of overrun permissible in finished ice cream and yet meet certain weight per gallon requirements, the following formula as listed by Burke

(1933), Sommer (1938), Turnbow, et al. (1947), and Lucas and Meiser (1950) is used:

$$\frac{\text{Weight of mix per unit volume} - \text{Weight of ice cream per unit volume}}{\text{Weight of ice cream per unit volume}} \times 100 = \text{Per cent overrun}$$

Thus, it is necessary to know the weight per gallon of a mix to calculate the overrun permitted in any ice cream which must meet certain weight per gallon standards.

Tables providing the composition and weight per gallon of dairy products as well as other ingredients used in compounding ice cream mixes have been compiled by Dahle (1927), Heller (1927), Tracy (1928), Burke (1933), and Lucas, et al. (1950). Variations in weights per gallon of the same products at a given temperature are often apparent in these tables.

Information concerning the weight per gallon of mixes of varying compositions is of a more limited nature or non-existent. Baer (1927) reported the weight per gallon of several mixes of varying compositions. These weights were based on the total solids content of the mixes with the weight per gallon of each mix dependent upon the percentage of milk fat included in the total solids. Heller (1927) listed the calculated weight per gallon of mixes of varying compositions. His table provides limited information since only a few mixes of different compositions are listed. Turnbow, et al. (1947) also reported the weight per gallon of mixes of varying compositions but no explanation as to the method used in determining these values was given.

Methods of Calculating Weight per Gallon of Mixes

From the literature reviewed concerning the calculation of the weight per gallon of ice cream mixes, it is apparent that Sommer (1921) proposed one of the first, if not the first, formula for calculating what he terms the theoretical weight per gallon of mixes. His formula is as follows:

$$\frac{100}{\frac{\%\ \text{fat}}{0.93} + \frac{\%\ \text{snf*}}{1.58} + \frac{\%\ \text{water}}{1.00}} \times 8.34 = \text{weight per gallon of mix.}$$

It is assumed in this formula that butterfat has a specific gravity of 0.93; serum solids, 1.58; and water, 1.00.

Heller (1927) proposed a method for calculating the weight per gallon of mixes of varying compositions based on the same principle as that employed by Sommer (1921). Hunziker (1949) reported a similar formula for calculating the specific gravity of sweetened condensed milk although he adopted

* Includes serum solids, sugar, and gelatin.

slightly different specific gravity values for use in the formula. The specific gravity values adopted by him are as follows: milk fat, 0.93; milk solids-not-fat, 1.608; and sucrose, 1.589.

Turnbow, et al. (1947) listed a formula for calculating the weight per gallon of mixes and condensed milk products. This formula is as follows:

1. Specific gravity =

$$1 + \frac{(4.87 \times \%\ \text{sugar}) + (4.41 \times \%\ \text{msnf}) - (0.88 \times \%\ \text{fat}) - 6.26 - (T^{o}C - 5)(0.0003)}{1{,}000}$$

2. Weight in pounds per gallon = Specific gravity x 8.34.

No explanation concerning the source of the many correction factors used in this formula could be found.

Frandsen and Nelson (1950) reported a formula for the calculation of the approximate weight per gallon of any mix for which the composition is known. His formula is as follows:

$$\frac{8.33585}{\%\ \text{fat}(1.07527) + (\%\ \text{t.s.} - \%\ \text{fat})(0.6329) + \%\ \text{water}} =$$

lbs. per gal. mix.

The principle of this formula is based on the specific gravity of the mix constituents, but the method employed for the calculation of the final result varies from the method proposed by Sommer (1921).

PLAN OF EXPERIMENT

From the previous discussion, the need for knowledge concerning the weight per gallon of mixes of varying compositions has been clearly established. A review of literature disclosed only limited information regarding the specific gravity from which the weight per gallon of the mixes could be calculated. Most of the available information had to do with only the specific gravity and weight per gallon of ingredients used in compounding mixes.

It was the purpose of this study to determine, if possible, the specific gravity, weight per gallon, and maximum overrun permitted for mixes of various compositions which are commonly used in the commercial ice cream industry. Because mixes are subjected to many varied procedures of processing, it was apparent that the scope of this study must be limited to the facilities available on a laboratory scale. With the above point in mind, the following experimental procedure was planned:

1. Preparation of mixes.

2. Determination of specific gravity and weight per gallon.

3. Calculation of specific gravity and weight per gallon.

4. Comparison of actual weights per gallon and calculated weights per gallon.

5. Calculation of maximum overrun.

GENERAL PROCEDURES

The following procedures were followed throughout the experiments. In cases where the procedures listed below were modified, the modifications are explained under the proper headings in the remainder of the study.

