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Physicochemical, functional and sensory properties of mellorine enriched with different vegetable juices and TOPSIS approach to determine optimum juice concentration

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ABSTRACT

In this study different concentrations (2.5%, 5%, 10%) of beetroot, red cabbage and broccoli juices were added to mellorine to increase its bio-functional properties. Some physicochemical (brix, pH) and bio-functional properties (total phenolic and flavanoid content and DPPH activity) of the juices were determined and total phenolic content of broccoli, beetroot, and red cabbage juices were found to be 419.8, 570.6 and 1131.9 mg/L, respectively. The rheological, physicochemical properties of mellorine mixes and functional and sensory properties of mellorine enrinched with vegetable juices in different concentrations were investigated. All mixes showed shear thinning behavior. The apparent viscosity and consistency index values (K) decreased with increase in vegetable juice concentration. Total phenolic, total flavonoid and DPPH radical scavenging activity increased with increasing all vegetable juice concentration added to the formulation. Regarding sensory properties, among the samples containing vegetable juice, broccoli juice containing sample in concentration of 5% had the highest scores considering colour and appearance, body and consistency and taste and colour properties. TOPSIS (Technique for order preference by similarity to ideal solution) was performed to determine optimum vegetable juice type and concentration regarding bio-functional and sensory properties. According to TOPSIS, the mellorine including 10% red cabbage juice was found as the best sample when considering determined conditions.

1. Introduction

Mellorine, mainly composed of milk, vegetable oil, sugar, emulsifier and stabiliser, is one of the ice cream products or frozen desserts (Clarke, 2004) and it has a complex structure similar to the dairy ice cream (Goff, 2002). Unlike dairy ice cream, in mellorine formulation, all or some proportion of dairy fat is substituted with vegetable based oils (Clarke, 2004; Keeney, 2012). Using vegetable oils in the production of mellorine does not negatively influence sensory profiles of mellorine, even they contribute to a positive effect on human nutrition since they contain remarkable amount of

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unsaturated fatty acids (Anonymous, 2013; Hyvönen, Linna, Tuorila, & Dijksterhuis, 2003; Nadeem, Abdullah, & Ellahi, 2010). Mellorine is consumed by people of all age throughout worldwide as an alternative product to ice cream (Karasu, Doğan, Toker,& Doğan, 2014); therefore, increasing functionality of the product is important for human health since mellorine is poor in terms of natural phytochemicals such as phenolics (O'Connell & Fox, 2001). Bio-functional properties of mellorine or dairy ice cream can be improved by adding biologically active compounds or substances containing these compounds to ice cream formulation. For this reason, in recent years, a variety of researches has been conducted to fortify ice cream formulation with phenolic compounds by adding some fruits (Karaman et al., 2014; Sun-Waterhouse, Edmonds, Wadhwa, & Wibisono, 2011), fruit pulp (El–Samahy, Youssef, & Moussa–Ayoub, 2009), herbal tea (Karaman & Kayacier, 2012) and some phenolics (Sagdic, Ozturk, Cankurt, & Tornuk, 2012) to ice cream mix in different concentrations.

Fruits and vegetables are rich in phenolic compounds which contribute to colour and taste of the product (Blasa, Gennari, Angelino, & Ninfali, 2010). Furthermore, plants contain a variety of antioxidants such as phenolics and flavonoids, which have a protective effect against some diseases, for instance cardiovascular diseases and some types of cancer caused by free radicals, especially reactive oxygen species (Fraga, 2010; Keller, 2009). Broccoli and red cabbage are among *Cruciferous* vegetables, which have attracted much interest in recent years due to a number of compounds with high antioxidant activities, such as phenolics, predominantly kaempferol and hydroxycinnamic acids derivates, and cyanidin derivates, respectively (Chun, Smith, Sakagawa, & Lee, 2004; Heimler, Vignolini, Dini, Vincieri, & Romani, 2006; Wu and Prior, 2005). They are also a good source of glucosinolates, known as sulphur-containing substances which have cancer-protective properties. The sulphur-containing substances have been studied to understand their functional specifications in cancer research in vitro and vivo studies (Higdon, Delage, Williams, & Dashwood, 2007; Podsedek, 2007). One of these researches, Boivin et al. (2009), studied the antiproliferative and antioxidant activities of common vegetables, and those vegetables were divided into four groups (little, intermediate, high, and very high) according to their effects on certain types of cancerous tumour cells. According to this classification beetroot, broccoli and red cabbage were classified in high group; therefore usage of these vegetables for improving functionality of the product is beneficial for human health.

Increasing the bio-functional properties of the product alone is not sufficient for the acceptability of the product (Gurmeric, Dogan, Toker, Senyigit, & Ersoz, 2013). Therefore, sensorial analysis was performed to determine consumer's acceptance or rejection of a new product. Although sensory analysis is useful for determination of the formulation of the product, it is very difficult to interpret the results since as one sample might be preferred regarding one sensory property (such as taste), the other sample might be preferred considering the other sensory property (such as odor). Obtaining one score from different sensory properties, which might be carried out by multi-criteria decision techniques, is facilitative for interpretation or decision. Multi-criteria decision techniques can deal with decision problems considering a number of decision criteria simultaneously (Pohekar & Ramachandran, 2004). They can be used for the evaluation of alternatives based on the determined criteria by using a number of qualitative and/or quantitative criteria (Ozcan, Celebi, & Esnaf, 2011). One of the multi-criteria decision techniques is the TOPSIS (technique for order preference by similarity to ideal solution) which provides a decision hierarchy and requires pairwise comparison between criteria (Balli & Korukoglu, 2009). According to the TOPSIS method, the best alternative is nearest to the positive ideal solution and farthest from the negative ideal solution (Benitez, Martin, & Roman, 2007; Lin, Wang, Chen, & Chang, 2008). Although there have been many studies about the application of multi-criteria decision making techniques in different areas, we have found only two studies, one of them is related to application of different multi-criteria decision techniques on sensory properties of the prebiotic pudding sample (Gurmeric et al., 2013) and the other one is about combination of sensory properties and bioactive properties of persimmon enriched ice cream with TOPSIS method (Karaman et al., 2014), about this subject in the food bioscience field.

