Eur Food Res Technol (2016) 242:953–966
DOI 10.1007/s00217-015-2602-z

ORIGINAL PAPER

A methodology to evaluate the sensory properties of instant hot chocolate beverage with different fat contents: multi-criteria decision-making techniques approach

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Received: 1 September 2015 / Revised: 20 November 2015 / Accepted: 21 November 2015 / Published online: 3 February 2016

Abstract The multi-criteria decision-making techniques are applied in many areas such as integrated manufacturing systems, evaluation of technology investment, water and agriculture management and energy planning. However, there are very few studies in the field of food. In this work, the selection of optimum fat content in the model beverage of instant hot chocolate beverage was evaluated based on sensory analyses by performing multi-criteria decision techniques (analytic hierarchy process, simple additive weighting, technique for order preference by similarity to ideal solution and elimination et choixtraduisant la realite—elimination and choice translating reality). The wettability, solubility, bulk density, soluble solids, pH, color values, and rheological and sensory properties of the nine samples were evaluated. According to the results of multi-criteria decision techniques, sample S2 which had a relatively high amount of fat content was the most preferred beverage among the samples. Study showed that the use of different fat contents of milk and cocoa powder positively affected the rheological parameters and preferences of consumers. The findings may be considered to improve dairy and cocoa-based products formulation by the food industry.

Keywords Multi-criteria decision techniques · AHP · SAW · ELECTRE · TOPSIS · Hot chocolate · Cocoa · Fat · Sensory · Rheology

Introduction

Instant food industry is one of the leading food industries due to convenience and quickness of preparation in addition to having a long shelf life [1, 2]. Instant foods include food products ranging from liquid foods like soups to semisolids such as oatmeal. One of the main groups of instant foods is the instant beverages. Throughout the world, the trend of hot beverage on the go especially shows an increasing trend. Instant cocoa beverages belong to the group of hot instant drinks, and hot chocolate itself is one of the most popular dairy products within all age groups [3]. Moreover, their nutritional and sensory properties make them the favorable drinks by several groups of consumers, such as children. According to the research done by Daini et al. [4], hot beverages that contain cocoa have micronutrients and the amount of the nutrients increases the nutritional value of the drink.

Sensory, physical and rheological properties of instant products are strongly affected by the ingredients and in particular by the fat content of the ingredients [5]. Chocolate-containing hot beverages are prepared by adding powdered ingredients into hot water or milk [6]. In particular, the main ingredients of the instant hot chocolate drinks are sugar, cocoa powder, milk powder, whey powder, starch, flavorings, salt and gelling agents [2, 7]. Sensory properties

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of chocolate-containing hot beverages have become the subject of intense attention in the literature. Raats and Shepherd [8] found out that fat content of the milk has an impact on hot beverages sensory properties. Similarly, Folkenberg et al. [9] mentioned that in addition to the milk powder composition, sensory features of those drinks highly depend on the cocoa powder properties. Similarly, rheological properties of chocolate-containing hot drinks have been investigated thoroughly in the literature, and there is a general consensus that the flowing properties are mostly affected by the hydrocolloids and starch contents of the beverage [8–10]. Particularly hot chocolate shows time-dependant and shear-thinning flow behavior.

Consumer acceptability of foods basically depends on the satisfactory textural and other sensory attributes [11–14]. Texture is one of the main factors for preference, and it can be controlled with the rheological properties that are provided by the hydrocolloids such as thickeners, stabilizers, gelling agents and texture modifiers [15]. Besides starches and hydrocolloids, the textural attributes and satisfactory levels are also affected by the fat content of the ingredients. In particular, fat content affects the creaminess of the product, and therefore, it is not applicable to exclude the fat from the ingredients list immediately to produce a fat-free product. Hence, in the industry most common application to achieve fat-reduced product is to replace fat. Also concerns about consumers health are associated with fat consumption, and it is significant in daily diet for well-being as well [11]. The ingredients of instant hot chocolate include milk powder and cocoa powder which can be fat free, low fat or full fat. There has been research investigating the effects of fat reduction in rheology and sensory characteristics of: spreadable cheese [16], cream cheese [17], ice cream [18, 19], mayonnaise [20, 21], yogurt [22, 23] and kashar cheese [24]. However, there was a gap in the literature about the effect of fat contents effect on rheological and sensory properties of the instant hot chocolate drinks which could associate with all cocoa powder- and milk powder-containing products. The sensory properties of a product such as flavor, consistency, taste and color are important criteria for consumers and lead to consumers' acceptance or rejection of the product. While sensory properties of a product are significant for the development of a food formulation, the interpretation of the sensory analysis results is difficult because of the criteria mentioned above [25].