Composition of the Mixes

A series of mixes containing eight, 10, 12, and 14 per cent butterfat was prepared in 1,000-gram quantities. The milk solids-not-fat content ranged from eight to 13 per cent; whereas, the sugar content ranged from 14 to 16 per cent. All mixes prepared contained three-tenths per cent of a 275 bloom strength gelatin. Because of their voluminous nature the detailed compositions of the 48 mixes included in this study are listed in Tables I through IV which appear in the Experimental section that follows.

Calculation of the Mixes

The serum point method was used to calculate the amount of cream and condensed milk needed for each mix.

Mix Ingredients

Heavy sweet cream, 36 per cent, supplied the fat for the mixes in this experiment. Additional milk solids-not-fat was supplied by plain condensed skim milk. Sucrose was used as the sweetening agent, while the stabilizer consisted of a 275 bloom strength gelatin. The mixes were heated to pasteurization temperatures, 155°-160° F., and homogenized using a Manton-Gaulin laboratory model homogenizer with 2,500 pounds of pressure on the first stage and no pressure on the second stage. Following homogenization, the mixes were cooled by placing them under refrigeration at temperatures of 33° to 34° F.

Analysis of Mixes

After the mixes had been homogenized to insure uniform dispersal of the mix constituents and cooled to approximately 34° F., they were analyzed for total solids and fat by the Mojonnier method as outlined in Mojonnier and Troy (1925). Triplicate analyses for total solids were made. An arithmetical average was obtained using the two results which were in closest agreement. This average was then recorded as the final result for total solids. Duplicate determinations were made for fat. An arithmetical average was obtained and this value recorded.

Since it was found to be extremely difficult to prepare mixes that would conform exactly to the desired composition, a range of variation from the desired composition was set up for fat and total solids content of the prepared mixes. Mixes exhibiting variations of more than 0.2 per cent from the desired content for either fat or total solids were discarded and new mixes prepared that met this standard.

Determination of Specific Gravity and Actual Weight per Gallon of the Mixes

After the results of the Mojonnier analysis showed each mix to be within the limitations as set forth for fat and total solids content, a 10-milliliter sample of each mix was taken. The mix samples were held in a water bath at 14°-15° C. to insure a uniform temperature at the time of weighing. Each sample was then placed in a previously-weighed 10-milliliter volumetric flask and the difference between the weight of the flask and the total weight of the flask and sample recorded. Samples of each mix were weighed until two weights were obtained which differed by less than 0.001 gram. An arithmetical average weight was taken using these two samples.

The specific gravity for each sample was determined by dividing the weight of the sample by the weight of an equal volume of water. All calculations were made on a Friden calculator and the results recorded to include the first three decimal places.

The weights per gallon of the mixes were obtained by multiplying the specific gravity by 8.337, the weight of one gallon of water at 15° C., as listed by The Handbook of Chemistry and Physics (1943). These calculations were also made on a Friden calculator. The results in this case were recorded to include only the first two decimal places.

Calculation of Specific Gravity and Weight per Gallon by Formulas

Hunziker (1949) lists the following formula for calculating the specific gravity of sweetened condensed milk:

$$\frac{100}{\frac{\%\ \text{fat}}{\text{sp. gr.}} + \frac{\%\ \text{msnf}}{\text{sp. gr.}} + \frac{\%\ \text{sugar}}{\text{sp. gr.}} + \%\ \text{water}} = \text{specific gravity of sweetened condensed milk at } 60^{\circ}\ \text{F.}$$

By using the modification which is listed below, this formula was used to calculate the specific gravity of each mix.

$$\frac{100}{\frac{\%\ \text{fat}}{\text{sp. gr.}} + \frac{\%\ \text{msnf}}{\text{sp. gr.}} + \frac{\%\ \text{sugar}}{\text{sp. gr.}} + \frac{\%\ \text{stab.}}{\text{sp. gr.}} + \%\ \text{water}} =$$

specific gravity of mix at 60° F.

The values which Hunziker (1949) adopted for use in the specific gravity formula are: milk fat, 0.93, as reported by Richmond (1920) and Fleischmann (1908); milk solids-not-fat, 1.608, an average of the results reported by Richmond (1920) and Fleischmann (1908); sucrose, 1.589, as reported by Browne and Zerban (1941).

Since sweetened condensed milk contains no stabilizer, a specific gravity value for gelatin had to be incorporated in the formula. Larson and Lucas (1940) obtained a specific gravity of 1.5384 for a gelatin suspension which was subsequently included in the formula proposed by Hunziker (1949).