The aim of this study was to determine how different vegetable juices at different concentrations affect the bio-functional, rheological and some physicochemical properties of mellorine mix, and to determine the optimum concentration by the TOPSIS technique considering bioactive and sensorial features.

2. Material and methods

2.1. Material

Skimmed milk powder, vegetable oil (sunflower oil), sugar, potable water, broccoli, red cabbage and red beetroot were purchased from a local market in Kayseri, emulsifier (mono- and di-glyceride) was obtained from Safiye Cikrikcioglu Vocational College, in Erciyes University and xanthan gum was obtained from Sigma. Methanol, sodium carbonate, Folin-Ciocalteau reagent, sodium nitrite, aluminium chloride and sodium hydroxide were obtained from Merck Co. and DPPH was obtained from Sigma Co.

2.2. Preparation of mellorine

Broccoli, red cabbage and red beetroot were washed and then pressed to prepare their juices after they were cut small parts. Vegetable juices pasteurised at 90 °C for 1 min with magnetic stirrer prior adding to mellorine mix. The mellorine mix (basic mix) was prepared according to method described by Karaman and Kayacier (2012) with some modifications. The mix formulations contained 14% sugar, 11% skimmed milk powder, 7% vegetable oil, 0.3% emulsifier and 0.2% xanthan gum. Ingredients were added to the drinking water in the following order: vegetable oil at 30 °C, skimmed milk powder at 40 °C, sugar at 50 °C, dry mixture (remained sugar+ emülsifier+xanthan gum) at 70 °C. The mixture obtained was heated to 85 °C and held for 30 s at this temperature for pasteurisation. The pasteurised mix was cooled to 4 °C and then aged for 22 h at 4 °C. Pasteurised vegetable juices were added to the aged mix at concentrations of 2.5, 5 and 10% (w/w). All experiments were done in duplicate. The mellorine including vegetable juices was semi-frozen using a ice cream maker (Simac II Gelataio GC 5000). After the freezing process, which took exactly 16 min, the semi-frozen samples were packaged. The frozen mellorine samples were hardened by a batch freezer and stored at −18 °C for 24 h.

2.3. Rheological measurements

The rheological properties of the mixes were determined using a controlled rheometer (Thermo-Haake, RheoStress 1, Germany) with a temperature control unit (Haake, Karlsruhe K15 Germany). The measurements were carried out using a cone-plate configuration (cone diameter 35 mm, angle 4°, gap size 0.140 mm) in the shear rate range of 0.1–100 s^{-1} at 20 °C. The rheological parameters of the mixes were calculated using RheoWin Data Manager (RheoWin Pro V. 2.96, Haake, Karlsruhe, Germany) based on the Power law model

$$\sigma = K\dot{\gamma}^n \quad (1)$$

in which σ is shear stress (Pa), K is consistency coefficient (Pa s^n), γ is shear rate (1/s), and n is flow behaviour index (dimensionless).

The apparent viscosity of the mixes (η_{50}) represents the shear rate in the mouth (Bourne, 2002). To determine the effect of vegetable juice concentration on apparent viscosity at shear rate of 50 s^{-1}, the following equations were used

$$\eta_{50} = \eta_1(C^{a1}) \quad (2)$$

$$\eta_{50} = \eta_2 \exp(a_2 C) \quad (3)$$

where η_1 and η_2 is constant for concentration effect (Pa s), a_1 and a_2 are constant, C is concentration.

2.4. Physicochemical analysis

The total solids, pH, ash, colour, overrun and melting rate of the samples were determined. The samples were dried at 105 °C for 4 h in a drying oven (Memmert, Germany) (AOAC, 1990). The pH values were determined by a pH meter (Inolab Terminal Level 3, Germany) until a constant value was observed on the screen. The dry ash procedure was performed at 55 °C in an ash furnace (Protherm, Turkey) without black residual after it was dried at 105 °C for 3 h in the oven (Kurt, 1990). The colour values of the mix samples were measured with colourimeter (Lovibond RT Series Reflectance Tintometer, England) calibrated with a white and black area. Overrun was calculated according to the following equation (Arbuckle, 1986)

$$\text{Overrun}(\%) = \left(\frac{\text{weight of the mix} - \text{weight of the same volume of the sample}}{\text{weight of the same volume of the sample}}\right) \times 100 \quad (4)$$

The hardened samples (approximately 40 g) were placed on a wire mesh over a glass beaker and allowed to melt in the oven at 25 °C. The melting rate of the samples was calculated according to the proportion of the dripped weight to initial weight of the samples.

2.5. Bioactivity analysis

2.5.1. Extraction

Ten grams of each sample was weighed and put into a 100 mL bottle. The sample was diluted to 1:5 with 80% methanol. This mixture was left at room temperature for 15 h for extraction. The extracts were centrifuged at 13,000 rpm for 10 min, and the supernatant was filtered through a 0.22 μm microfilter into a 15 mL falcon tube. By following this procedure, extracts were obtained for analysis of total phenolic and flavonoid content and DPPH activity.

2.5.2. Total phenolic content

The amount of total phenolics in the samples was determined according to the method described by Sun, Powers, and Tang (2007) with some modifications. 1.5 mL of Folin-Ciocalteu reagent (1:10 v/v, diluted with distilled water) was added to 0.2 mL extract of the sample. After 5 min, 1.5 mL of 2% (w/v) of sodium carbonate was added and then the absorbance of all samples was measured at 750 nm using a UV–vis spectrophotometer (Agilent 8453, Germany) after incubating at room temperature for 30 min. Gallic acid was used as a standard.

