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Effect of single and integrated emulsifier-stabiliser on soy-ice confection

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Soy-ice confections were prepared incorporating locust bean gum (LBG), guar gum (GG), sodium carboxymethylcellulose (CMC) and alginate as single stabilisers with glyceromonostearate (GMS) as an emulsifier. The integrated emulsifier-stabiliser (IES) used was Sherex (mixture of mono-di glycerides, LBG, GG and carrageenan). All confections were analysed for viscosity, foam and texture properties, meltdown and shape factor, glass transition temperature (Tg), melting temperature (Tm) and sensory properties. Sherex imparted highest viscosity (8.88 Pa.s) to the confection mix. LBG, CMC and Sherex gave better foaming properties, with LBG providing the best air incorporation. All samples exhibited desirable melting characteristics. Sherex influenced the shape factor more than other stabilisers, with a highest score (125.3%). The Sherex-incorporated confection showed the highest Tg (−29.64°C) and Tm (2.59°C). Sherex, LBG and alginate provided good sensory attributes to the confection. It was concluded that an IES, such as Sherex, enhanced viscosity in the product mix, and hence could produce a soy-ice confection with improved quality as shown by better foaming and textural properties as well as better sensory attributes. © 1998 Elsevier Science Ltd. All rights reserved.

INTRODUCTION

Soy-ice confection is becoming popular among the calorie-conscious, cholesterol-watching and lacto-allergic and intolerant population. Development of soy-ice confection was based on the increased need for an alternative dairy-based product, especially among those who experience difficulties in consuming conventional dairy-based ice confection products. The increased demand for quality soy-ice confection will require improved functional ingredients. Improving technology for incorporating soy protein isolate, as well as emulsifying and stabilising agents, as ice confection ingredients will provide better markets for soy-ice confections.

The function of stabilisers in an ice confection is attributed to their water-binding capacity by forming a three dimensional network of hydrated molecules throughout the system. In this way they retard ice crystal growth and improve mix viscosity, air incorporation, body, texture and melting properties (Voulasiki and Zerfiridis, 1990). By utilising the functionality and characteristics of the individual stabiliser and emulsifier components, food technologists can thereby recommend a wide range of emulsifier-stabiliser blends to suit the specific demands for the various types of soy-ice confection. Integrated emulsifier-stabiliser systems are increasingly used in the manufacture of whipped and frozen dairy products. The demand for improved functional ingredient blends for ice confection is on the increase.

The aim of this study was to evaluate the effect of single and integrated emulsifying-stabilising systems in soy-ice confection. The evaluation was carried out by comparing the effects of different combinations of emulsifier-stabilisers. Locust bean gum (LBG), guar gum, alginate, and sodium carboxymethylcellulose (CMC) were used as single stabilisers, in conjunction with glycerol monostearate (GMS) as an emulsifier, while Sherex (mixture of mono-di glycerides, LBG, GG and carrageenan) was used as an integrated emulsifier-stabiliser.

MATERIALS AND METHODS

Ingredients for soy-ice confection

LBG (NP 217), GG (NP 89), and CMC (NP162) were supplied by Germantown Co. Alginate (Marloid CMS) was supplied by Kelco, Division of Merck and Co., Inc.

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Sherex IC9170, GMS (glyceromonostearate), vanilla flavour (CE 13669) and SoyTech (AP 05203) were supplied by Quest International. Coconut fat (Kreamolene) was supplied by Unilever Australia Ltd. Glucose syrup (40DE) was supplied by National Starch. Soy protein isolate (Supro Plus 651) was supplied by Protein Technologies International. Coconut fat and glucose syrup, were stored in a chilled room at −4°C, while all other ingredients were stored in sealed containers at room temperature throughout the study.

Manufacture of soy-ice confection

Soy-ice confections were prepared in 15 kg batches using the formulation shown in Table 1. Ingredients were added gradually to water heated to 60°C. The mix was stirred constantly and held in a water bath (70°C) for 1 hour. It was homogenised (13.8 and 3.45 MPa), and pasteurised (85°C for 20 min), followed by immediate cooling to 8°C and flavouring added. Ageing of the mix was done in a cold room at 4°C overnight. The mix was frozen in a batch freezer with an outlet temperature of −6°C, and an overrun of 70–80%. The ice confection was packaged in plastic cups and covered with plastic lids and stored in the hardening room at −20°C for one week.