Although the above specific gravity values were utilized throughout the experiment, it is interesting to note that numerous investigators do not agree as to the specific gravity of mix constituents. The following table records their findings:

Investigators	Specific Gravity of Mix Constituents			
	Fat	Msnf	Sucrose	Gelatin
Larson & Lucas (1940)	-	1.6185(60°C)	1.6107(60°C)	1.5384(60°C)
Lange (1934)	0.912(40°C)	-	1.5880(15°C)	-
Bailey (1919)	0.800(113°F)	-	-	-
Richmond (1920)	0.930(15°C)	1.6160(15°C)	1.6660(15°C)	-
Sharp & Hart (1936)	0.913(30°C)	1.5920(30°C)	1.6300(30°C)	-

The formula proposed by Turnbow, *et al*. (1947) and used in this study is as follows:

1. Specific gravity =

$$\frac{(4.87 \times \%\ \text{sugar}) + (4.41 \times \%\ \text{msnf}) - (0.88 \times \%\ \text{fat}) - 6.26 - (T^{o}C - 5)(0.0003)}{1{,}000}$$

2. Weight in pounds per gallon = Specific gravity x 8.34.

The formula proposed by Frandsen, *et al*. (1950) and used in this study is as follows:

$$\frac{8.33585}{\%\ \text{fat}(1.07527) + (\%\ \text{t. s.} - \%\ \text{fat})(0.6329) + \%\ \text{water}}$$

lbs. per gal. mix.

The weights per gallon of the mixes were calculated using the above formulas in order to obtain a comparison of the values. The fat and total solids values used in these formulas are those obtained by the Mojonnier analysis. Since the sugar and gelatin were weighed independently of the mix these values were assumed to be those originally calculated. The percentage milk solids-not-fat was determined by subtracting the total per cent of sugar, fat, and gelatin from the total solids as determined by Mojonnier analysis.

All calculations involving the use of these formulas were made on a Friden calculator. The results that include specific gravity values were recorded to include only the first three decimal places; whereas, the weight per gallon of each mix was recorded to include only the first two decimal places.

Calculation of Maximum Overrun

According to the standards set forth by Act Number 208 (1951), ice cream to be legally sold in Michigan must meet the following requirements:

1. Shall weigh not less than four and five-tenths pounds per gallon;
2. Shall contain:
    a. Not less than 12 per cent of milk fat;
    b. Total food solids in the proportion of not less than one and six-tenths pounds per gallon and total milk solids in the proportion of not less than nine-tenths pounds per gallon of finished product.

These requirements do not pertain to fruit, nut, or chocolate ice cream.

The maximum overrun, which permits the finished product to meet the above requirements, for the series of mixes containing 12 and 14 per cent fat was calculated using the following formula:

$$\frac{\text{Weight of mix per unit volume} - \text{Weight of ice cream per unit volume}}{\text{Weight of ice cream per unit volume}} \times 100 = \text{Per cent overrun}$$

This is the formula for the calculation of overrun that is listed by Turnbow, _et al_. (1947), Sommer (1938), and others.

EXPERIMENTAL

Variation of Weight per Gallon in Mixes

Since it is known that ice cream mixes are of a heterogeneous nature, one would expect the weight per unit volume or weight per gallon to vary according to the composition. The amount of variation in weight is a result of the differences in specific gravities of the constituents which are used in compounding the mix. To determine the variation in weight per gallon produced by various percentages of mix constituents, the following experiment was conducted.

Mixes containing from eight to 14 per cent butterfat were prepared in the laboratory. The milk solids-not-fat content of these mixes was varied from eight to 13 per cent to determine the effect of this component on the weight per gallon of each mix. The variation in sugar content of the mixes ranged from 14 to 16 per cent because most commercially-prepared mixes contain a similar amount of sugar. The amount of gelatin utilized in each mix was three-tenths per cent. This constituent was not varied because it is present in all mixes in such quantities that its effect upon the weight per gallon is of minor importance.

A total of 48 mixes of varying compositions were prepared for this study. The specific gravity and weight per gallon of each mix was determined in the laboratory by previously-described methods. Since it would take too much space to describe all the variations in mixes included, the composition of each mix as determined by Mojonnier analysis and the results of the analytical determinations for specific gravity and weight per gallon are recorded in Tables I, II, III, and IV.

These tables also include the calculated values for the weight per gallon of the mixes as obtained by the formulas proposed by Hunziker (1949), Frandsen, _et al._ (1951), and Turnbow, _et al._ (1947). Formula calculations were based on the compositions of the mixes as determined by Mojonnier analysis.