2.5.3. Total flavonoid content

Total flavonoid analysis was performed according to the aluminium chloride colourimetric method described by Zhishen, Mengcheng, and Jianming (1999). 4 mL of distilled water was added to 1 mL of the extract. 0.3 mL of 5% $NaNO_2$ (w/v) was added to the test tube before adding 0.3 mL of 10% $AlCl_3$ (w/v) at 5th min. After 2 mL of NaOH (1M) was added to the test tube at 11th min, the total volume was completed to 10 mL with distilled water. The absorbance of the samples was measured at 510 nm using the UV–vis spectrophotometer against the prepared blank and observed data were expressed as mg catechin equivalent.

2.5.4. DPPH radical scavenging activity

DPPH radical scavenging activity (RSA) was determined according to the method described by Faller and Fialho (2009). After 0.1 mL of the filtrate was mixed in with 3.9 mL of 0.1 mM DPPH solution (in 80% methanol), the mixture was covered with aluminium foil and incubated at room temperature in the dark place for 30 min. The absorbance of the samples was measured at 517 nm using the UV–vis spectrophotometer. The antioxidant capacity of the samples was calculated using the following equation

$$\%\text{RSA} = \left(1 - \frac{\text{absorbance of sample at 517 nm}}{\text{absorbance of control at 517 nm}}\right) \quad (5)$$

2.5.5. Sensory evaluation

Twenty eight panelists were selected from academic staff or graduate students of the Food Engineering Department at

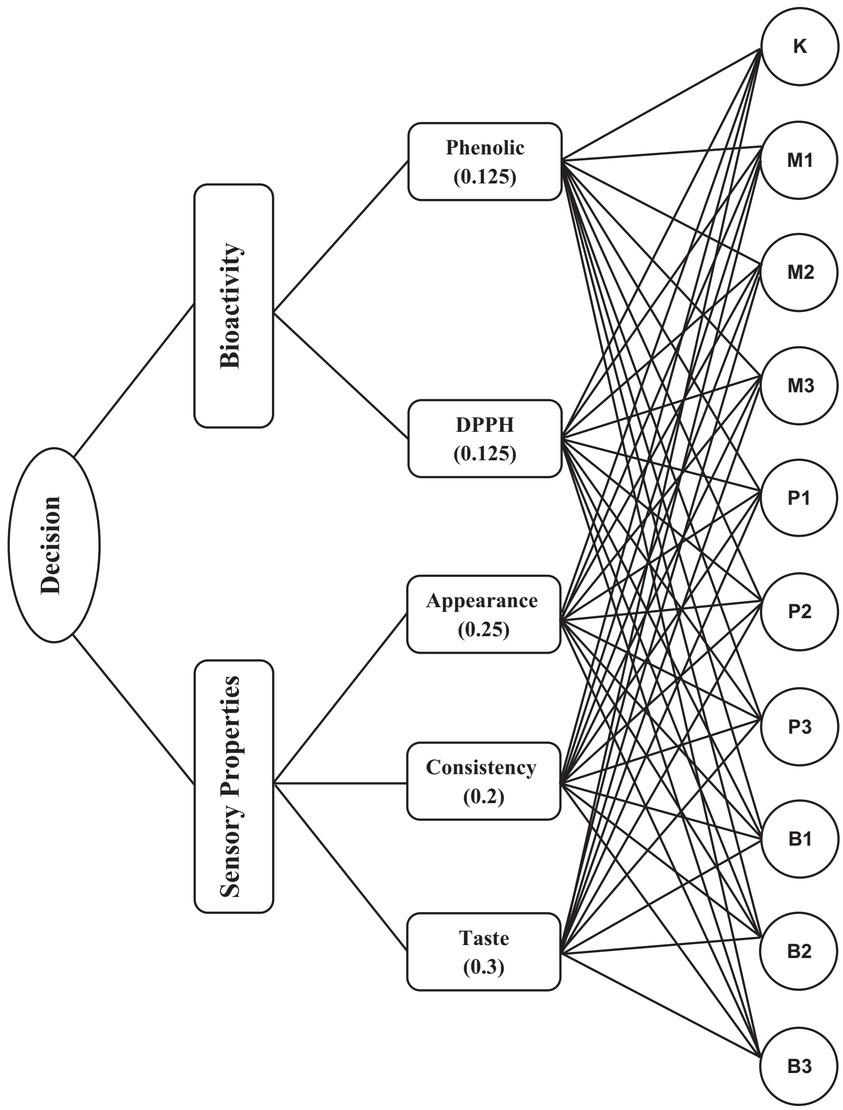

Fig. 1 – The decision hierarchy of the determination of vegetable juice concentration added to mellorine based on the sensorial and bioactivity properties (B: Broccoli, M: Red cabbage, P: Beetroot, 1: 2.5%, 2: 5%, 3: 10%). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Erciyes University, Kayseri. Panelists cleaned their palates with potable water after analysing each sample. Before sensory analyses, the panelists were informed about the aim and requirements of the sensorial analyses. The colour and appearance, taste and odour, and consistency of the ice cream samples were evaluated by the panelists. Panelists were cleaned their palate before proceeding the next sample. Five-point hedonic scale was used for the sensory evaluation of the samples (1: extremely dislike, 2: dislike, 3: not too bad, 4: like, 5: extremely like).

2.6. *Application of TOPSIS method*

The hierarchy of TOPSIS for decision is shown in Fig. 1. The TOPSIS method is composed of six steps (Balli & Korukoglu, 2009).

Step 1. The decision matrix is normalised by the following equation

$$x_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \qquad k = 1,\ 2,\ 3\ldots, i, \ldots, k, \quad i = 1, 2, \ldots \tag{6}$$

where x_{ij} is the normalised value and a_{ij} is the real value of the criteria.

