International Food Research Journal 21(5): 1777-1787 (2014)
Journal homepage: *http://www.ifrj.upm.edu.my*

Effect of different types of hydrocolloids on the physical and sensory properties of ice cream with fermented glutinous rice (*tapai pulut*)

[1]Shukri, W. H. Z., [1]Hamzah, E. N. H., [1]Halim, N. R. A., [2]Isa, M. I. N. and [1*]Sarbon, N. M.

[1]*School of Food Science and Technology, Universiti Malaysia Terengganu, 21030, Kuala Terengganu, Terengganu, Malaysia*
[2]*School of Fundemental Science, Universiti Malaysia Terengganu, 21030, Kuala Terengganu, Terengganu, Malaysia*

Article history

Received: 20 January 2014
Received in revised form: 20 March 2014
Accepted: 23 March 2014

Keywords

Ice-cream
Fermented glutinous rice
Hydrocolloids
Physical properties
Sensory

Abstract

The aim of this work is to study the effect of hydrocolloids (guar gum, xanthan gum and carboxymethyl cellulose (CMC) on the physical properties and sensory evaluation of ice cream produced in order to investigate the potential of applying fermented glutinous rice (*tapai pulut*) as a value-added ingredient. The addition of 25% fermented glutinous rice was the most reliable amount to enhance the physical and sensory properties of ice cream when incorporating hydrocolloids. The addition of hydrocolloids significantly ($p < 0.05$) increased the pH, firmness, overrun, and melting rate of fermented glutinous rice ice cream. The addition of guar gum scored the highest firmness value (5403 g) followed by CMC (4630 g) and xanthan gum (3481 g). Fermented glutinous rice ice cream with xanthan gum added, induced a noticeable change in overrun value (62%) while the addition of CMC decreased the melting rate compared to the control. The FTIR spectrum of fermented glutinous rice ice cream with different hydrocolloids containing carboxyl, amide and carbonyl group was appeared at 3362-3379 cm^{-1}, 1639-1640 cm^{-1} and 1026-1064 cm^{-1}, respectively. In conclusion, the addition of xanthan gum presented great potential to improve the quality of fermented glutinous rice ice cream produced in terms of its firmness, overrun and melting rate.

Introduction

Fermented glutinous rice or tapai pulut is an instant traditional food consumed in Asia, especially in the South East region, which includes Indonesia, Malaysia, Philippines and China. In Malaysia, fermented glutinous rice (*tapai pulut*) is consumed freshly after being chilled or added in a dessert such as ice-cream or cendol (Law *et al*., 2011). It is consumed in different ways in different countries. For instance, in India, where it is known as tape Katella, is consumed after frying in oil and made by fermenting cassava roots (Joshi and Pandey, 1999). *Tapai pulut* is a fermented food product that has a sweet, sour and mildly alcoholic taste. The alcoholic taste comes from the fermentation process of glutinous rice, which involves starch hydrolysis by inoculum (fermentation starters) also referred to as 'ragi' in Southeast Asian countries or 'koji' in Japan (Nik *et al*., 2010) where it is produced using an ethanol compound. This process causes the *tapai pulut* to have a higher acidic content (pH range, 3.4 - 4.0) (Zaharah and Yeoh, 2004).

In many of the research conducted, fermented food products have their own benefit on human health. According to Steinkraus (1994), fermented foods have great potential for nutritional significance because they provide and preserve a vast quantity of nutritious food in a wide diversity of flavours, aromas and textures that enrich the human diet. Steinkraus (1994) also found that tapai pulut provided enrichment through its protein content. To transform that benefit, the fermented food, especially *tapai pulut*, should be included in the most consumed and popular foods such as ice cream. Cruz *et al.* (2009) reported that ice cream is a highly accepted product by children, adolescents, and adults, as well as by the elderly.

However, the development of a new food product is increasingly challenging, as it has to fulfil consumer expectations for products that are simultaneously relished and healthy (Cruz *et al*., 2009). According to Erkaya *et al.* (2011), the use of some ingredients in ice cream manufacture that have nutritional and physiological properties, such as some fruits, probiotics, alternative sweeteners, dietary fibres and natural antioxidants, has increased due to the increasing consumer interest in healthier and functional food in recent years. However, consumers prefer products that contain natural ingredients compared to artificial food products and prefer to use probiotic products (Cruz *et al*., 2009), such as *tapai pulut*, which contain natural ingredients from yeast fermentation.

Many studies have been conducted to determine the effects of hydrocolloids on the properties of ice

*Corresponding author.
Email: *norizah@umt.edu.my*
Tel: + 609 668 4968; Fax: + 609 668 4949

cream (Mousavi *et al.*, 2003; Murtaza *et al.*, 2004; Soukoulis *et al.*, 2008; Moeenfard and Tehrani, 2008). The primary purpose for using hydrocolloids as a stabilizer in ice cream is to improve the viscosity, stabilize the mix, aid in suspension of flavouring particles, produce stable foam, provides uniformity and to produce smoothness in texture during consumption (Marshall *et al.*, 2003). In addition, the selected hydrocolloids affect the storage quality of ice cream (Soukolis *et al.*, 2008). In rheological properties, xanthan gels are freely flowing, and thus, perform a strong shear thinning behaviour, while guar gum and CMC are characterized by a random coil conformational ability, which also favours pseudo plasticity (shear thinning of fluid mechanism), albeit to a lesser extent. Hwang *et al.* (2009) also reported that the addition of hydrocolloids as a stabilizer or polysaccharide to ice cream will increase the viscosity and reduce the melting rate of the ice cream. According to Murtaza *et al*. (2004), the typical compositional range of hydrocolloids in ice cream is 0-0.5%. Therefore, in our study we used 0.3% of hydrocolloids to incorporate into fermented glutinous rice ice cream which was within the typical compositional range that commonly used.

Fermented glutinous rice (*tapai pulut*) provides a good supply of protein in ice cream production. This is a good way to develop *tapai pulut* ice cream as a source of protein since the protein requirement and other sources of vitamin and essential amino acids are provided in fermented food (Steinkraus, 1997). The development of tapai pulut ice cream is one way of providing a healthy diet that is convenient to be consumed, which is in accordance with the preference of consumers nowadays. *Tapai pulut* was evaluated because it is a traditional food dessert that has great potential to meet the modern trend for diversification in the consuming style. Therefore, the objectives of this study are to produce fermented glutinous rice (*tapai pulut*) ice cream, as well as to determine the best formulation of fermented glutinous rice (*tapai pulut*) ice cream, to investigate the effects of different hydrocolloids (guar gum, xanthan gum and carboxymethyl cellulose (CMC)) on the physical properties (pH, firmness, overrun, melting rate, color, structure) and the overall acceptance level of the fermented glutinous rice (*tapai pulut*) ice cream produced.