Due to the limited space available for listing the data in tabular form, the following abbreviations are utilized throughout the subsequent tables:

_A_ - Values obtained by analytical techniques.
_F_ - Values obtained using the formula proposed by Frandsen, _et al._ (1950).
_H_ - Values obtained using the formula proposed by Hunziker (1949).
_T_ - Values obtained using the formula proposed by Turnbow, _et al._ (1947).

TABLE I

WEIGHTS PER GALLON OF EIGHT PER CENT BUTTERFAT MIXES

Method*	Mix No.	% Fat	% Msnf	% Sugar	% T.S.	Sp. Gr.	Lbs. per Gal.	Difference from A.
A	1	8.00	9.95	14.0	32.25	1.085	9.04	
F						1.091	9.09	+0.05
H						1.092	9.10	+0.06
T						1.098	9.15	+0.11
A	2	8.03	10.90	14.0	33.23	1.090	9.08	
F						1.094	9.12	+0.04
H						1.096	9.13	+0.05
T						1.102	9.19	+0.11
A	3	8.08	11.83	14.0	34.21	1.096	9.13	
F						1.098	9.15	+0.02
H						1.100	9.17	+0.04
T						1.106	9.22	+0.09
A	4	8.09	13.01	14.0	35.40	1.100	9.17	
F						1.104	9.20	+0.03
H						1.106	9.22	+0.05
T						1.112	9.27	+0.10
A	5	7.81	10.13	15.0	33.24	1.090	9.08	
F						1.096	9.13	+0.05
H						1.097	9.14	+0.06
T						1.104	9.20	+0.12
A	6	7.93	11.10	15.0	34.33	1.096	9.13	
F						1.099	9.16	+0.03
H						1.102	9.18	+0.05
T						1.108	9.24	+0.11

TABLE I (Continued)

Method*	Mix No.	% Fat	% Msnf	% Sugar	% T.S.	Sp. Gr.	Lbs. per Gal.	Difference from A.
A	7	7.91	12.11	15.0	35.21	1.098	9.15	
F						1.104	9.20	+0.05
H						1.105	9.21	+0.06
T						1.113	9.28	+0.13
A	8	8.04	12.97	15.0	36.31	1.104	9.20	
F						1.108	9.23	+0.03
H						1.110	9.25	+0.05
T						1.116	9.30	+0.10
A	9	8.17	9.82	16.0	34.29	1.094	9.12	
F						1.098	9.15	+0.03
H						1.100	9.17	+0.05
T						1.107	9.23	+0.11
A	10	8.15	10.97	16.0	35.42	1.097	9.14	
F						1.104	9.20	+0.06
H						1.105	9.21	+0.07
T						1.112	9.27	+0.13
A	11	8.12	11.98	16.0	36.40	1.102	9.18	
F						1.108	9.23	+0.05
H						1.110	9.25	+0.07
T						1.117	9.31	+0.13
A	12	8.13	13.01	16.0	37.44	1.107	9.22	
F						1.112	9.27	+0.05
H						1.115	9.29	+0.07
T						1.121	9.34	+0.12

* A, Obtained by analytical methods; F, Calculations by Frandsen's, *et al.* (1950) formula; H, Calculations by Hunziker's (1949) formula; T, Calculations by Turnbow's, *et al.* (1947) formula.

TABLE II

WEIGHTS PER GALLON OF TEN PER CENT BUTTERFAT MIXES

Meth-od*	Mix No.	% Fat	% Msnf	% Sugar	% T.S.	Sp. Gr.	Lbs. per Gal.	Difference from A.
A	13	9.98	10.00	14.0	34.28	1.084	9.03	
F						1.088	9.07	+0.04
H						1.090	9.08	+0.05
T						1.097	9.14	+0.11
A	14	10.08	10.74	14.0	35.12	1.089	9.07	
F						1.092	9.10	+0.03
H						1.094	9.12	+0.05
T						1.100	9.17	+0.10
A	15	10.14	11.99	14.0	36.43	1.093	9.11	
F						1.097	9.14	+0.03
H						1.099	9.16	+0.05
T						1.105	9.21	+0.10
A	16	10.13	12.92	14.0	37.35	1.097	9.14	
F						1.102	9.18	+0.04
H						1.103	9.19	+0.05
T						1.109	9.24	+0.10
A	17	9.85	10.30	15.0	35.45	1.086	9.05	
F						1.094	9.12	+0.07
H						1.096	9.13	+0.08
T						1.103	9.19	+0.14
A	18	10.00	10.87	15.0	36.17	1.092	9.10	
F						1.100	9.17	+0.07
H						1.102	9.18	+0.08
T						1.105	9.21	+0.11

TABLE II (Continued)