Step 2. The weighted normalised decision matrix is formed (weight of each criteria as presented in Fig. 1, determined based on opinion of the staff and graduate students (totally 15 person) of the Food Engineering Department in Erciyes University (average value was calculated for each criterion)) using Eq. (7).

$$v_{ij} = x_{ij} \times w_{ij} \tag{7}$$

where v_{ij} is the weighted normalised value and w_{ij} is the weight of each criteria.

Step 3. The positive and negative ideal solutions are determined.

$A^* = \{v_{1*}, v_{2*}, v_{3*} \ldots, v_{n*}\}$ (maximum values)

$A^- = \{v_1^-, v_2^-\ v_3^- \ldots, v_n^-\}$ (minimum values)

Step 4. The distance of each alternative from the positive and negative ideal solution is calculated according to the following equations

$$d_i^* = \sqrt{(v_{ij} - v_j^*)^2} \quad (8)$$

$$d_i^- = \sqrt{(v_{ij} - v_j^-)^2} \quad (9)$$

where d_i^* and d_i^- is the distance of alternative from positive and negative ideal solution, respectively.

Step 5. The closeness coefficient of each alternative (C) is obtained using Eq. (10).

$$C = \frac{d_i^-}{d_i^* + d_i^-} \quad (10)$$

Step 6. The ranking of the alternatives is determined based on the C values. The alternative with the highest C value is selected as the best alternative.

2.7. *Statistical analysis*

The statistical analysis of the samples was performed by the SPSS Statistics 17.0.1 programme. Differences between the samples were determined by Duncan's test (Ural & Kilic, 2006).

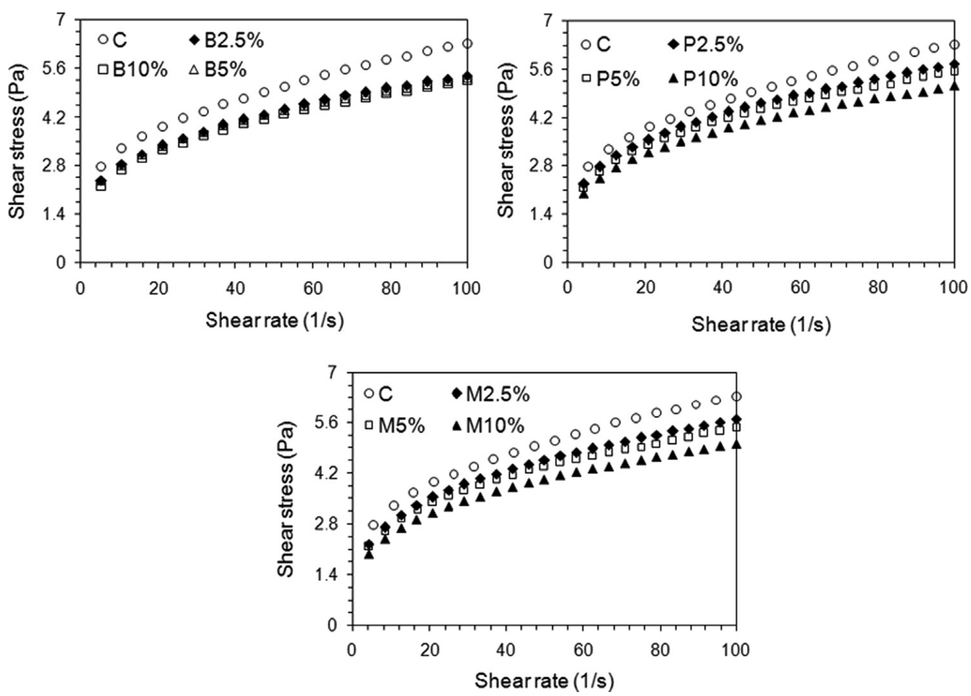

Fig. 2 – Shear rate versus shear stress curves of the mellorine samples,. (K: Control mix, P: Samples containing beetroot juice, M: Samples containing red cabbage juice, B: Samples containing broccoli juice, 1: 2.5%, 2: 5%, 3: 10%).

Table 1 – Rheological parameters of the Power law model determined for the mellorine mixes.

Sample	K (Pa s^n)	n	R^2	η_{50} (Pa s)
K	1.626 ± 0.022^a	0.306 ± 0.017^a	0.998	0.097 ± 0.003^a
P1	1.411 ± 0.064^{cb}	0.304 ± 0.017^a	0.999	0.087 ± 0.002^{bc}
P2	1.344 ± 0.034^{cd}	0.307 ± 0.011^a	0.999	0.084 ± 0.001^{cd}
P3	1.233 ± 0.049^e	0.309 ± 0.009^a	0.999	0.078 ± 0.002^{ef}
M1	1.429 ± 0.093^{cb}	0.303 ± 0.013^a	0.999	0.086 ± 0.004^{bcd}
M2	1.380 ± 0.039^c	0.299 ± 0.009^a	0.999	0.083 ± 0.001^{cde}
M3	1.209 ± 0.059^e	0.307 ± 0.008^a	0.999	0.076 ± 0.002^f
B1	1.481 ± 0.066^b	0.299 ± 0.006^a	0.999	0.086 ± 0.004^{bcd}
B2	1.384 ± 0.039^{cb}	0.292 ± 0.003^a	0.999	0.083 ± 0.001^{cde}
B3	1.272 ± 0.028^{de}	0.308 ± 0.011^a	0.999	0.076 ± 0.002^f

Different letters in the same column indicate significant differences ($P < 0.05$), (K: Control mix, P: Samples containing beetroot juice, M: Samples containing red cabbage juice, B: Samples containing broccoli juice, 1: 2.5%, 2: 5%, 3: 10%).

Table 2 – Effect of the type and concentration of vegetable juices on the apparent viscosity of mixes at 20 °C.