Viscosity, foam expansion, foam liquid stability and whippability assessments were carried out on the ice confection mix, after overnight ageing at 4°C, whereas texture profile analysis (TPA), colour, melt-down/shape factor, differential scanning calorimetry (DSC) and sensory assessments were carried out with ice confection samples which had been stored at −20°C for one week period.

Table 1. Soy-ice confection formulation

	% (w/w)
Hydrogenated vegetable oil	8.0
Sugar	13.0
Glucose syrup	10.0
Soy protein isolate	4.0
Stabiliser[a]	0.2–0.7
Emulsifier[b]	0.45
Soy-tech flavour	0.125
Vanilla	0.1
Water	64.075–64.325

[a]Control (no stabiliser), locust bean gum (0.20%), guar gum (0.20%), alginate (0.25%), carboxymethylcellulose (0.20%), Sherex (0.70% without glyceromonostearate).
[b]Glyceromonostearate.

Viscosity

All measurements were made with a Brookfield viscometer, model DVII+, Version 3.0, with spindle number 2 at 0.6 rpm. Viscosities of the samples were measured at 22°C.

Total solids

Total solids was determined by the Gravimetric method (AOAC, 1990). Two grams of prepared sample were weighed into a flat-bottom dish. Samples were heated on a steam bath for 30 min, and then in an air-oven for 3.5 h at 105°C. The per cent residue was reported as total solids.

Foam expansion

Foam expansion (FE%) was determined by the method of Poole *et al.* (1984), after modification. Samples (125 ml) were diluted with distilled water (125 ml), and whipped at maximum speed for 5 min in a Philips mixer Model HR1190/BS. Foams plus remaining unfoamed liquid were transferred immediately to a 2 litre glass measuring cylinder.

$$\%\text{ foam expansion (FE)} = \frac{\text{foam volume (ml)}}{\text{initial liquid volume (250 ml)}} \times 10$$

Foam liquid stability

Foam liquid stability (FLS) was measured according to the method of Poole *et al.* (1984), after modification. The same samples for FE after immediately recording foam volume were allowed to stand for 30 min. The volume of liquid (ml) retained in foam after 30 min was recorded.

$$\text{FLS} = \frac{\text{volume of liquid (ml) retained in foam after 30 min}}{\text{volume of liquid prior to whipping (250 ml)}} \times 100$$

Whippability

Whippability was measured using the method of Haggett (1976), after modification. Mix samples (125 ml) were diluted with distilled water (125 mL), then whipped in a Philips mixer model HR1190/BS at full speed for 5 min. Foams and remaining unfoamed liquid were transferred immediately to a 2 litre glass measuring cylinder. The final whipped volume was recorded and the results expressed as:

$$\text{percentage overrun (\%OR)} = \frac{100 \times (\text{Vf} - \text{Vi})}{\text{Vi}}$$

where Vf is final whip volume; Vi is initial mix volume.

Texture profile analysis (TPA)

Analysis was carried out using a Stable Micro Systems Texture Analyser (XT.RA Dimension V3.7G). TPA graphs were plotted as force vs time with acquisition rate of 200 pps. Force units were measured within 1.00 mm^2 contact area and contact force of 5.0 *g*. Pretest speed was set at 2.0 mm s^{-1}, test speed at 1.0 mm s^{-1}, and post-test speed at 5.0 mm s^{-1}. Distance was set at 15.00 mm with a time interval of 5.00 s, and trigger force of 5 *g*.

Colour measurements

Colour was measured using the Nippon Denshoku Colour Meter Model ND-20DP. Both the CIE (X, Y, Z), and Hunter (L, a, b) methods were used.

Meltdown and shape factor

Meltdown and shape factor (SF) were determined by the method of Cottrell *et al.* (1979). Ice confection was made in the shape of rectangular block and held at −20°C for one week. A stainless steel sieve with a mesh size of 2.5 mm was used as a screen, and placed over a 2 l beaker. Frozen samples were then placed over the screen and allowed to melt at room temperature (20°C). The SF was determined by measuring the ice block dimensions at zero time and 2.5 h after melting, and expressed as:

$$SF = \frac{\text{original length}}{\text{original depth}} \times \frac{\text{final depth}}{\text{final length}} \times 100$$

The amount of melted sample which had dripped for a period of 2.5 h was weighed and reported as % original weight of sample.