Meth-od*	Mix No,	% Fat	% Msnf	% Sugar	% T.S.	Sp. Gr.	Lbs. per Gal.	Difference from A.
A	19	9.95	12.02	15.0	37.27	1.096	9.13	
F						1.102	9.18	+0.05
H						1.104	9.20	+0.07
T						1.111	9.26	+0.13
A	20	10.05	12.78	15.0	38.13	1.100	9.17	
F						1.105	9.21	+0.04
H						1.107	9.22	+0.05
T						1.114	9.29	+0.12
A	21	9.98	10.02	16.0	36.30	1.091	9.09	
F						1.098	9.15	+0.06
H						1.099	9.16	+0.07
T						1.107	9.23	+0.14
A	22	10.01	11.07	16.0	37.38	1.097	9.14	
F						1.102	9.18	+0.04
H						1.104	9.20	+0.06
T						1.111	9.26	+0.12
A	23	10.12	11.94	16.0	38.36	1.101	9.17	
F						1.106	9.22	+0.05
H						1.108	9.23	+0.06
T						1.115	9.29	+0.12
A	24	9.93	12.95	16.0	39.18	1.106	9.22	
F						1.111	9.26	+0.04
H						1.113	9.27	+0.05
T						1.120	9.34	+0.12

* A, Obtained by analytical methods; F, Calculations by Frandsen's, et al. (1950) formula; H, Calculations by Hunziker's (1949) formula; T, Calculations by Turnbow's, et al. (1947) formula.

TABLE III

WEIGHTS PER GALLON OF TWELVE PER CENT BUTTERFAT MIXES

Meth- od*	Mix No.	% Fat	% Msnf	% Sugar	% T.S.	Sp. Gr.	Lbs. per Gal.	Difference from A.
A	25	12.01	10.04	14.0	36.35	1.082	9.02	
F						1.087	9.06	+0.04
H						1.089	9.07	+0.05
T						1.095	9.13	+0.11
A	26	12.04	11.10	14.0	37.44	1.086	9.05	
F						1.092	9.10	+0.05
H						1.093	9.11	+0.06
T						1.100	9.17	+0.12
A	27	11.97	11.98	14.0	38.25	1.091	9.09	
F						1.096	9.13	+0.04
H						1.097	9.14	+0.05
T						1.104	9.20	+0.11
A	28	11.97	13.13	14.0	39.40	1.095	9.12	
F						1.100	9.17	+0.05
H						1.103	9.19	+0.07
T						1.109	9.24	+0.12
A	29	11.80	10.07	15.0	37.17	1.085	9.04	
F						1.092	9.10	+0.06
H						1.093	9.11	+0.07
T						1.100	9.17	+0.13
A	30	11.95	10.99	15.0	38.24	1.091	9.09	
F						1.096	9.13	+0.04
H						1.097	9.14	+0.05
T						1.104	9.20	+0.11

TABLE III (Continued)

Meth-od*	Mix No.	% Fat	% Msnf	% Sugar	% T.S.	Sp. Gr.	Lbs. per Gal.	Difference from A.
A	31	12.10	11.84	15.0	39.24	1.095	9.12	
F						1.099	9.16	+0.04
H						1.101	9.17	+0.05
T						1.108	9.24	+0.12
A	32	12.13	12.95	15.0	40.38	1.101	9.17	
F						1.104	9.20	+0.03
H						1.106	9.22	+0.05
T						1.113	9.28	+0.11
A	33	12.01	10.08	16.0	38.39	1.092	9.10	
F						1.096	9.13	+0.03
H						1.098	9.15	+0.05
T						1.105	9.21	+0.11
A	34	12.00	11.17	16.0	39.47	1.097	9.14	
F						1.100	9.17	+0.03
H						1.103	9.19	+0.05
T						1.110	9.25	+0.11
A	35	12.03	12.01	16.0	40.34	1.101	9.17	
F						1.104	9.20	+0.03
H						1.107	9.22	+0.05
T						1.114	9.29	+0.12
A	36	12.01	13.11	16.0	41.42	1.106	9.22	
F						1.110	9.25	+0.03
H						1.112	9.27	+0.05
T						1.118	9.32	+0.10

* A, Obtained by analytical methods; F, Calculations by Frandsen's, et al. (1950) formula; H, Calculations by Hunziker's (1949) formula; T, Calculations by Turnbow's, et al. (1947) formula.