Materials and Methods

Materials

The main ingredients for fermented glutinous rice (*tapai pulut*) production were glutinous rice and fermentation starters (*ragi*). Glutinous rice was purchased from the local market at Kuala Terengganu, Terengganu, Malaysia. The fermentation starter (*ragi*) was obtained from the Malaysian Agricultural Research and Development Institute (MARDI) Serdang, Selangor, Malaysia. The materials for ice cream were purchased from the local market in Kuala Terengganu, Terengganu, Malaysia. The three types of hydrocolloids; guar gum (GG), xanthan gum (XG) and carboxymethyl cellulose (CMC) were obtained from Sigma.

Preparation of fermented glutinous rice (tapai pulut)

Fermented glutinous rice (*tapai pulut*) was prepared by using the steaming method. In preparation of tapai pulut, 500 g of glutinous rice was washed and soaked for 1 h before cooking. The cooked glutinous rice was then steamed for 20 mins. At this stage, the glutinous rice was half cooked. Approximately 300 ml of water was added into the steamed glutinous rice and mixed well before it was steamed again for 15 mins. The steamed glutinous rice was cooled at room temperature before 0.1% of 'ragi' (in powder form) was spread over the glutinous rice and mixed well. Fermented glutinous rice was obtained after the fermentation process for 48 to 72 h at room temperature.

Preparation of fermented glutinous rice (tapai pulut) ice cream

The ice cream was prepared by mixing 125 g egg yolk and 140 g castor sugar until thick and light as described by Gisslen (2010). Approximately 500 ml of fresh milk was gradually scalded and tempered with the egg mixture. The mixtures were heated for about 20-30 sec until reaching 80^oC for pasteurisation before each hydrocolloid was added. The mixtures were then added to 250 ml of cold whipping cream and stirred quickly to stop the cooking process. The mixtures were kept in the chiller for 1 h at 4^oC for the aging process and 1.0 ml of vanilla essence was added. *Tapai pulut* was added prior to the freezing process, which was conducted for about 1 h using a soft serve ice cream machine (GELATO PRO 3000, UK). Ice cream samples were then stored at -18^oC in a blast chiller.

Different formulations of tapai pulut ice creams produced such as Formulation 1 (F1) (10% *tapai pulut* added), Formulation 2 (F2) (15% *tapai pulut* added), Formulation 3 (F3) (25% *tapai pulut* added) and Formulation 4 (F4) (50% *tapai pulut* added) were developed and sensory evaluation of the overall acceptance as described in sensory analysis was conducted in order to determine the best formulation of tapai pulut with ice cream. The most accepted formulation by the panel was used as a sample to incorporate with hydrocolloids.

The result obtained from the first phase sensory evaluation conducted (Table 1) showed that 25% *tapai pulut* added in ice cream has been choosen for the further analyses. Therefore, five samples of *tapai pulut* ice cream were evaluated in further analyses. These included the control, ice cream with 25% *tapai pulut* added (F3) (the most accepted formulation), *tapai pulut* ice cream with guar gum added (S1), *tapai pulut* ice cream with xanthan gum added (S2) and *tapai pulut* ice cream with CMC added (S3). Each of ice cream samples was incorporated with the same volume of hydrocolloid (0.3%) and the analysis was conducted in triplicate.

Determination of pH

The determination of pH was conducted according to the method by Hwang *et al.* (2009). About 10 g of ice cream samples were dissolved in 90 ml of distilled water. After homogenization, the pH was measured by using a pH meter (CyberScan Series 600, pH-10^3 Merthom/Brinkmann, Brinkmann Instrument Inc., Westbury, NY), which was calibrated by using a standard pH buffer solution, (pH 7 and pH 4). The values were presented as the means of triplicate analyses.

Determination of firmness

The firmness of ice cream samples were measured according to the method described by Hwang *et al.* (2009). The firmness of ice cream was determined by using a texture analyser (Stable Micro System, Godalming, UK) with a load cell of 5 kg, cylinder probe (diameter 50 mm). The samples were cut into 2.5 x 2.5 x 2.5 cm cubes and compressed at a speed of 10 mm/s and return strain of 50 mm. The reading was the average of three determinations. The firmness of the samples was determined as the peak of compression force (in g) detected when the probe proceeded to penetrate into the ice cream. The values were presented as the means of triplicate analyses.

Determination of overrun

To determine the overrun, the ice cream mix was put in a standard 200 ml cup and weighed. Once the ice cream mix was made into frozen ice cream, the same volume of frozen ice cream was cut and put in the container. The overrun was calculated according to the standard equation as below (Laaman, 2011).

$$\text{The overrun} = \frac{(W_A - W_B)}{W_B} \times 100$$

Where, W_A = weight of mix for fixed volume
W_B = weight of finished product for fixed volume

The sample in the same volume was weighed before and after the ice cream mix was made into frozen ice cream. The sample was performed in triplicate and the result obtained was expressed as mean ± SD.

Determination of colour

The colour changes were measured according to the method described by Hwang **et al.** (2009). The colours of the samples were determined by using a Colorimeter, Chromameter (Model CR-400, Konica Minolta Sensing, Inc., Osaka, Japan). The colorimeter was calibrated with a white tile (L^* = 93.80, a^* = 0.3111, b^* = 0.3196). The sample was placed in a 25 ml plastic cup with an upper diameter of 5.5 cm. The screen on the glass light projection tube was pressed on the sample for light penetration. The results were shown on the screen of the colorimeter and were recorded according to the value of lightness (L^*), greenness/redness (a^*) and blueness/yellowness (b^*). The result was expressed as mean ± SD.

Determination of melting rate

The melting rate tests were conducted as described by Sofjan and Hartel (2004), with some modification. The melting rate was measured at room temperature (20°C). About 50 g of ice cream sample was weighed and placed on a 2 cm cooling rack above a small aluminium bowl, which was used to collect the melted ice cream. The timing of the melt down rate began when the first drop of material that melted touched the bottom of the bowl. The amount of melted sample was recorded every 5 mins until the ice cream completely melted. The first dripping and complete melting times of the samples were determined in seconds. The melting rate was determined based on graphs of the melted portion as a function of time. This analysis was performed in triplicate and the results obtained were expressed as mean ± SD.