Differential scanning calorimetry (DSC)

A Perkin–Elmer 7 Series (Perkin–Elmer Corp., Norwalk, CT) thermal analyser equipped with a Perkin–Elmer differential scanning calorimeter (DSC) cell base was utilised. The purge gas was nitrogen at 20 ml/min. The DSC was calibrated with high purity melting-point standards and the heat of indium. Samples were hermetically sealed in aluminium pans using the Perkin sample encapsulation press. The temperature was lowered rapidly by liquid nitrogen in the quench cooling assembly from ambient to −60°C, and scanned at a heating rate of 40°C min^{-1} from −60 to 5°C.

Sensory evaluation

Sensory evaluation was conducted using a structured scale method with 25 panellists. Six different characteristics were scored, based on appearance, colour, texture (creaminess and iciness), flavour, and overall acceptability. One hour prior to evaluation, samples were removed from the hardening cabinet (−20°C) and tempered in a refrigerator until evaluation (8°C). Samples in 100 ml cups were presented in random order on individual trays served with a response form. Evaluations were conducted in individually lighted booths. Water was provided for rinsing between samples. The data were analysed by one way analysis of variance (ANOVA), followed by Duncan least significant difference technique, using Costat as a statistical package software.

RESULTS AND DISCUSSION

Viscosity, foam properties, colour and total solids of soy-ice confections

Compared with the control, as expected, all stabilisers showed the ability, in varying degrees, to provide the mix with high viscosity as desired in ice confection manufacturing, with integrated emulsifier-stabiliser (Sherex) exhibiting extremely high viscosity (Table 2).

The mix viscosity showed an irregular trend and generally, a high viscosity of the mix retarded the rate of whipping (Bhandari and Balachandran, 1984). The whippability results obtained from the present study agree with this statement, except for CMC. Even though it has a high level of viscosity (1.37 Pa.s.), CMC still exhibited a strong level of whippability (Table 2). This is probably because of the CMC's ability to provide better aeration and accommodate better protein orientation in a whipped system, which could lead to better foam properties, even at high levels of viscosity. In this respect, the present results agreed with those of Abu-Lehia *et al.* (1989) who reported that high mix viscosity is a desirable property, due to its ability to impart a desirable whippability, body and texture.

Mix viscosity gave high positive correlation with colour intensity of the ice confection ($r = 0.92$). This is probably due to the effect of stabilisers on increasing mix viscosity, thus stabilising the system and causing the constituents to disperse evenly. This increases the uniformity, thereby influencing the colour intensities of the products.

The six samples exhibited variable foam expansion values (FE). The LBG (158%) and CMC (155%) incorporated samples were two of the single stabilisers which gave FE values greater than that exhibited by the integrated one (Sherex, 153%). These FE results, with several exceptions, are in agreement with Townsend and Nakai (1983), who reported that high viscosity is associated with an optimum foaming capacity. These trends, however, were not found to be true in the case of LBG. Even though it showed low viscosity, LBG performed better and gave the highest score for its FE value and % OR.

Those samples that provided high FE values, after 5 min of whipping, generally exhibited low foam liquid stability (FLS), compared to samples with poor FE values. The single and integrated systems provided the

Table 2. Mix viscosity, total solids, and foam properties of soy-ice confections[a]

Sample	Viscosity (Pa.s.)	Total solids (%)	FE (%)[b]	FLS (%)[c]	WP (% OR)[d]	C I (%)[e]
Control	0.15 ± 0.00	36.4 ± 0.01	21.3 ± 0.08	95.3 ± 0.01	21.3 ± 0.47	7.5
LBG	0.50 ± 0.10	38.2 ± 0.00	158.0 ± 0.01	86.7 ± 0.03	58.0 ± 0.03	7.5
Guar gum	1.03 ± 0.03	37.4 ± 0.01	108.0 ± 0.02	98.0 ± 0.02	8.0 ± 0.25	7.5
Alginate	0.52 ± 0.06	37.8 ± 0.01	122.7 ± 0.01	74.7 ± 0.06	22.7 ± 0.05	7.5
CMC	1.37 ± 0.02	36.3 ± 0.00	154.7 ± 0.01	82.7 ± 0.03	54.7 ± 0.02	10.0
Sherex	8.88 ± 0.01	38.4 ± 0.01	153.3 ± 0.04	86.8 ± 0.07	53.3 ± 0.11	12.5