TABLE IV

WEIGHTS PER GALLON OF FOURTEEN PER CENT BUTTERFAT MIXES

Meth-od*	Mix No.	% Fat	% Msnf	% Sugar	% T.S.	Sp. Gr.	Lbs. per Gal.	Difference from A.
A	37	13.80	8.24	14.0	36.34	1.071	8.92	
F						1.078	8.98	+0.06
H						1.079	8.99	+0.07
T						1.086	9.05	+0.13
A	38	14.06	9.14	14.0	37.50	1.076	8.97	
F						1.081	9.01	+0.04
H						1.083	9.02	+0.05
T						1.089	9.08	+0.11
A	39	14.04	10.00	14.0	38.38	1.080	9.00	
F						1.085	9.04	+0.04
H						1.087	9.06	+0.06
T						1.093	9.11	+0.11
A	40	14.07	11.11	14.0	39.48	1.086	9.05	
F						1.090	9.08	+0.03
H						1.092	9.10	+0.05
T						1.098	9.15	+0.10
A	41	14.02	7.80	15.0	37.12	1.073	8.94	
F						1.080	9.00	+0.06
H						1.081	9.01	+0.07
T						1.088	9.07	+0.13
A	42	13.82	9.16	15.0	38.28	1.079	8.99	
F						1.086	9.05	+0.06
H						1.087	9.06	+0.07
T						1.095	9.13	+0.14

TABLE IV (Continued)

Method*	Mix No.	% Fat	% Msnf	% Sugar	% T.S.	Sp. Gr.	Lbs. per Gal.	Difference from A.
A	43	13.89	10.19	15.0	39.38	1.084	9.03	
F						1.091	9.09	+0.06
H						1.092	9.10	+0.07
T						1.099	9.16	+0.13
A	44	14.16	11.03	15.0	40.49	1.088	9.07	
F						1.094	9.12	+0.05
H						1.096	9.13	+0.06
T						1.102	9.19	+0.12
A	45	14.12	7.89	16.0	38.31	1.080	9.00	
F						1.085	9.04	+0.04
H						1.086	9.05	+0.05
T						1.094	9.12	+0.12
A	46	14.20	8.99	16,0	39.49	1.083	9.02	
F						1.090	9.08	+0.06
H						1.091	9.09	+0.09
T						1.098	9.15	+0.13
A	47	14.07	10.03	16.0	40.40	1.090	9.09	
F						1.094	9.12	+0.03
H						1.096	9.13	+0.04
T						1.103	9.19	+0.10
A	48	14.04	10.95	16.0	41.29	1.095	9.12	
F						1.098	9.15	+0.03
H						1.100	9.17	+0.05
T						1.107	9.23	+0.11

* A, Obtained by analytical methods; F, Calculations by Frandsen's, *et al.* (1950) formula; H, Calculations by Hunziker's (1949) formula; T, Calculations by Turnbow's, *et al.* (1947) formula.

Maximum Overrun

Maximum overrun in this study refers to the amount of air which can be incorporated into an ice cream mix and still meet the legal minimum weight in the State of Michigan of four and five-tenths pounds per gallon. Today maximum overrun is of vital importance to the commercial ice cream manufacturers since the industry is faced with regulations governing the weight per gallon of finished ice cream. To provide the industry with overrun information for mixes of varying compositions, Tables V and VI have been prepared.

Table V gives the specific gravity, weight per gallon, and the maximum overrun for various mixes containing eight and 10 per cent butterfat. This table is of little importance to the commercial ice cream manufacturers in Michigan because the butterfat content of the mixes listed is below the minimum requirement of Act Number 208 (1951). In states that have lower minimum butterfat requirements, this information should be of value.

Table VI contains the same information as Table V except that the various mixes listed contain 12 and 14 per cent butterfat; thus, the overrun information provided in this

TABLE V

MAXIMUM OVERRUN FOR EIGHT AND TEN PER CENT BUTTERFAT MIXES*

Mix No.	% Fat	% Msnf	% Sugar	% T.S.	Sp. Gr.	Lbs. per Gal.	% Maximum Overrun
1	8.0	10.0	14.0	32.30	1.091	9.09	102.0
2	8.0	11.0	14.0	33.30	1.094	9.12	102.6
3	8.0	12.0	14.0	34.30	1.099	9.16	103.5
4	8.0	13.0	14.0	35.30	1.104	9.20	104.4
5	8.0	10.0	15.0	33.30	1.094	9.12	102.6
6	8.0	11.0	15.0	34.30	1.099	9.16	103.5
7	8.0	12.0	15.0	35.30	1.104	9.20	104.4
8	8.0	13.0	15.0	36.30	1.109	9.24	105.3
9	8.0	10.0	16.0	34.30	1.099	9.16	103.5
10	8.0	11.0	16.0	35.30	1.104	9.20	104.4
11	8.0	12.0	16.0	36.30	1.109	9.24	105.3
12	8.0	13.0	16.0	37.30	1.112	9.27	106.0
13	10.0	10.0	14.0	34.30	1.088	9.07	101.5
14	10.0	11.0	14.0	35.30	1.093	9.11	102.4
15	10.0	12.0	14.0	36.30	1.098	9.15	103.3
16	10.0	13.0	14.0	37.30	1.102	9.18	104.0
17	10.0	10.0	15.0	35.30	1.093	9.11	102.4
18	10.0	11.0	15.0	36.30	1.098	9.15	103.3
19	10.0	12.0	15.0	37.30	1.102	9.18	104.0
20	10.0	13.0	15.0	38.30	1.106	9.22	104.8
21	10.0	10.0	16.0	36.30	1.098	9.15	103.3
22	10.0	11.0	16.0	37.30	1.102	9.18	104.0
23	10.0	12.0	16.0	38.30	1.106	9.22	104.8
24	10.0	13.0	16.0	39.30	1.111	9.26	105.7