Sample	Power-law model			Exponential model		
	$\eta_{50}=\eta_1\,(C^{a1})$			$\eta_{50}=\eta_2\exp(a_2C)$		
	η_1	a_1	R^2	η_2	a_2	R^2
P	0.093973	−0.077749	0.979	0.090279	−0.014586	0.999
M	0.093919	−0.087612	0.970	0.089846	−0.016591	0.999
B	0.095156	−0.068159	0.964	0.091243	−0.011591	0.895

P: Samples including beetroot juice, M: Samples including red cabbage juice, B: Samples including broccoli juice.

3. Results and discussion

3.1. Rheological properties

The shear stress versus shear rate data of the mellorine samples including different vegetable juices in different concentrations are shown in Fig. 2. As seen, the apparent viscosity of the samples decreased with shear rate, indicating the shear thinning behaviour of the mellorine mix samples. Shear thinning behavior of ice cream mixes was reported in different studies (Dogan, Kayacier, Toker, Yilmaz, & Karaman, 2013a; Toker et al., 2013a; Toker, Yılmaz, Karaman, Doğan, & Kayacıer, 2012a). Usage of vegetable oil instead of milk fat did not influence the flow behavior of the sample. Dickinson and Stainsby (1982) reported that the shear thinning behaviour of the ice cream mix is related with the complex involvement of partially broken-down micellar casein at the droplet surface. The rheological parameters (consistency coefficient (K), flow behaviour index (n) and apparent viscosity values (η_{50})) of the mellorine samples including different vegetable juices at different concentrations are summarized in Table 1. It can be seen that the Ostwald de Waele model (also known as Power law model) described well the steady shear flow behaviour of the mellorine samples ($R^2 \geq 0.998$), which was agreement with the previous studies (Dogan et al., 2013a; Karaman & Kayacier, 2012; Toker et al., 2012a, 2013a).

The consistency coefficient and apparent viscosity values of the mixes decreased with increase in the vegetable juice concentration while there were no significant changes in the flow behaviour index (n) ($P>0.05$). The results reported for trend between K and n or η_{50} and n were consistent with previous studies (Dogan, Toker, & Goksel, 2011; Dogan, Toker, Aktar & Goksel, 2013b; Goksel et al., 2013; Toker, Dogan, Canyılmaz, Ersöz, & Kaya, 2013b; Toker, Dogan, & Goksel, 2012b). The consistency coefficient of the samples varied between 1.209 and 1.626 Pa s^n, which decreased with increasing fruit juice concentration in the mix samples. The n values of the samples changed between 0.292 and 0.309, thus also indicating shear thinning behaviour of the mellorine samples. The results of our study were similar to the findings of Karaman and Kayacier (2012), Aime, Arntfield, Malcolmson, and Ryland (2001), and Dogan and Kayacier (2007).

The apparent viscosity value of mixes at 20 °C ranged between 0.076 and 0.097 Pa s. The η_{50} value of mix samples was significantly affected by the addition of vegetable juices ($P<0.05$), but no significant difference was found among the vegetable juice type and concentration ($P>0.05$). Karaman and Kayacier (2012) investigated the rheological and physicochemical properties of ice cream mix enriched with some tea, and they reported that the η_{50} value of the ice cream mix and mix enriched with black tea brewed at 40 °C was found to be 0.91 Pa s and 1.13 Pa s at 20 °C, respectively. In addition, η_{50} value of ice cream mixes, prepared with dairy cream, were determined as higher (0.467–1.950 Pa s) than that of the mixes found in this study. The raw materials used in ice cream production, such as fat type, sweetener and stabiliser/emulsifier, and their concentrations affect the viscosity of ice cream mix (Junior & Lannes, 2011; Bahramparvar & Tehrani, 2011). Lower η_{50} value of mellorine when compared with ice cream mixes might have explained by the fact that viscosity of vegetable oil found in the formulation is lower than that of the dairy fat. Yalcin, Toker, and Dogan (2012) reported that viscosity of oils decreased with increase in polyunsaturated fatty acid composition of the oils. Because of the high water content in the vegetables juices, the water content of the samples increased with vegetable juice concentration, which caused a decrease in the viscosity values of the mellorine mixes. El–Samahy et al. (2009) reported that the viscosity of ice cream enriched with cactus pulp increased as concentration of cactus pulp increased, whereas Hwang, Shyu, and Hsu (2009) found that the viscosity of ice cream containing grape wine lees increased by increasing of grape wine lees concentration from 50 g/kg to 150 g/kg.

The relationship between vegetable juice concentration and the η_{50} values was determined using power-law and exponential models. As shown in Table 2, the effect of vegetable concentration on the η_{50} of the samples was explained better by the exponential model for the mellorine containing beetroot juice and red cabbage juice, while the power-law model explained better the relation between juice concentration and η_{50} value of mellorine containing broccoli juice. In the study of Dogan et al. (2013a), effect of gum concentration on the η_{50} values of the ice cream samples was better described by the exponential model ($R^2=0.980$).

3.2. The physicochemical characteristics

Brix value of the broccoli, beetroot and red cabbage juices was found to be 5.60, 6.67 and 9.91, respectively. pH value of these juices was determined as 7.09, 6.69 and 6.98, respectively. Some physicochemical properties of the mellorine mixes with different concentrations of vegetable juices are shown in Table 3. The effect of vegetable juice type and

Table 3 – Physicochemical properties of the mellorine mixes with different concentrations of vegetable juices.