Sensory analysis

The sensory evaluation was conducted by 30 untrained panellists. A 7 point hedonic scale, anchored by ‘dislike extremely’ and ‘like extremely’ was employed and the score test used comprised flavour, body and texture (firmness), colour and appearance, resistant to melting and overall acceptability (Klesment *et al*., 2011).

Two phases of sensory evaluation were carried out in this study. The first phase of sensory evaluation was to determine the best formulation of different quantities of *tapai pulut* (fermented glutinous rice) in the ice cream produced. The samples included control (original ice cream), formulation 1 (10% of *tapai pulut* added), formulation 2 (15% of *tapai pulut* added), formulation 3 (25% of *tapai pulut* added) and formulation 4 (50% of *tapai pulut* added). The second phase of sensory evaluation involved 5 samples, which included control, formulation 3 (25% of *tapai pulut* added), sample 1 (formulation 3 + 0.3% guar gum), sample 2 (formulation 3 + 0.3% xanthan gum) and sample 3 (formulation 3 + 0.3% CMC) in order to determine the most accepted *tapai pulut* (fermented glutinous rice) ice cream among these three different hydrocolloids used.

Fourier Transform Infrared (FTIR) analysis

Fourier Transform Infrared (FTIR) spectroscopy (Bruker Instruments, Billerica, MA) was used in order to identify the functional groups obtained in the fermented glutinous rice (*tapai pulut*) ice cream produced. In FTIR analysis, samples of the ice cream were placed on the sample compartment of the spectroscope. The FTIR spectra of samples were obtained using a Golden-gate Diamond single reflectance ATR in a FTS 7000 FTIR spectrophotometer with a DTGS detector (Nicolet 380). The spectra of fermented glutinous rice (*tapai pulut*) ice cream were recorded at the absorbance mode from 1000 to 4000 cm^{-1} with a resolution of 4 cm^{-1} with 128 co-added scans (Pavia *et al*., 2009).

Statistical analysis

Statistical analysis was performed using software MINITAB14 for windows version to calculate the mean ± SD of values for each sample. All data were analysed using the one-way ANOVA method and the level of significance used was 95% ($p < 0.05$); using Fisher's test. The graphical treatment data were imported into the graphics package of MS Excel.

Results and Discussion

Production of fermented glutinous rice (tapai pulut) ice cream

Table 1 shows that there was no significant difference ($p > 0.05$) between the formulations on aroma, colour, sweet and sour taste, after taste and overall acceptance between all samples of tapai pulut ice cream in the first phase of sensory evaluation conducted in order to determine the best formulation. However, a significant difference was observed between formulation 1 (F1), formulation 2 (F2) and formulation 3 (F3) with formulation 4 (F4) for texture.

Table 1 presented that the result obtained for taste acceptance was higher for F2 and F3 than control. However, F4 presented a less acceptance as compared to all samples which the score was only 4.13. The addition of 50% fermented glutinous rice (*tapai pulut*) in F4 probably caused the taste of the original ice cream to change and resulted in the strong taste of fermented glutinous rice (*tapai pulut*).The addition of fermented glutinous rice (*tapai pulut*) decreased the acceptance level of aroma, colour and texture compared to the control sample (Table 1). However, there were no significant difference ($p > 0.05$) in these attributes between control and all samples except for the texture acceptance of S3. The addition of 25% fermented glutinous rice (*tapai pulut*) in F3 increased the acceptance level of sweet and sour taste, after taste of fermented glutinous rice (*tapai pulut*) and overall acceptance when compared to other formulations (first phase sensory). Therefore, tapai pulut ice cream with 25% of *tapai pulut* added (F3) was considered to be selected as the best formulation to carry out for further analyses.

Table 1. Sensory evaluation (I) on determination of formulation

Sample	Attribute					
	Aroma	Colour	Texture	Sweet and sour taste	After taste	Overall acceptance
Control	5.13±1.55^a	5.39±1.20^a	5.26±1.54^a	4.17±1.92^a	4.30±1.74^a	4.65±1.77^a
F 1 (10% of *tapai pulut*)	4.74±1.39^a	5.09±1.31^a	4.74±1.51^a	4.44±1.34^a	4.52±1.56^a	4.52±1.53^a
F 2 (15% of *tapai pulut*)	4.61±1.70^a	5.17±1.64^a	4.65±1.61^a	4.48±1.90^a	4.56±1.53^a	4.48±1.65^a
F 3 (25% of *tapai pulut*)	4.91±1.23^a	5.35±1.11^a	4.65±1.34^a	4.78±1.28^a	5.00±1.35^a	5.30±1.02^a
F 4 (50% of *tapai pulut*)	4.52±1.56^a	4.83±1.70^a	3.04±1.46^b	4.13±1.39^a	4.30±1.42^a	4.26±1.71^a

*Data are expressed as mean ± standard deviation. $^{a-b}$ within a row with different letters are significantly different ($p < 0.05$).

Table 2. The effect of different hydrocolloids on the physical properties of fermented glutinous rice (*tapai pulut*) ice cream

Ice cream sample	pH	Firmness (g)	Overrun (%)	Colour		
				L	a*	b*
Control	6.71±0.00^a	1423.50^b	40.59±31.62^{ab}	88.36±0.36^b	-4.06±0.22^a	+30.82±0.82^{bc}
F3	6.01±0.01^d	2721.92^{ab}	6.48±7.47^c	86.27±0.58^c	-5.22±0.02^c	+33.84±1.10^a
S1 (guar gum)	6.13±0.02^b	5402.50^a	38.06±37.30^b	89.25±0.06^b	-4.65±0.04^b	+30.54±0.11^{bc}
S2 (xanthan)	6.08±0.01^c	3480.73^{ab}	61.86±34.86^a	91.15±1.41^a	-4.76±0.13^b	+28.48±0.24^c
S3 (CMC)	6.15±0.00^b	4630.38^a	23.87±23.46^b	88.47±0.09^b	-4.53±0.02^b	+31.05±0.82^b

*Data are expressed as mean ± standard deviation. $^{a-c}$ within a row with different letters are significantly different ($p < 0.05$).

pH determination

The addition of *tapai pulut* significantly decreased ($p < 0.05$) the pH value of F3 as compared to control (without *tapai pulut*), as shown in Table 2. This was due to the acidification of the medium during fermentation process of *tapai pulut* (Kimaryo *et al.*, 2000). Conversely, the pH value slightly increased when the hydrocolloids were added into tapai pulut ice cream. *Tapai pulut* ice cream without hydrocolloids (F3) had the lowest pH value (6.01 ± 0.01) and was significantly different ($p < 0.05$) among all the ice cream samples. However, the use of hydrocolloids significantly ($p < 0.05$) increased all the pH of the different tapai pulut ice creams. The pH of the sample ice cream with guar gum and CMC added was not significantly different ($p > 0.05$) while xanthan gum shows a lower pH compared to the ice cream with guar gum and CMC added. A study by Soukoulis *et al.* (2010) showed that there were similar effects on the pH with the addition of guar gum (5.41 ± 0.09), xanthan gum (5.22 ± 0.09) and CMC (5.49 ± 0.11) to the probiotic ice cream. The results indicated that guar gum and CMC had increased the pH value for the acidic content of ice cream compared to xanthan gum. The increased of pH may result from the hydrocolloid characteristic of being a stabilizer. According to Regand and Goff (2003); Soukoulis *et al.* (2007), the stabilizer must be used in partially or fully acidified frozen dairy desserts because the vulnerability of stabilizers to acidic conditions is of particular importance for their action, which is stable in fermented milk and assists in thickening.