*Maximum overrun refers to the overrun which produces finished ice cream that will weigh 4.5 pounds per gallon. Calculations for weight per gallon of the mixes are based upon the formula proposed by Frandsen, et al. (1951). The total solids include 0.30 per cent gelatin.

TABLE VI

MAXIMUM OVERRUN FOR TWELVE AND FOURTEEN PER CENT BUTTERFAT MIXES*

Mix No.	% Fat	% Msnf	% Sugar	% T.S.	Sp. Gr.	Lbs. per Gal.	% Maximum Overrun
25	12.0	10.0	14.0	36.30	1.087	9.06	101.3
26	12.0	11.0	14.0	37.30	1.091	9.09	102.0
27	12.0	12.0	14.0	38.30	1.096	9.13	102.8
28	12.0	13.0	14.0	39.30	1.100	9.17	103.7
29	12.0	10.0	15.0	37.30	1.091	9.09	102.0
30	12.0	11.0	15.0	38.30	1.096	9.13	102.8
31	12.0	12.0	15.0	39.30	1.100	9.17	103.7
32	12.0	13.0	15.0	40.30	1.104	9.20	104.4
33	12.0	10.0	16.0	38.30	1.096	9.13	102.8
34	12.0	11.0	16.0	39.30	1.100	9.17	103.7
35	12.0	12.0	16.0	40.30	1.104	9.20	104.4
36	12.0	13.0	16.0	41.30	1.109	9.24	105.3
37	14.0	8.0	14.0	36.30	1.076	8.97	99.3
38	14.0	9.0	14.0	37.30	1.081	9.01	100.2
39	14.0	10.0	14.0	38.30	1.085	9.04	100.8
40	14.0	11.0	14.0	39.30	1.090	9.08	101.7
41	14.0	8.0	15.0	37.30	1.081	9.01	100.2
42	14.0	9.0	15.0	38.30	1.085	9.04	100.8
43	14.0	10.0	15.0	39.30	1.090	9.08	101.7
44	14.0	11.0	15.0	40.30	1.094	9.12	102.6
45	14.0	8.0	16.0	38.30	1.085	9.04	100.8
46	14.0	9.0	16.0	39.30	1.090	9.08	101.7
47	14.0	10.0	16.0	40.30	1.094	9.12	102.6
48	14.0	11.0	16.0	41.30	1.098	9.15	103.3

* Maximum overrun refers to the overrun which produces finished ice cream that will weigh 4.5 pounds per gallon. Calculations for weight per gallon of the mixes are based upon the formula proposed by Frandsen, et al. (1951). The total solids include 0.30 per cent gelatin.

table applies to ice cream meeting the requirements of Act Number 208 (1951).

The total food solids and the total milk solids requirements per gallon do not have to be considered in these calculations since it was found that any mix containing a minimum of 12 per cent fat, 10 per cent serum solids, and 14 per cent sugar which is frozen into ice cream weighing four and five-tenths pounds per gallon will exceed these requirements. The same holds true for the series of mixes containing 14 per cent fat.

The calculations for specific gravity and weight per gallon of the mixes included in these tables were made using the formula proposed by Frandsen, _et al_. (1951) since previous observation from this study found it to be the most accurate of the formulas included in this investigation. All calculations for maximum overrun were made as described under _General Procedures_.

DISCUSSION

In the early part of this investigation, it was established that the weight per gallon of ice cream mixes varied. Further study indicated a range in weight variation between eight and ninety-seven hundredths pounds per gallon for a mix containing 14 per cent fat, eight per cent milk solids-not-fat, 14 per cent sugar, and three-tenths per cent gelatin to nine and twenty-seven hundredths pounds per gallon for a mix containing eight per cent fat, 13 per cent milk solids-not-fat, 16 per cent sugar, and three-tenths per cent gelatin.