Sample	pH	Dry matter[x]	Ash[x]	L	a	b
K	7.68±0.01[a]	33.72±0.17[a]	0.334±0.002[f]	65.23±0.11[a]	−1.53±0.02[d]	2.55±0.05[e]
P1	7.61±0.01[d]	32.74±0.36[b]	0.343±0.006[e]	56.61±0.11[e]	9.98±0.08[c]	1.80±0.12[f]
P2	7.55±0.03[e]	31.94±0.30[c,d]	0.355±0.007[d]	52.18±0.14[f]	14.98±0.10[b]	2.59±0.10[e]
P3	7.48±0.01[f]	30.81±0.35[e]	0.394±0.007[a]	46.33±0.65[g]	19.97±0.62[a]	4.32±0.07[d]
M1	7.65±0.01[b]	32.56±0.02[b]	0.344±0.005[e]	56.45±0.59[e]	−4.93±0.15[h]	−7.07±0.29[g]
M2	7.61±0.00[d]	31.86±0.14[d]	0.352±0.005[d]	52.32±0.39[f]	−6.32±0.11[i]	−10.59±0.11[h]
M3	7.56±0.00[e]	30.75±0.19[e]	0.362±0.005[c]	45.74±0.68[h]	−6.34±0.14[i]	−14.70±0.09[i]
B1	7.63±0.01[c]	32.80±0.11[b]	0.345±0.003[e]	64.65±0.20[b]	−2.32±0.06[e]	4.66±0.10[c]
B2	7.61±0.01[d]	32.19±0.22[c]	0.353±0.006[d]	63.91±0.23[c]	−2.92±0.02[f]	6.28±0.13[b]
B3	7.55±0.00[e]	30.60±0.12[e]	0.380±0.002[b]	62.56±0.29[d]	−3.91±0.07[g]	9.13±0.03[a]

Different letters in the same column are statistically significant by Duncan's test at 0.05 level of significance, (K: Control mix, P: Samples containing beetroot juice, M: Samples containing red cabbage juice, B: Samples, containing broccoli juice, 1: 2.5%, 2: 5%, 3: 10%).
[x] Expressed as a percentage.

Table 4 – Physical properties of the mellorine with different concentrations of vegetable juices.

Sample	Overrun[x]	Melting rate[x]		
		45th min	60th min	75th min
K	33.62±0.63[a]	11.38±0.85[e]	42.22±0.92[e]	74.76±0.48[e]
P1	32.70±0.13[b]	14.51±0.32[d]	45.14±0.44[d]	79.40±0.34[c,d]
P2	30.70±1.16[c,d]	15.49±0.41[c]	46.28±1.22[c,d]	80.76±0.34[b]
P3	29.90±0.69[d]	18.37±0.14[a,b]	48.61±0.42[a,b]	83.46±0.42[a]
M1	32.53±0.46[b]	14.43±0.24[d]	44.96±0.45[d]	78.86±0.69[c,d]
M2	31.27±0.52[c]	15.48±0.32[c]	45.37±0.40[d]	79.79±0.52[b,c]
M3	30.01±0.46[d]	17.88±0.15[b]	48.32±0.24[b]	83.17±0.99[a]
B1	32.43±0.29[b]	14.21±0.13[d]	45.06±0.61[d]	78.90±0.32[d]
B2	31.19±0.55[c]	15.25±0.07[c]	47.54±1.30[b,c]	79.91±0.49[b,c]
B3	30.01±0.96[d]	18.57±0.29[a]	49.65±0.57[a]	82.98±0.88[a]

Different letters in the same column are statistically significant by Duncan's test at 0.05 level of significance (K: Control mix, P: Samples containing beetroot juice, M: Samples containing red cabbage juice, B: Samples containing broccoli juice, 1: 2.5%, 2: 5%, 3: 10%).
[x] Expressed as a percentage.

concentration on pH, dry matter and ash content of the mellorine was found as statistically significant ($P<0.05$). The dry matter, pH values and ash content of the mixes varied between 30.60–33.72%, 7.48–7.68, 0.334–0.394%, respectively. The dry matter and pH values of the mellorine mixes decreased with increasing vegetable juice concentration while its ash content increased.

The overrun values of ice cream samples ranged from 29.90% to 33.62%. Vegetable juice type and concentration significantly influenced the overrun values of the samples ($P<0.05$). Overrun, which is a measure of increase in volume, influences some characteristics of ice cream, such as melting down and hardness (Sofjan & Hartel, 2004). The overrun of mellorine decreased as vegetable juices concentration increased, since water content of the ice cream samples increased with addition of vegetable juice. Hwang et al. (2009) observed that the overrun of samples decreased as grape wine lees were added to the ice cream. Similar results considering overrun values were also reported by Sun-Waterhouse et al. (2011) and El–Samahy et al. (2009).

The melting rate of the ice cream samples was determined as a function of time (45th min, 60th min, 75th min). The addition of vegetable juice affected the melting rate, depending on the concentration of vegetable juice ($P<0.05$), but no difference between the type of vegetable juices was found ($P>0.05$). Previous studies indicated that stabiliser/emulsifiers had an important role in some of the desirable properties of ice cream and related products, such as melting resistance and overrun (Guven, Karaca, & Kacar, 2003; Keçeli & Konar, 2003; Moeenfard & Tehrani, 2008; Rezaei, Khomeiri, Kashaninejad, & Aalami, 2011). A decrease in overrun and an increase in melting rate in the mellorine samples including vegetable juices could be explained by the higher water content of the vegetable juices, resulting the decaying of the stabiliser/emulsifier system (Bahramparvar & Tehrani, 2011; Lal, O'Connor, & Eyres, 2006). The possible reason for the higher melting rate of the mellorine containing vegetable juices could be explained by the effect of overrun on melting properties (Sofjan & Hartel, 2004). The authors revealed that resistance to melting in the ice cream with higher overrun was better than with lower overrun Table 4.

3.3. *Bioactive properties of the mellorine samples*

Phenolic content of the broccoli, red beetroot and red cabbage juices was determined to be 420, 571 and 1132 mg/L, respectively. Red cabbage juice was found as the juice one had the highest phenolic content. Flavanoid content of these juices

Table 5 – Some bio-functional properties of the mellorine with vegetable juice.