Firmness properties

The firmness of ice cream is related to the structure and texture, which would affect the acceptance level of the ice cream (Lim *et al.*, 2010). Results obtained showed that the firmness of F3, S1, S2 and S3 ice creams produced were significantly increased ($p < 0.05$) by the addition of fermented glutinous rice (*tapai pulut*) into the ice cream as compared to the control (Table 2). The increased of firmness values of the ice creams was due to the starch contained in the rice granule that thickened the ice cream mixture (Abbas *et al*., 2010).

The highest score for firmness was obtained by the addition of guar gum (5402.50 g) followed by CMC (4630.38 g) and xanthan gum (3480.73 g) to the fermented glutinous rice (*tapai pulut*) ice cream. In comparison, ice cream with guar gum and CMC added was firmer than the control while F3 and xanthan gum was not significantly different from any sample. The higher firmness score for the ice cream with guar gum and CMC added was because both hydrocolloids were stable over the range of pH and have a high viscosity (less air was incorporated into an ice cream) (Phillips and Williams, 2000). The results obtained by Hwang *et al*. (2009) showed that the firmness of ice cream decreased with the increase in grape wine lees concentration. Conversely, in this study, the addition of *tapai pulut* increased the firmness of the ice cream compared to the control sample however, there was no significant difference ($p > 0.05$) between both samples. Xanthan gum was a good hydrocolloid to increase the smoothness of ice cream with the lowest score of firmness compared to the ice cream with guar gum and CMC added and was able to maintain the viscosity over a broad pH range compared to ice cream with guar gum and CMC added.

The lower firmness resulting from the addition of xanthan gum was due to the higher overrun property. Less firmness means that more air was incorporated, which resulted in the higher overrun and increased smoothness of the ice cream. In the preparation of ice cream, more air corporation with the smaller size is needed to stabilize the ice cream. The results showed that the addition of xanthan gum was the best choice to increase the smoothness of the ice cream. However, based on the results in Table 2, the firmness of all ice cream samples were not significantly difference ($p > 0.05$). Therefore, it can be concluded that the incorporation of hydrocolloid did not influence the firmness of the fermented glutinous rice (*tapai pulut*) ice cream.

Overrun properties

The results in Table 2 showed that the addition of xanthan gum into fermented glutinous rice (*tapai pulut*) ice cream presented the highest value (61.86%) followed by guar gum (38.06%) and CMC (23.87%) in overrun property. Meanwhile, the addition of these hydrocolloids into fermented glutinous rice (*tapai pulut*) ice cream significantly increased ($p < 0.05$) the overrun values as compared to F3 and there was a significant difference ($p < 0.05$) in overrun value between control and S1, S2 and S3. The overrun value was influence by the whipping force applied to the ice cream mixture during freezing and the aeration process in the ice cream freezer, which was strong enough to break and distribute air bubbles into the same shape and size (Sofjan and Hartel, 2004). The air bubbles in these mixes were immediately trapped in the unfrozen serum phase by crystallized fat partial coalescence and fixed by ice crystals during the freezing process (Thaiudom *et al.*, 2008). Based on the results in Table 2, it showed that the whipping force of fermented glutinous rice (*tapai pulut*) ice cream with the incorporation of hydrocolloids had strong whipping force to break and distributes air bubbles in the mixture.

There were several studies on overrun of ice cream made by different types of hydrocolloids. A research conducted by Moeenfard and Tehrani (2008) showed the overrun range of 39% - 47% in ice cream type frozen yogurt incorporated with different type and concentration of stabilizers while Murtaza *et al.* (2004) showed the overrun range of 53% - 58% in ice cream prepared with different stabilizers. The other research conducted by Soukoulis *et al.* (2008) showed the overrun range of 50% - 100% in ice cream with different hydrocolloids and κ-carrageenan. Based on the results from other studies, it can be concluded that the overrun values of ice cream with the incorporation of hydrocolloids from our study with the exception of overrun value obtained by ice cream with CMC were within the range of the overrun values obtained from other studies.

Colour measurement

As shown in Table 2, the L^* value indicated the lightness of the sample colour. The control sample presented a similar result (88.36 ± 0.36) as obtained by Herald *et al*. (2008) for the L^* value of vanilla ice cream (88.11 ± 0.18). The L^* value was significantly ($p < 0.05$) lower after the addition of 25% of tapai pulut as in F3. However, the addition of hydrocolloids significantly increased the L^* value but was not significantly different ($p > 0.05$) from the control sample except for the fermented glutinous rice (*tapai pulut*) ice cream with xanthan gum added. *Tapai pulut* ice cream with xanthan gum scored the highest L^* value (91.15 ± 1.41) and was significantly different ($p < 0.05$) among the other formulations, which may due to the higher overrun and low firmness properties as it was able to incorporate more air during the freezing stage. The increased value for lightness in this study was similar to the finding by Laaman (2011), in which products incorporating hydrocolloids were brighter. From the results obtained, it can be concluded that the addition of xanthan gum would improve the L^* value of the ice cream as compared to the control. Therefore, ice cream with xanthan gum had the highest lightness as compared to other ice cream formulations. This is supported by Izydorczyk *et al.* (2005), in which xanthan gums are able to give excellent suspension to ice cream mixture thus contribute to the lightness property (L^* value).

The negative value in a^* indicated the green colour of the sample. As shown in Table 2, the addition of fermented glutinous rice (*tapai pulut*) significantly increased the a^* value ($p < 0.05$). Although, the addition of hydrocolloids into fermented glutinous rice (*tapai pulut*) ice cream decreased the a^* value, there is no significant different ($p > 0.05$) between all samples. This indicated that each type of hydrocolloid had a similar effect on decreasing the greenness of fermented glutinous rice (*tapai pulut*) ice cream.