[a]Means of triplicate assessments (Mean ± SE).
[b]FE: foam expansion.
[c]FLS: foam liquid stability.
[d]WP (%OR): whippability (% overrun).
[e]CI: colour intensity.

ice confections with lower FLS compared to the control, with alginate exhibiting the lowest FLS (Table 2). FLS showed positive correlation with cohesiveness (a texture attribute), with $r = 0.82$. Foam is stabilised by low interfacial tension, high viscosity of liquid phase, and strong, elastic films of adsorbed protein (Cheftel *et al.*, 1985).

The same trend as in the FE results was observed in whippability which showed a strong positive correlation with FE ($r = 1.00$). Whippability of an ice confection mix is impaired by increased mix viscosity (Arbuckle, 1986; Cottrell *et al.*, 1979).

Even though the integrated emulsifier-stabiliser provided the resulting products with the highest total solids, all samples were similar in total solids which indicates that the use of stabilisers did not influence total solids in a significant way (Table 2).

Differences in lightness between samples (ΔL) were detected from the L, a, b, colour meter results. The lightness difference values ranged from 0.3% in samples of Guar gum-Sherex to 4.0% in samples of Control-CMC. Samples with LBG, guar gum, alginate, CMC and Sherex, respectively, were 0.6, 3.1, 2.5, 4.0 and 3.4% darker than the control (Table 3). The colour difference values ranged from 0.6 (Guar gum-Sherex) to 3.6 (Control-Sherex). The colour difference (ΔE) results (Table 3) indicated that all stabilisers have the ability to affect the colour and lightness of soy-ice confection. However, the effect is not likely to be significant, since all samples appeared in the illuminant 'C' region of the chromaticity diagram.

Texture attributes of soy-ice confection

TPA parameters varied considerably among samples, which reflected textural differences of soy-ice confections (Table 4). Sherex showed textural attributes similar to LBG and alginate with regard to springiness, cohesiveness and hardness, and was similar to guar gum with regard to chewiness, gumminess, adhesiveness and hardness.

The lack of cohesiveness could lead to crumbly products, due to low solids or ineffective stabilisation whereas the excessive chewiness might cause the body of the ice confection to be too heavy (Jimenez-Florez *et al.*, 1993). The present results agree with this statement. CMC had the lowest total solids and has also exhibited the lowest score for cohesiveness.

Cohesiveness showed high positive correlation with springiness ($r = 0.93$), and high negative correlation with hardness ($r = -0.93$). Hardness showed high negative correlations with springiness ($r = -0.83$), and adhesiveness ($r = -0.86$). Fracturability has high positive correlations with shape factor (SF) and melting temperature (T_m), with $r = 0.92$ and 0.89, respectively, while gumminess correlates highly with appearance, flavour, and overall acceptability, with $r = 0.87$, 0.93, and 0.91, respectively.

Meltdown properties, shape factor and glass transition properties of soy-ice confection

All samples showed similar meltdown values (Table 5), which indicates that the use of stabilisers did not influence the meltdown property in a significant way. However, when compared to control, the use of single stabilisers has a tendency to slightly decrease the rate of

Table 3. Lightness and colour differences between samples[a]

Colour comparison	ΔL[b]	ΔE[c]
Control–LBG	0.6	1.2
Control–Guar gum	3.1	3.2
Control–Alginate	2.5	2.7
Control–CMC	4.0	0.8
Control–Sherex	3.4	3.6
LBG–Guar gum	2.5	2.5
LBG–Alginate	1.9	2.2
LBG–CMC	3.4	3.5
LBG–Sherex	2.8	2.9
Guar gum–Alginate	−0.6	1.2
Guar gum–CMC	0.9	1.0
Guar gum–Sherex	0.3	0.6
Alginate–CMC	1.5	1.6
Alginate–Sherex	0.9	1.3
CMC–Sherex	−0.6	0.8

[a]Means of triplicate assessments, with four readings for each replication.
[b]Lightness difference,
[c]ΔE: colour difference.