It was also noted that the mix which weighed nine and twenty-seven hundredths pounds per gallon contained 37.30 per cent total solids whereas the mix which weighed eight and ninety-seven hundredths pounds per gallon contained 40.30 per cent total solids. Thus, the weight per gallon of ice cream mixes does not always increase as the percentage total solids is increased.

Observations made from the studies concerning the determination of weight per gallon of a mix show that there is close agreement between the results of the analytical method of determination and the calculated results obtained using the formula proposed by Frandsen, et al. (1951) and Hunziker (1949). A comparison of the arithmetical differences of these calculated weights per gallon from the analytical determinations are listed in the following tables:

TABLE VII

Average Difference in Weight per Gallon Values Calculated by Formula Proposed by Frandsen, et al. (1951) from the Values Determined by Analytical Methods

	Lbs./Gal.
1. Mixes containing 8 per cent fat	+0.040
2. Mixes containing 10 per cent fat	+0.046
3. Mixes containing 12 per cent fat	+0.039
4. Mixes containing 14 per cent fat	+0.043
Combined average difference for all mixes . . .	+0.043

TABLE VIII

Average Difference in Weight per Gallon Values Calculated by Formula Proposed by Hunziker (1949) from the Values Determined by Analytical Methods

	Lbs./Gal.
1. Mixes containing 8 per cent fat	+0.056
2. Mixes containing 10 per cent fat	+0.060
3. Mixes containing 12 per cent fat	+0.054
4. Mixes containing 14 per cent fat	+0.059
Combined average difference for all mixes . . .	+0.057

A comparison of the results obtained when calculating the weight per gallon of the mixes used in this investigation by the formula proposed by Turnbow, et al. (1947) indicated that this formula gave consistently higher results than those resulting from the formulas proposed by Frandsen, et al. (1951) and Hunziker (1949). A summary of these findings is as follows:

TABLE IX

Average Difference in Weight per Gallon Values Calculated by Formula Proposed by Turnbow, et al. (1947) from the Values Determined by Analytical Methods

	Lbs./Gal.
1. Mixes containing 8 per cent fat	+0.113
2. Mixes containing 10 per cent fat	+0.117
3. Mixes containing 12 per cent fat	+0.114
4. Mixes containing 14 per cent fat	+0.119
Combined average difference for all mixes . . .	+0.116

Since the primary purpose of this study was to find the most accurate formula for the calculation of weight per gallon of ice cream mixes, it can be stated that the formula proposed by Frandsen, et al. (1951) is the most accurate of those included in this investigation. Therefore this formula was used in the calculation of weight per gallon of the mixes included in the maximum overrun tables.

Of the mixes studied, the maximum overrun which permits finished ice cream to weigh four and five-tenths pounds per gallon varied from a minimum of 99.3 per cent for the mix that weighed eight and ninety-seven hundredths pounds per gallon to a maximum of 106.0 per cent for the mix that weighed nine and twenty-seven hundredths pounds per gallon. Since a larger percentage of overrun can be incorporated into the mix containing eight per cent fat and still meet the weight per gallon requirement of four and five-tenths pounds, it is evident that Act Number 208 penalizes the manufacturer of high fat mixes.

SUMMARY AND CONCLUSIONS

1. The weight of ice cream mixes studied varied from eight and ninety-seven hundredths pounds per gallon to nine and twenty-seven hundredths pounds per gallon depending upon the composition.

2. Weights per gallon of ice cream mixes calculated by the formulas proposed by Frandsen, et al. (1951), Hunziker (1949), and Turnbow, et al. (1947) do not agree for mixes of the same composition.

3. Arithmetical averages of the values obtained using the formula proposed by Turnbow, et al. (1947) exhibited the greatest deviation from the analytical values.

4. Values calculated by the formulas proposed by Frandsen, et al. (1951) and Hunziker (1949) were in close agreement. Frandsen's, et al. (1951) formula appeared to be the more accurate of the two since it was within forty-three thousandths pounds of the analytical results.

5. The range for maximum overrun varied from 99.3 per cent for a 14 per cent fat, eight per cent milk solids-not-fat, 14 per cent sugar, and three-tenths per cent gelatin mix to 106.0 per cent for an eight per cent fat, 13 per cent milk solids-not-fat, 16 per cent sugar, and three-tenths per cent gelatin mix.

6. Manufacturers of high fat content mixes are penalized by Act Number 208.

7. Increasing the total solids content of ice cream mixes does not guarantee an increase in the weight per gallon.

8. Tables are presented which give the weight per gallon and maximum overrun for mixes which contain from eight to 14 per cent fat with variations in milk solids-not-fat and sugar.

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