Sample	Total phenolic[x]	Total flavonoid[y]	DPPH[z]
K	40.022±0.594[h]	31.196±0.815[g]	11.79±0.32[j]
P1	59.928±0.738[f]	47.799±1.964[e]	18.66±1.04[g]
P2	70.353±0.898[e]	64.830±2.340[c]	21.33±0.23[f]
P3	101.874±1.199[c]	92.930±2.681[a]	31.18±0.37[d]
M1	88.305±0.591[d]	40.721±3.182[f]	32.35±1.53[c]
M2	127.705±0.998[b]	57.325±2.300[d]	46.59±0.35[b]
M3	202.776±2.363[a]	90.783±4.794[a]	67.54±0.11[a]
B1	58.040±0.964[g]	38.479±6.278[f]	13.94±1.67[i]
B2	69.821±1.721[e]	50.116±2.936[e]	16.47±0.19[h]
B3	88.135±1.723[d]	69.085±4.644[b]	27.60±0.12[e]

Different letters in the same column are statistically significant by Duncan's test at 0.05 level of significance, (K: Control mix, P: Samples containing beetroot juice, M: Samples containing red cabbage juice, B: Samples, containing broccoli juice, 1: 2.5%, 2: 5%, 3: 10%).
[x] Expressed as mg gallic acid equivalent/L.
[y] Expressed as mg catechin equivalent/L.
[z] Expressed as a percentage.

was found as 249, 453 and 327 mg/L, respectively. As seen red beetroot was the richest sample regarding flavanoid content. As expected, strong correlation was observed between phenolic content and DPPH activity which found to be 53.76%, 60.23% and 85.30% for broccoli, red beetroot and red cabbage juices, respectively. The total phenolic and total flavonoid content and antioxidant capacity (DPPH) of the mellorine mixes are shown in Table 5. It can be seen that, vegetable juice type and concentration significantly affected the functional properties of mellorine ($P<0.05$). Total phenolic content of the samples ranged from 40.022 to 202.776 mg/L. It was determined that the K (control sample) had the lowest total phenolic content and the M3 had the highest. As expected, ice cream samples increasing red cabbage juice had the highest phenolic content, followed by the samples including red beetroot juice and broccoli juice, respectively. As seen in Table 5, the total flavonoid content of the samples changed between 31.196 and 92.930 mg/L and it was seen that the P3 had the highest total flavonoid quantity. DPPH, which is a measure of antioxidant capacity, was affected by the addition of vegetable juice to mellorine, and an increase in the antioxidant capacity was observed as the concentration of vegetable juice rose from 2.5% to 10%. While the DPPH of the K sample (11.79%) was found to be lowest among the samples, the M3 had the highest antioxidant capacity (67.54%).

Hwang et al. (2009) reported that incorporation of grape wine lees, a waste product in the production of grape wine, to ice cream resulted in an increase in amount of phenolic compounds because it was rich in terms of phenolics, and the phenolic content of ice cream enriched with grape wine lees was found as 1.52 mg/mL. Karaman and Kayacier (2012) reported that phenolic content of ice cream enriched with herbal teas increased up to 415.2 mg/kg with tea addition. They emphasized that ice cream could be fortified by material which is abundant in terms of phenolics. Similar result was reported by Sagdic et al. (2012).

3.4. *Sensory attributes*

The sensory scores of the mellorine samples are illustrated in Table 6. As seen, adding vegetable juice to mellorine caused a decrease in sensory scores. Control sample had the highest sensory scores regarding all of the properties evaluated by sensory analyses. As seen from the table, color and appearance scores of the mellorine samples enriched with vegetable juices were found as close to control sample, which might be explained by the fact that coloring compounds found in the vegetable juices improved attarctiveness of the ice cream. Among the vegetable juice containing samples, the B2 sample had the highest scores considering colour and appearance, body and consistency and taste and colour properties. Body and consistency scores of the ice cream decreased with addition of vegetable juices, thus increasing water content of the mellorine mix samples, which might result in icy structure, negatively affected body and consistency of the samples. Body and consistency of ice cream samples including vegetable juices could be improved by decreasing water amount added during production of ice cream.

Vegetable juice addition also caused a decrease in taste and odour scores of the ice cream. As known, ice cream is a sweet product and addition of vegetable juice decreased sweetness of the product; therefore, mellorine enriched with vegetable juice had lower taste and odour scores.

3.5. *Combination of biological activity and sensory scores*

In the present study, rheological characteristics of the mellorine mix samples and physicochemical (dry matter, ash content, pH and color values), bio-functional (total phenolic content, flavanoid content and DPPH activity) and sensory properties of the mellorine were determined. As seen from the results, physicochemical properties were slightly influenced by the juice addition. Rheological analyses were performed in mellorine mix samples. In addition to the rheological analyses, in this part of the study, we focused on sensory and bio-functional properties of the mellorine samples enriched with different juices in different concentrations. The combination of the bio-functional and sensory properties of the samples is important for the determination of the best sample since awareness of consumers about the consumption of healthy food is growing. Decision making is very difficult because there are six different results (total phenolic, DPPH, flavanoid, colour and appearance, taste

Table 6 – Sensory scores of the mellorine samples.

Sample	Colour and appearance	Body and consistency	Taste and odour
K	4.86 ± 0.38^{a}	4.57 ± 0.54^{a}	4.57 ± 0.54^{a}
P1	3.71 ± 0.76^{b}	3.71 ± 0.76^{ab}	3.57 ± 0.79^{bc}
P2	4.00 ± 0.82^{b}	3.57 ± 1.13^{b}	3.71 ± 0.95^{abc}
P3	4.00 ± 0.58^{b}	3.29 ± 0.76^{b}	3.29 ± 0.76^{bc}
M1	3.71 ± 0.49^{b}	3.43 ± 0.79^{b}	2.71 ± 0.49^{c}
M2	3.71 ± 0.95^{b}	3.57 ± 0.54^{b}	3.00 ± 0.82^{c}
M3	4.14 ± 0.90^{ab}	3.14 ± 0.70^{b}	3.14 ± 1.35^{bc}
B1	4.43 ± 0.54^{ab}	3.71 ± 0.76^{ab}	3.43 ± 0.54^{bc}
B2	4.57 ± 0.54^{ab}	3.86 ± 0.69^{ab}	4.14 ± 0.70^{ab}
B3	4.29 ± 0.76^{ab}	3.43 ± 0.98^{b}	3.00 ± 1.00^{c}

Different letters in the same column are statistically significant by Duncan's test at 0.05 level of significance, (K: Control mix, P: Samples containing beetroot juice, M: Samples containing red cabbage, juice, B: Samples containing broccoli juice, 1: 2.5%, 2: 5%, 3: 10%).