Table 4. Texture profile parameters[a] for soy-ice confections

Sample	SP	CO	CH	GU	AD	FR (g)	HD (g)
Control	0.51 (0.42)	0.2 (0.39)	21.4 (0.76)	38.9 (0.72)	−288.3 (0.36)	NA	232.9 (0.77)
LBG	0.45 (0.62)	0.13 (0.40)	18.2 (1.47)	73.8 (0.20)	−821.5 (0.09)	NA	607.5 (0.26)
Guar	0.61 (0.26)	0.18 (0.33)	25.6 (0.53)	41.8 (0.48)	−344.4 (0 26)	NA	249.3 (0.61)
Alginate	0.45 (0.92)	0.09 (0.01)	37.1 (1.09)	55.0 (1.07)	−569.1 (1.16)	298.7 (0.00)	580.7 (1.05)
CMC	0.26 (1.89)	0.05 (0.89)	19.4 (0.87)	39.3 (0.93)	−655.1 (0.29)	636.0 (0.00)	743.0 (0.69)
Sherex	0.46 (0.91)	0.15 (0.86)	33.3 (1.24)	44.9 (1.18)	−477.8 (1.14)	494.0 (0.00)	315.8 (0.45)

[a]SP: springiness; CO: cohesiveness; CH: chewiness; GU: gumminess; AD: adhesiveness; FR: fracturability; HD: hardness. Mean of three determinations, (): numbers in parentheses refer to ±SD. NA = not analysed.

Table 5. Meltdown, shape factor and glass transition properties for soy-ice confections[a]

Sample	Meltdown (%)	SF (%)[b]	T_g (°C)[c]	T_m (°C)[d]
Control	25.9 ± 0.14	70.6 ± 0.06	−35.94 ± 2.52	−0.06 ± 0.84
LBG	25.6 ± 0.57	71.2 ± 0.31	−36.57 ± 1.51	−1.38 ± 2.32
Guar gum	24.4 ± 0.23	91.8 ± 0.14	−38.56 ± 0.81	0.36 ± 1.48
Alginate	25.5 ± 0.38	93.7 ± 0.06	−41.62 ± 1.04	0.39 ± 1.26
CMC	25.9 ± 0.53	124.1 ± 0.13	−34.39 ± 2.83	2.43 ± 0.40
Sherex	26.0 ± 0.53	125.3 ± 0.10	−29.64 ± 4.27	2.59 ± 0.61

[a]Means of triplicate assessments (mean ± SE)
[b]SF: shape factor
[c]T_g: glass transition temperature.
[d]T_m: melting temperature.

meltdown, while the integrated emulsifier-stabiliser has shown a slightly higher rate of meltdown.

The results indicate that stabilisers are likely to alter T_g and T_m of ice confections to some degree, with Sherex exhibiting the highest T_g and T_m. T_m showed positive correlations with fracturability ($r = 0.89$) and SF ($r = 0.96$). Hence incorporation of Sherex will contribute to a better quality product, and storage stability of soy-ice confection.

Sensory evaluation of soy-ice confections

The appearance attribute has positive correlations with creaminess ($r = 0.87$), flavour ($r = 0.92$), and overall acceptability ($r = 0.97$). The mean scores for colour ranged from 1.12 to 1.44 (Table 6). There was no significant difference in colour between samples ($p < 0.05$). These results, with some exception, were found to be in agreement with colour analysis by colour meter, which indicated that the colour of all samples appears in the illuminant ‘C’ white region.

Texture was evaluated by scoring creaminess and iciness attributes, since these two are important to the perceived quality of final products. Results indicate that the use of stabilisers, with exceptions for CMC and guar gum, could impart better texture for soy-ice confection, with regard to creaminess and iciness, with LBG exhibiting the best results.