Multi-criteria decision-making (MCDM) allows deciding between alternatives using qualitative and quantitative data [26]. Although MCDM techniques are applied in many areas such as integrated manufacturing systems, evaluation of technology investment, water and agriculture management and energy planning [27], there are very few studies in the field of food. Gurmeric et al. [25] applied to MCDM techniques to determine optimum flavor of prebiotic pudding using sensory data, and similarly, Ozturk et al. [28] used TOPSIS approach to evaluate optimum juice concentration on mellorine which was enriched with different vegetable juices.

Thus, the aim of this study was to determine how the fat content of the cocoa powder and milk powder affects the rheological and sensory properties of the instant hot chocolate and to evaluate the optimum fat composition using multi-criteria decision-making techniques considering sensory analysis. As a result of this study, the optimum instant hot chocolate formulation can be determined by using MCDM based on consumer preference of the product.

Materials and methods

Materials

Instant hot chocolate samples were prepared with the following ingredients: sugar, low-fat cocoa (10–12 % fat) (Bayrak Food Co., Turkey), reduced-fat cocoa (about 15–17 % fat) and high-fat cocoa (20–22 % fat) (Altınmarka, Turkey), skimmed milk powder (0.5 % fat) (Bayrak Food Co., Turkey), low-fat milk powder (about 13 % fat), whole-fat milk powder (26.5 % fat) (Enka, Konya, Turkey), modified corn starch (Cargill Co., USA), whey powder (Bayrak Food Co., Turkey), potato starch (Cargill Co., USA), chocolate powder (Melodi Co., Turkey), xanthan gum (Sigma-Aldrich Co., USA) locust been gum (Sigma-Aldrich Co., USA) and chocolate flavor (Aromatech, France).

Preparation of instant hot chocolate beverages

Samples were prepared according to the method that was used by Dogan and Toker [2]. In this respect, 12 g sugar, 3 g milk powder, 2 g whey powder, 6 g cocoa, 0.25 g potato starch, 2.25 g modified corn starch, 0.25 g powdered chocolate, 0.1 g chocolate flavor, 0.025 g salt and 0.2 g gum (0.118 g xanthan, 0.082 g locust been gum) were mixed. Nine different instant mixtures including different fat contents were prepared. To obtain different fat contents, reduced-fat cocoa, full-fat cocoa, whole milk powder, skimmed milk powder and their mixtures were used. The combinations in model formulations are shown in Table 1. To prepare instant hot chocolate beverages, ingredients were added slowly into 180 ml distilled water that was at 80 °C and constantly stirred at 80 °C for 15 min. Then, the hot chocolate beverages were cooled to 60 °C and utilized at this temperature for the physical and sensory analysis.

The samples used in study were classified into two main groups according to the fat contents of milk and cocoa powder. Group 1 was classified according to the fat content