Table 7 – Normalised and weighted normalised decision matrix.

	Alternatives	Appearance	Consistency	Taste	Phenolic	DPPH
Normalised	K	0.3695	0.3962	0.4132	0.1255	0.1128
	P1	0.2821	0.3217	0.3228	0.1879	0.1786
	P2	0.3041	0.3095	0.3354	0.2205	0.2041
	P3	0.3041	0.2853	0.2975	0.3193	0.2984
	M1	0.2821	0.2974	0.2450	0.2768	0.3096
	M2	0.2821	0.3095	0.2712	0.4003	0.4458
	M3	0.3148	0.2723	0.2839	0.6357	0.6463
	B1	0.3368	0.3217	0.3101	0.1819	0.1334
	B2	0.3475	0.3347	0.3743	0.2189	0.1576
	B3	0.3262	0.2974	0.2712	0.2763	0.2641
Weighted normalised	K	0.0924	0.0792	0.1240	0.0157	0.0141
	P1	0.0705	0.0643	0.0968	0.0235	0.0223
	P2	0.0760	0.0619	0.1006	0.0276	0.0255
	P3	0.0760	0.0571	0.0892	0.0399	0.0373
	M1	0.0705	0.0595	0.0735	0.0346	0.0387
	M2	0.0705	0.0619	0.0814	0.0500	0.0557
	M3	0.0787	0.0545	0.0852	0.0795	0.0808
	B1	0.0842	0.0643	0.0930	0.0227	0.0167
	B2	0.0869	0.0669	0.1123	0.0274	0.0197
	B3	0.0815	0.0595	0.0814	0.0345	0.0330

(K: Control mix, P: Samples containing beetroot juice, M: Samples containing red cabbage juice, B: Samples containing broccoli juice, 1: 2.5%, 2: 5%, 3: 10%).

and odour, consistency). While one sample is better when considering one criterion, another sample is better based on different criteria. Therefore, a comparison of the alternatives or the samples is very difficult. In order to ease comparison, the TOPSIS method was applied. As seen from Fig. 1, there are ten alternatives and five criteria. Initially, the importance of the criteria is determined by considering different opinions obtained from students and academicians. Fig. 1 also shows the ratio of the criteria. For example, while the importance of the total phenolic content was 12.5%, that of taste was 30% in decision making. Table 7 shows the normalised and weighted normalised matrices which are formed as mentioned in Section 2 by using real values. After obtaining the weighted normalised matrices, the positive and negative ideal solutions of each criterion were determined (Table 8). The distance of each alternative from the negative and positive ideal solution was calculated by using Eqs. (8) and (9). Table 9 shows the distance values and closeness

Table 8 – Positive (A^*) and negative ideal solution (A^-) for the criteria.

Criteria	A^*	A^-
Appearance and colour	0.0924	0.0705
Body and consistency	0.0792	0.0545
Taste and odour	0.1240	0.0735
Total phenolic	0.0795	0.0157
DPPH	0.0808	0.0141

coefficient of each sample. As seen from the C values, the M3 sample was selected as the best sample based on the determined criteria. This result was interesting because the sensory scores of that sample were very low when compared with the other samples. However, the total phenolic and DPPH activity of that sample was very high, which is the reason why the M3 sample

Table 9 – Distance from positive (d_i^*), negative (d_i^-) and closeness coefficient (C) values of each alternative.

Alternatives	d_i^*	d_i^-	C
K	0.0923	0.0919	0.4991
P1	0.0894	0.0677	0.4309
P2	0.0828	0.0679	0.4506
P3	0.0736	0.0564	0.4340
M1	0.0848	0.0522	0.3810
M2	0.0639	0.0561	0.4676
M3	0.0480	0.0753	0.6107
B1	0.0926	0.0656	0.4147
B2	0.0822	0.0755	0.4787
B3	0.0814	0.0535	0.3968

(K: Control mix, P: Samples containing beetroot juice, M: Samples containing red cabbage juice, B: Samples containing broccoli juice, 1: 2.5%, 2: 5%, 3: 10%).

was the best sample. Determination of weight of criteria is very important for decision. The ranking of the samples changed as the weight of criteria is changed. The difference between C values of the unenriched and enriched samples might be decreased by increasing of weight of sensory scores. However, as the importance of the bioactive properties is increased, the differences between the C values of the samples might be increased; therefore, assigning a weight of criteria will eventually affect the final decision. According to the results, it was seen that TOPSIS can be successfully used in food industry to ease comparison and decision.

4. Conclusion

The addition of vegetable juices to the mellorine mix decreased the apparent viscosity, dry matter and overrun, however, the ash content and melting rate increased. All mixes had a pseudoplastic flow behaviour. The bio-functional properties, such as phenolic, flavonoid and DPPH, of the mellorine containing vegetable juices were significantly affected by increasing the vegetable juice concentration. Mellorine with 10% red cabbage juice (M3) was higher than the other samples in terms of the phenolic quantity and DPPH while control (K) was the lowest. In order to compare the samples easily, the TOPSIS method was used considering the bioactivity and sensory properties. In the determined conditions, M3 sample was found as the best sample. According to the results of this study, it is observed that the use of TOPSIS or similar techniques is possible in the food industry area in order to facilitate decision making or comparison.

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