The increasing iciness was perceived by the judges as an increase in ice crystal size in the products. Increasing

Table 6. Sensory scores for soy-ice confections[a]

Sample	Sensory attributes[b]					
	Appearance[c]	Colour[d]	Creaminess[e]	Iciness[f]	Flavour[g]	OA[h]
Control	5.08 c	1.12 a	4.60 b	3.40 b	6.12 ab	5.92 ab
LBG	6.20 ab	1.44 a	5.96 a	2.96 b	7.12 a	7.12 a
Guar Gum	5.24 bc	1.36 a	4.48 b	5.92 a	6.28 ab	5.96 ab
Alginate	6.28 a	1.44 a	5.92 a	3.20 b	6.72 ab	6.88 ab
CMC	4.96 c	1.28 a	4.44 b	5.96 a	5.80 b	5.60 b
Sherex	5.44 abc	1.36 a	5.84 a	3.12 b	6.40 ab	6.40 ab

[a]Means of 25 sensory scores.
[b]Means followed by the same letter in the same column are not significantly different ($p < 0.05$) by Duncan multiple range test.
[c]Based on 9-point scale; 9: excellent; 1: poor.
[d]Based on 9-point scale; 9: extremely yellow; 1: white.
[e]Based on 9-point scale; 9: extremely creamy; 1: not creamy.
[f]Based on 9-point scale; 9: extremely icy; 1: not icy.
[g]Based on 9-point scale; 9: like extremely; 1: dislike extremely.
[h]Overall acceptability; based on 9-point scale; 9: like extremely; 1: dislike extremely.

viscosity restricts molecule migration to the crystal nuclei which limits the size of the ice crystals (Moore and Shoemaker, 1981; Voulasiki and Zerfiridis, 1990). This indicates that the iciness may be related to the mix viscosity.

This conclusion, however, does not appear to be a satisfactory explanation for the results obtained with guar gum and CMC. It was found that, even with a relatively high mix viscosity, samples with guar gum and CMC have high iciness scores.

Creaminess has positive correlations with total solids and flavour, with $r = 0.86$ and 0.83, respectively. The effect of total solids on creaminess is due to its ability to reduce the amount of free water to be frozen, obstructing the ice crystal growth, thus enhancing the creamy mouth feel of the product (Arbuckle, 1986; Fox, 1992). The creaminess will lead to better overall acceptability, as indicated by their high positive correlation ($r = 0.92$).

Flavour has a positive correlation with overall acceptability, with $r = 0.97$. Results indicate that the use of a single stabiliser (except for CMC), and integrated emulsifier-stabiliser could provide the soy-ice confections with improved sensory properties, with LBG exhibiting the best overall acceptability (Table 6).

CONCLUSIONS

Sherex provided the highest mix viscosity and better quality attributes with regard to foaming properties, texture, and sensory scores. The use of stabilisers is not likely to influence the total solids of the ice confections.

The higher FE favours continuous liquid drainage and the tendency to rupture, thus reducing the FLS of the mixes. Whippability does not necessarily depend upon high mix viscosity, but more likely relates to the emulsifier-stabiliser's ability to confer air-incorporation stability in a whipped system, while high overrun imparts a smoother texture.

Stabilisers affect the soy-ice confection's texture in varying degrees, with Sherex, alginate and LBG providing better textural characteristics.

All stabilisers used in this study are not likely to affect the ice confection's colour, as they appear in the same chromaticity region (illuminant 'C'), although several degrees of colour intensities and colour differences may occur.

The use of stabiliser did not influence the meltdown property in a significant way. However, all samples showed desirable melting characteristics which were very similar to the characteristics of the original mix, without any foamy or curdy meltdown.

The use of stabilisers is likely to alter the T_g and T_m of soy-ice confection to some extent. The highest T_g of Sherex, which corresponds with the highest T_m, indicates its contribution to better product quality and storage stability, due to its reducing the water mobility and changing the disordered liquid in the ice confection system to an ordered solid state quicker than other stabilisers, thus resulting in better texture and prolonged storage by restricting recrystallisation.

The use of stabiliser in soy-ice confection, except for CMC, resulted in better sensory attributes with regard to appearance, creaminess, iciness, flavour, and overall acceptability. LBG, alginate, and Sherex provided better quality attributes among others with LBG exhibiting the best results, as indicated by the highest score for appearance (6.20), creaminess (5.96), flavour (7.12), and overall acceptability (7.12), and the lowest score of iciness (2.96).

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