Table 1 Fat content of milk and cocoa powder in instant hot chocolate beverages

Sample codes	Powder weight (g/100 ml sample)					
	Milk powder (g/100 ml sample)			Cocoa powder (g/100 ml sample)		
	Whole fat	Low fat	Skimmed	High fat	Reduced fat	Low fat
S1	–	1.46	–	–	2.91	–
S2	–	1.46	–	2.91	–	–
S3	–	1.46	–	–	–	2.91
S4	1.46	–	–	–	2.91	–
S5	1.46	–	–	2.91	–	–
S6	1.46	–	–	–	–	2.91
S7	–	–	1.46	–	2.91	–
S8	–	–	1.46	2.91	–	–
S9	–	–	1.46	–	–	2.91

of milk power: S1, S2 and S3 had the low-fat-containing milk powder; similarly S4, S5 and S6 had the whole-fat-containing milk powder; likewise S7, S8 and S9 had the skimmed milk powder. Group 2 was classified according to the fat content of cocoa powder: S1, S4 and S7 had the low-fat-containing cocoa powder; similarly S2, S5 and S8 had the full-fat-containing cocoa powder; likewise S3, S6 and S9 had the fat-reduced cocoa powder. The statistical comparison between the fat content of milk and cocoa powder in samples was made according to these 2 groups.

Methods

Wetting test

The wettability of samples was tested by static wetting test described by Freudig and Hogekamp [29] with some modifications. Four grams of instant hot chocolate powder was poured into the cylindrical container that had 40 ml of water at 80 °C. The time (s) required for all particles to disappear was recorded as the wetting time of the samples with visual observation.

Solubility

The solubility of the samples was determined with the method of Takahashi and Seib [30]. Four grams of sample was added into the water which was 80 °C. Then, the mixture was continuously stirred for 30 min and then centrifuged at 6000 rpm. Fifteen grams of supernatant was dried to a stable weight in an evaporating dish. Analyses were performed in triplicate for each of two repetitions.

Bulk density

Bulk density is defined as the weight of the sample per unit volume of the sample (g/ml) [31]. During the experiments to measure the bulk density of the samples, prepared instant hot chocolate samples were transferred into 10-ml graduated cylinders that were previously weighed. The bottom of the cylinder was gently tapped on a laboratory bench several times until no further diminution of the sample level was observed, and the weight was divided into the volume of the cylinder (10 ml) to calculate the bulk density.

Soluble solids and pH

The soluble solid contents were measured with a digital refractometer (Reichert AR 700, USA), with the prepared samples of hot chocolates at room temperature, and the results were given as Brix at 25 °C. The pH values were determined using a pH meter (WTW-Inolab Level 3 Terminal, Germany) at room temperature. Measurements were taken in triplicate for each sample.

Color measurements

The L^*, $a^*$and b^* values which indicate brightness, redness and yellowness, respectively, of each samples were measured at room temperature with a colorimeter (Lovibond Reflactance Tindometer 962, Canada). Measurements were taken in triplicate for each of the two repetitions.

Rheological measurements

The rheological properties of the hot chocolate samples were determined using a strain-/stress-controlled rheometer (Haake Mars III, Germany) equipped with a temperature module (Haake Mars, TM-PE-P, Germany) and a cone–plate configuration with a cone radius of 35 mm and a gap of 0.5 mm between the cone and plate. Measurements were taken in the shear rate range of 1–100 s^{-1} at a constant temperature of 60 °C. A total of 25 data points were recorded at 10-s intervals during the shearing. Each measurement was