The positive value in b^* indicated the yellow colour of the sample. The addition of fermented glutinous rice (*tapai pulut*) in F3 significantly increased the b^* value ($p < 0.05$). This showed that the presence of granules of fermented glutinous rice (*tapai pulut*) in ice cream increased the yellowness of the ice cream sample. However, when fermented glutinous rice (*tapai pulut*) ice cream were incorporated with hydrocolloids, the b^* value was significantly decreased ($p < 0.05$). The addition of xanthan gum in fermented glutinous rice (*tapai pulut*) ice cream presented the lowest score and was significantly different ($p < 0.05$) compared to that to which guar gum and CMC had been added. This indicated that the use of xanthan gum resulted in different effects on fermented glutinous rice (*tapai pulut*) ice cream. It showed that the highest score for lightness (L^* value), greenness (a^* value) and the lowest score for yellowness (b^* value) compared to the addition of guar gum and CMC. The positive value in b^* indicated the redness and yellowness colour of the sample. The addition of fermented glutinous rice (*tapai pulut*) in F3 significantly increased the b^* value (+33.84) ($p < 0.05$). This showed that the presence of granules of fermented glutinous rice (*tapai pulut*) in ice cream increased the yellowness value of the ice cream. However, when fermented glutinous rice (*tapai pulut*) ice cream incorporated with hydrocolloids, the b^* value was significantly decreased ($p < 0.05$) in S1 (+30.54), S2 (+28.48) and S3 (+31.05). In contrast to the lightness, the b^* values of all samples were decreased with the incorporation of hydrocolloids in ice creams. The addition of xanthan gum in fermented glutinous rice (*tapai pulut*) ice cream presented the lowest score of b^* value and was significantly different ($p < 0.05$) compared to the ice cream with CMC added.

In conclusion, ice cream with xanthan gum adeed showed the highest score for lightness (L^* value), and the lowest score for yellowness (b^* value) compared to the addition of guar gum and CMC. According to Keshtkaran and Mohammadifar (2013), the intensity of the light scattered is proportional to the particle size. Therefore, the intensity of the light scattered difference in L^*, a^* and b^* values of all formulations was due to the presence of the rice granules with different sizes that contained in the ice cream.

Melting rate

The addition of 25% of *tapai pulut* (F3) resulted in the increased melting rate, which was completely melted in the shortest time (13 mins) as compared to other samples. This was possibly due to the low acidic content of fermented glutinous rice (*tapai pulut*) in ice cream. A similar result was obtained by Hwang *et al*. (2009), who confirmed that an increase in the acidic component of ice cream increased the melting rate. Sofjan and Hartel (2004) found that ice cream with a lower overrun value might possibly melt quicker than that made with higher overrun due to other factors, such as the difference in fat destabilization or air cell and ice crystal size.

Figure 1 demonstrates the effects of the addition of different hydrocolloids on the melting rate of

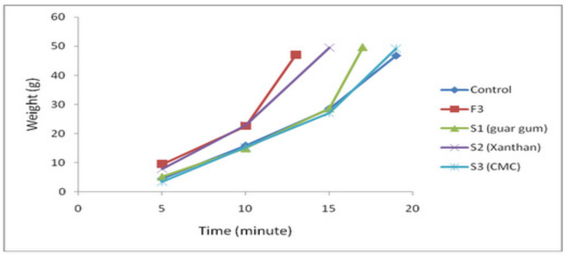

Figure 1. The effect of hydrocolloids on the melting rate of fermented glutinous rice (*tapai pulut*) ice cream

Table 3. Sensory evaluation (II) on different formulations of ice cream incorporated with hydrocolloids

Sample	Attribute				
	Colour and appearance	Flavour	Body and texture	Resistant to melting	Overall acceptance
Control	5.33 ± 1.27^{a}	5.90 ± 1.23^{a}	5.30 ± 1.34^{a}	5.20 ± 1.50^{a}	5.93 ± 0.91^{a}
S1 (guar gum)	5.47 ± 1.22^{a}	5.40 ± 1.55^{a}	5.03 ± 1.16^{a}	4.78 ± 1.31^{a}	5.20 ± 1.38^{a}
S2 (xanthan gum)	5.03 ± 1.52^{a}	5.30 ± 1.42^{a}	4.40 ± 1.16^{a}	4.60 ± 1.28^{a}	5.17 ± 1.37^{a}
S3 (CMC)	4.97 ± 1.40^{a}	5.27 ± 1.64^{a}	4.67 ± 1.38^{a}	4.73 ± 1.39^{a}	5.03 ± 1.67^{a}

*Data are expressed as mean ± standard deviation. $^{a-b}$ within a row with different letters are significantly different ($p < 0.05$).

fermented glutinous rice (*tapai pulut*) ice cream. The addition of xanthan gum resulted in a higher melting rate (completely melted within 15 min) compared to guar gum and CMC. Based on the previous results, the score for firmness and overrun (Table 2) determination for *tapai pulut* ice cream with the addition of xanthan gum was higher than fermented glutinous rice (*tapai pulut*) ice cream with the addition of guar gum and CMC. These results demonstrated that xanthan gum was able to increase the melting rate of fermented glutinous rice (*tapai pulut*) ice cream compared to guar gum and CMC. This may due to the natural characteristic of xanthan gum which quickly dispersed into the mixture when it is added (Naresh and Shailaja, 2006). However, the dispersion of xanthan gum in the ice cream mixture might be disturbed by the presence of glutinous rice which not well grinds during sample preparation, thus resulting in the disability of the xanthan gum to disperse uniformly. Sofjan and Hartel (2004) found that a higher overrun decreased the hardness and increased the melting rate of ice cream, which was similar to the results obtained.

In this study, the extent of fat destabilization and ice crystal size was not measured. However, based on Sofjan and Hartel (2004), a slower melting rate was due to greater fat destabilization, which was influenced by the higher shear stress that occurred with higher overrun. Another potential cause of the slower melting rate with higher overrun may cause by the difference in heat transfer rate due to the greater presence of air. Air is a good insulator and undoubtedly slowed the rate of heat transfer into the ice cream with higher overrun.

In addition, it has been reported that the addition of a hydrocolloid stabilizer or polysaccharides in ice cream reduced the melting rate (Goff and Sahagian, 1996; Segall and Goff, 2002). CMC was observed to slow the meltdown and improve resistance to dripping (Phillips and Williams, 2000). However, the use of xanthan in fermented glutinous rice (*tapai pulut*) ice cream has greater potential compared to guar gum and CMC. The lowest melting rate scored by CMC also supported the research by Murray *et al.* (2000), where the addition of CMC slowed down the melting rate and improved its resistance to dripping.

Sensory evaluation

The sensory analysis conducted in this study, would be a great advantage to investigate the effects of different hydrocolloids on the sensory profile of fermented glutinous rice (*tapai pulut*) ice cream. Table 3 shows the scores for the acceptance level (second phase sensory) of fermented glutinous rice (*tapai pulut*) ice cream. The results obtained showed that there were no significant differences ($p > 0.05$) between each of the hydrocolloids for colour and appearance, flavour and resistance to melting attribute. This showed that each hydrocolloid had similar effects on the colour and flavour of fermented glutinous rice (*tapai pulut*) ice cream, in which the panel found it hard to identify a difference. For the body and texture, there were no significant differences ($p > 0.05$) between guar gum, xanthan gum and CMC, however, guar gum also had no significant difference ($p > 0.05$) to the control sample. In overall acceptance, there were no significant differences ($p > 0.05$) among the types of hydrocolloid that were added but there was a significant difference ($p < 0.05$) with the control sample.

The results indicated that none of the hydrocolloids added have a different effect on the sensory evaluation of fermented glutinous rice (*tapai pulut*) ice cream. However, the overall acceptance was the control sample which obtained the highest acceptance score compared to the fermented glutinous rice (*tapai pulut*) ice cream with hydrocolloids. Although the ice cream with hydrocolloids incorporation did not score the highest acceptance, the average score was still within the ranged of acceptance level (4 to 6) (like moderately-very like). A study conducted by Soukoulis *et al.* (2008) showed that ice cream with xanthan gum had the highest score on the flavour. The same result was also shown for the resistant to melting attribute as xanthan gum was the most efficient cryoprotectant based on the instrumental data. However, Table 3 showed that fermented glutinous rice (*tapai pulut*) ice cream with xanthan gum obtained the same score with guar gum and CMC in terms of flavour, resistant to melting and colour. Meanwhile, fermented glutinous rice (*tapai pulut*) ice cream with guar gum had higher score on colour and body and texture compared to xanthan gum and CMC. The result of the higher score on body and texture of fermented glutinous rice (*tapai pulut*) ice cream with guar gum was in the same agreement with the study conducted by Klesment *et al.* (2011). As a conclusion, the development of fermented glutinous rice (*tapai pulut*) ice cream was accepted by the panellists.

FTIR Spectroscopy

The application of infrared spectroscopy on dairy products is a valuable technique to investigate the condition of the structure on the texture and flavour properties (Karoui *et al.*, 2003). Thus, the application of FTIR techniques would be valuable in this study and have broad applications in understanding the food structure and properties. The FTIR results have been shown in the abstract. The structure properties of fermented glutinous rice ice cream produced has been investigated through the functional group detected from the FTIR spectrum. While, the flavour of fermented glutinous rice ice cream has been evaluated using FTIR through the present of functional group such as hydroxyl and carboxyl group which was 3362-3379 cm^{-1} and 1026-1064 cm^{-1}, respectively.

Figure 2 demonstrates the FTIR spectra of ice cream for sample C (control), which was in the range of 4000-700 cm^{-1}. The peak at 3371 cm^{-1} was responsible for O-H banding, which is associated with water. According to Safar *et al.* (1994), water is a very strong infrared absorber with prominent bands centred at 3360 cm^{-1} (H-O stretching band), at 2130 cm^{-1} (water association band) and at 1640 cm^{-1} (the H-O-H bending vibration). However, the addition of fermented glutinous rice (*tapai pulut*) increased the transmittance percentage (%) of water to 3385.1 cm^{-1}, as shown in Figure 3. Figure 3 presents the spectra of F3 (ice cream with 25% of *tapai pulut*). The increased wavenumber was possibly due to the presence of alcohol in the fermented glutinous rice. According to Coates (2000), the high degree of association between hydroxyl and the ether compound results in extensive hydrogen bonding with other hydroxyl groups. A strong hydrogen bonding will be presented at lower frequency. Therefore, the wavelength increase of 14.1 cm^{-1} (3371 to 3385.1 cm^{-1}) was due to the presence of weak bonding of ethyl alcohol in fermented glutinous rice (*tapai pulut*), which interacted with the water solution in the ice cream.

Furthermore, the amine group of the ice cream with and without fermented glutinous rice (*tapai pulut*) added were presented in the range of 1641-1640 cm^{-1}, as shown in Figure 2 and 3, respectively.

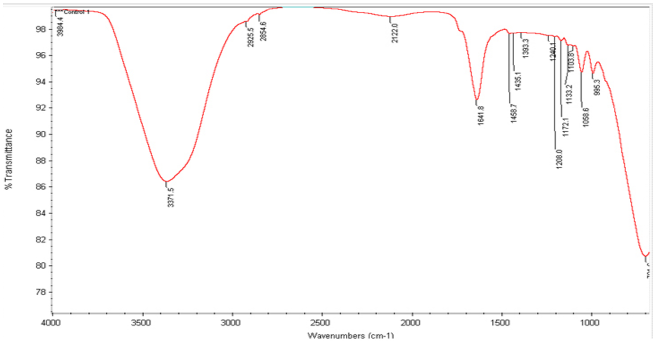

Figure 2. FTIR spectrum of control sample of ice cream in the range of 4000-700 cm^{-1}

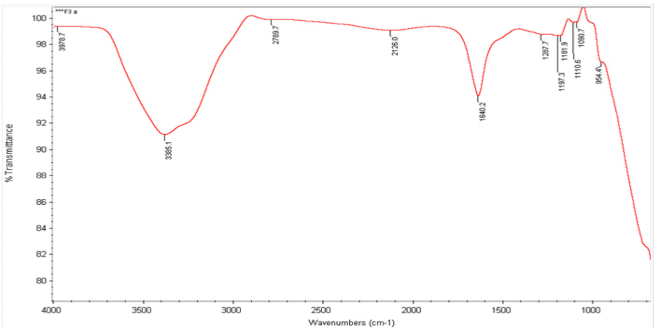

Figure 3. FTIR spectrum of Formulation 3 (25% of tapai pulut ice cream) in the range of 4000-700 cm^{-1}

According to Fox (1989), Amide I and Amide II bands (1700-1500 cm^{-1}) are known to be sensitive to the conformation adopted by the protein backbone. Coates (2000) observed that the amine and amino compounds group frequency ranged between 1650 and 1550 cm^{-1} for the secondary amine (N-H bend). Based on the results observed in Figure 2 and Figure 3, it showed that the addition of fermented glutinous rice (*tapai pulut*) was not strongly affected by the amino group in the ice cream.

In this study, the range of 1172-1058 cm^{-1} for the control sample and the range of 1197-1090 cm^{-1} for the F3 sample was expected due to the presence of glucose in the samples. This result showed that ice cream with fermented glutinous rice (*tapai pulut*) increased in the C-O-C group due to the glucose molecule production as the end product of starch hydrolysis during fermentation process. According to Nik *et al.* (2010), a glucose structure was shown in the FTIR spectra in the range of 1152-1078 cm^{-1} with the C-O-C group in a six membered ring while the alcohol compound was shown in the peak range of 1420-1228 cm^{-1}.

Furthermore, secondary amine with C-N stretch was presented in the range of 1190-1130 cm^{-1} (Coates, 2000). There were several components in the same range due to the chemical interaction of fat, protein and glucose from fermented glutinous rice (*tapai pulut*) during the mixing process. Based on the spectrum obtained, the major compound involved

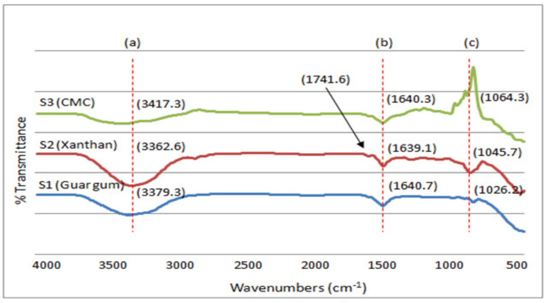

Figure 4. FTIR spectrum for fermented glutinous rice (tapai pulut) ice cream with hydrocolloids. S1-guar gum, S2- xanthan gum, S3- CMC

was in the range of 1197-1058 cm^{-1} in both the control and F3 sample. This was probably the amine group, which is equal to the protein compound, and was due to the increase in transmittance peak after the addition of fermented glutinous rice (*tapai pulut*) into an ice cream that contains high protein. Thus, the FTIR application provided excellent analysis to explore the effects of hydrocolloid to the ice cream properties in this study. Figure 4 demonstrates the FTIR spectra of fermented glutinous rice (*tapai pulut*) ice cream incorporating guar gum, xanthan and CMC, respectively. Several peaks of the FTIR spectra were affected by different types of hydrocolloid. On line (a) (Figure 4), the wavenumber range of 3379-3417 cm^{-1} was responsible for O-H bonding, which is associated with water (Safar *et al*., 1994). The addition of different types of hydrocolloid resulted in the different wavelengths on the O-H bonding. Xanthan gum showed the lowest range of wavelength (3362.6 cm^{-1}) while CMC showed the highest range of wavelength (3417.3 cm^{-1}). The low range of wavelength as xanthan gum added was due to its viscosity properties. Xanthan gum in solution is also able to form intermolecular associations that result in the formation of a complex network of weakly bound molecules (Sworn and Monsanto, 2000).

The results obtained by FTIR also confirmed the previous results on firmness and overrun (Table 2). The lower the range of O-H bonding in the water group as xanthan was added shows that the water was weakly absorbed, which resulted in a lower firmness and higher overrun. The high water content affected the smooth texture of fermented glutinous rice (*tapai pulut*) ice cream with xanthan gum more than the other hydrocolloids. In a study by Phillips and Williams (2000), CMC added was observed to affect the slow meltdown and improve resistance to dripping. This supported the result of the high wave number obtained by CMC added, which is more stable and has strong hydrogen bonding.

In addition, a wave number of 1741.6 cm^{-1} was detected in the fermented glutinous rice (*tapai pulut*) ice cream with the xanthan gum added. The wavenumber of 1750 cm^{-1} (C=O) was responsible for triacylglycerol's ester linkage, which determined the fat and only occurred in the xanthan structure (Karoui *et al*., 2003). Research by Belton *et al.* (1987) also found that the fat was identified at the wave number of 1744 cm^{-1} (C=O; ester). Other fat related bands occur at 1477-1400 cm^{-1} (C-H bend), 1240 cm^{-1} and 1195-1129 cm^{-1} (C-O stretching). This result showed that the fat structure was stable and strong in fermented glutinous rice (*tapai pulut*) ice cream with the addition of xanthan gum.

Line (b) shows the structure of the amino group. There were no difference in the wavelength of each hydrocolloid, which ranged between 1639 and 1640 cm^{-1}. This shows that the amino structure in ice cream was not affected by the addition of each type of hydrocolloid. Subsequently, line (c) was responsible for alcohol group in this fermented glutinous rice (*tapai pulut*) ice cream. CMC presented an increase in the wavenumber followed by xanthan and guar gum.

Conclusion

Based on the results obtained, it can be concluded that hydrocolloids are able to increase the quality aspect of the physical properties of fermented glutinous rice (*tapai pulut*) ice cream in terms of increasing the overrun, decreasing the melting rate and increasing the smoothness properties. Therefore, xanthan gum was the best stabilizer to enhance the smoothness of fermented glutinous rice (*tapai pulut*) ice cream. The higher overrun will affect the high stability of the fermented glutinous rice (*tapai pulut*) ice cream. The use of CMC resulted in slowing the melting rate compared to other hydrocolloids. In conclusion, xanthan gum was presented to have great potential in order to enhance the quality of fermented glutinous rice (*tapai pulut*) ice cream, which resulted in increasing the smoothness, overrun and stability of ice cream with acidic condition. Overall, research on the development of fermented glutinous rice (*tapai pulut*) ice cream will indirectly optimize the variety of usage of fermented glutinous rice (*tapai pulut*) by using ice cream as a medium.

References

Abbas, K. A., Khalil, S. K. and Hussin, A. S. M. 2010. Modified starch and their usages in selected food products: A review study. Journal of Agriculture Science 2(2): 90-100.

Belton P. S., Safa, A. M. and Wilson R. H. 1987. The potential of Fourier Transform Infrared Spectroscopy for the analysis of confectionary products. Food Chemistry 53-61.

Coates, J. 2000. Interpretation of infrared spectra, a practice approach. In: Meyers, R. A. editor. Encyclopaedia of Analytical Chemistry, p. 10815-10837. Chichester: John Wiley & Son Ltd.

Cruz, A. G., Antunes A. G. and Sousa, A. L. 2009. Ice cream as a probiotic food carrier. Food Research International 42: 1233-1239.

Erkaya, T., Dagdemir, E. and Sengul, M. 2011. Influence of cape gooseberry (*Physalis peruviana* L.) addition on the chemical and sensory characteristics and mineral concentration of ice cream. Food Research International 45: 331-335.

Fox, P. F. 1989. The milk protein system. In: Fox, P. F. editor. Development in Dairy Chemistry, p. 1-54. New York: Elsivier Applied Science.

Gisslen, W. 2011. Professional cooking. 7th Ed. USA: John Wiley & Sons.

Goff, H. D. and Sahagian, M. E. 1996. Glass transitions in aqueous carbohydrate solutions and their relevance to frozen food stability. Thermo-chimica Acta 280-281: 449-464.

Herald, T. J., Aramount, F. M. and Abu-Ghoush, M. H. 2008. Comparison study of egg yolks and egg alternative in French vanilla ice cream. Journal of Texture Study 39: 284-295.

Hwang, J. Y., Shyu, Y. S. and Hsu, C. K. 2009. Grape wine lees improve the rheological and adds antioxidant properties to ice cream. Food Science and Technology 42: 312-318.

Joshi, V. K. and Pandey, A. 1999. Biotechnology: food fermentation. New Delhi: Educational Publishers and Distributers.

Karoui, R., Mazerolles, G. and Dufour, E. 2003. Spectroscopic techniques coupled with chemometric tools for structure and texture determinations in dairy product. International Dairy Journal 13: 607-620.

Keshtkaran, M. and Mohammadifar, M. A. M. 2013. The effects of date syrup and gum tragacanth on physical and rheological properties of date milk beverage. World Journal of Dairy and Sciences 8 (2): 147-155.

Kimaryo, V. M., Massawe, G. A., Olasupo, N. A. and Holzapfel, W. H. 2000. The use of a starter culture in the fermentation of cassava for the production of "kivunde", a traditional Tanzanian food product. Food Microbiology 56: 179-190.

Klesment, T., Stekolstsikova, J. and Laos, K. 2011. The influence of hydrocolloids on storage quality of 10% dairy fat ice cream. Agronomy Research 9: 403-408.

Laaman, T. R. 2011. Hydrocolloids in food processing. In: Institute of Food Technology, p. 7-9. USA: John Wiley & Sons, Ltd.

Law, S.V., Abu Bakar, F., Mat Hashim, D. and Abdul Hamid, A. 2011. Mini review: Popular fermented foods and beverages in Southeast Asia. International Food Research Journal 18: 475-484.

Lim, C. W., Norziah, M. H. and Lu, H. F. S. 2010. Effect of flaxseed oil towards physicochemical and sensory characteristic of reduced fat ice creams and its stability in ice creams upon storage. International Food Research Journal 17: 393-403.

Marshall, R. T., Goff, H. D. and Hartel, R. W. 2003. Ice cream. 3rd Ed. p. 355. New York: Aspen Publishers.

Moeenfard, M. and Tehrani, M. M. 2008. Effect of some stabilizers on the physicochemical and sensory properties of ice cream type frozen yogurt. American-Eurasian Journal of Agriculture and Environmental Science 4(5): 584-589.

Mousavi, Bazmi, S. M., Ehsani, M. A., Reza, M. and Caroline, M. M. 2003. Effect of surface properties on textural characteristics of ice cream. 3rd International Symposium on Food Rheology and Structure, p. 389-392.

Murray J. C. F., Limited, H. and Reigate. 2000. Cellulosics. In Phillips, G. O. and Williams, P.A. Handbook of hydrocolloid, 1st Ed., p. 219-230. England: Woodhead Publishing in Food Science and Technology.

Murtaza, M. A., Mueenuddin, G., Huma, N., Shabbir, M. A. and Mahmood S. 2004. Quality evaluation of ice cream prepared with different stabilizers/emulsifiers blends. Agriculture and Biology 6: 65-67.

Nik, S. F., Zainal, N. F. A., Azira, A., Mohamed, F., Abdullah, S., Ahmed, A. Z. and Rusop, M. 2010. Functionality of inoculums in fermented glutinous rice for the preparation of carbon nanotubes. Solid State Science and Technology 18: 330-336.

Pavia, D. L., Lampman, G. M., Kriz, G. S. and Vyvyan, J. R. 2009. Introduction to spectroscopy. 4th Ed. USA: Brooks/Cole, Cengage Learning.

Phillips, G. O. and Williams, P. A. 2000. Handbook of hydrocolloid. 1st Ed. p. 11. England: Woodhead Publishing in Food Science and Technology.

Regand, A. and Goff, H. D. 2003. Structure and ice recrystallization in frozen stabilized ice cream models systems. Food Hydrocolloids 17: 95-102.

Safar, M., Bertrand, P. R., Devaux M. F. and Genot, C. 1994. Characterization of edible oils, butters, and margarines by Fourier Transform Infrared Spectroscopy with attenuated total reflectance. Journal of the American Oil Chemists' Society 71(4): 371-377.

Segall, K. L. and Goff, H. D. 2002. A modified ice cream processing routine that promotes fat destabilization in the absence of added emulsifier. International Dairy Journal 12: 1013-1018.

Sofjan, R. P. and Hartel, R. W. 2004. Effects of overrun on structural and physical characteristics of ice cream. International Dairy Journal 14: 255–262.

Soukoulis, C., Chandrinos, I. and Tzia, C. 2008. Study of the functionality of selected hydrocolloids and their blends with k-carrageenan on storage quality of vanilla ice cream. Food Science and Technology 4: 1816-1827.

Soukoulis, C., Panagiotidis, P., Koureli, R. and Tzi, C. 2007. Industrial yogurt manufacture; monitoring of the fermentation process improvement of final product quality. Journal of Dairy Science 90: 2641-2654.

Soukoulis, C., Rontogianni, E. and Tzia, C. 2010. Contribution of thermal, rheological and physical measurements to the determination of sensorially perceived quality of ice cream containing bulk sweeteners. Journal of Food Engineering 100: 634-641.

Steinkraus, K. H. 1994. Nutritional significance of fermented food. Food Research International 27: 259-267.

Steinkraus, K. H. 1997. Classification of fermented foods: worldwide review of household fermentation techniques. Food Control 8 (5-6): 311-317.

Sworn, G. and Monsanto. 2000. Xanthan gum: In Phillips, G. O. and Williams, P. A. Handbook of hydrocolloid. 1st Ed. p. 103-115. England: Woodhead Publishing in Food Science and Technology.

Zaharah, M. and Yeoh, Q. L. 2004. Industrialization of indigenous fermented foods, revised and expanded. In: Steinkraus, K. H. editor. Tapai processing in Malaysia. CRC Press.