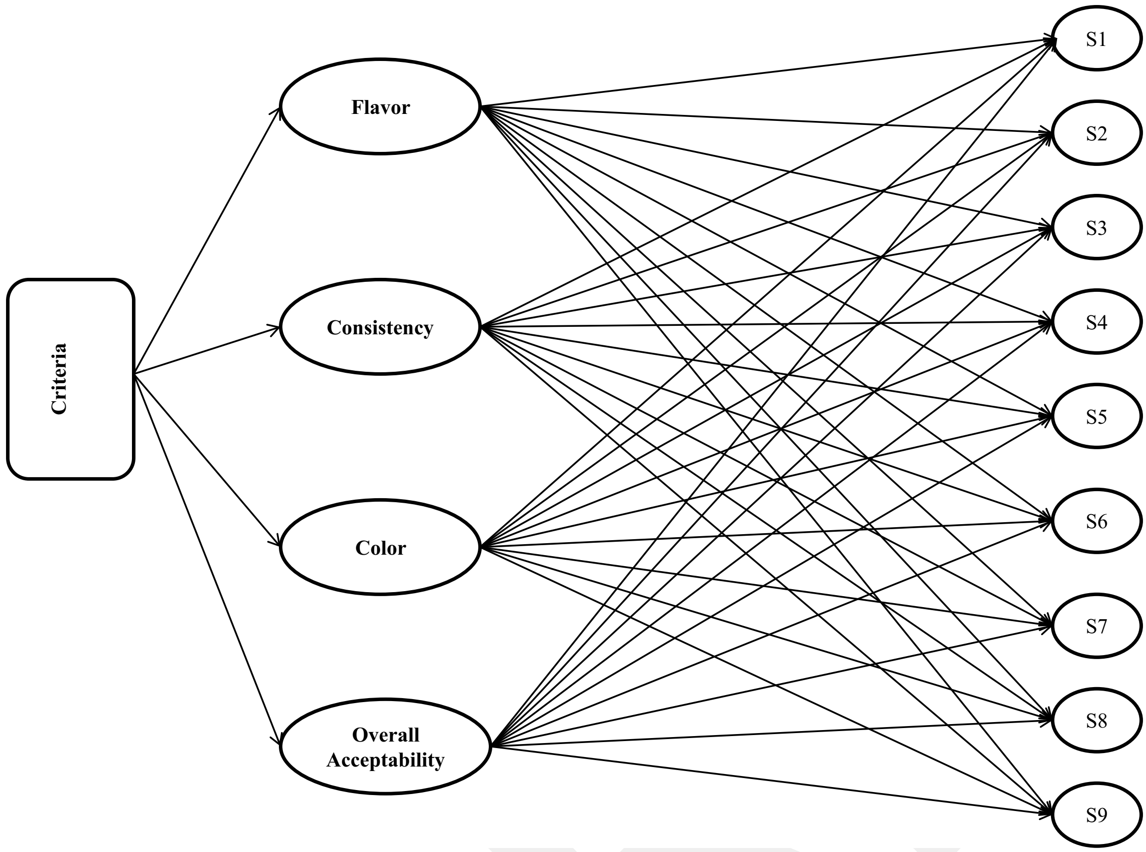

Fig. 1 Decision hierarchy process of the hot chocolate beverage sensory properties

taken in 5 replicates, and shear stress values versus shear rate values were recorded. The obtained flow data were fitted to the Ostwald de Waele model. The consistency coefficient and the flow behavior index values were calculated according to the following models using Haake Rheo Win Data Manager.

$$\text{Ostwald–de Waele} \qquad \sigma = K\gamma^n$$

where σ is shear stress (Pa), K is the consistency index (Pa s^n), γ is the shear rate (per second), and n is the dimensionless flow behavior index.

Sensory analysis

A total of 28 panelists composed of 23 females and 5 males with an average age of 25.7 ± 3.4 were recruited among the students and staff of Food Engineering Department in Erciyes University, Kayseri, Turkey. All subjects were non-smokers and currently in good health condition. They reported no medical complications, no eating disorders, and they were not on a special eating planned-based treatment. Participation in the study was voluntary, and all subjects who agreed to take part in the study were informed verbally. Sensory analysis was conducted in a room with controlled temperature. Before analysis, the panel members were informed about the general terminology and properties related to hot chocolate drinks. The definitions in the sensory evaluation form were described to the panelist group. Panelists were asked to rinse their mouth with water to cleanse their palates prior to each sample. The hot chocolate samples were presented to participants in a single sensory session. For each sample, a panelist received 100 ml of hot chocolate beverage in a transparent glass labeled with a three-digit random numbers and was asked to evaluate consistency, flavor, color and overall liking using 9-point hedonic scale (1 = disliked extremely, 5 = neither liked nor disliked and 9 = liked extremely).

Application of AHP, TOPSIS, ELECTRE and SAW techniques to sensory analysis

The decision hierarchy of the fat content of hot chocolate selection is shown in Fig. 1.

AHP method

Analytic hierarchy process (AHP) is a widely used method used for shaping and analyzing the competing alternatives in multi-objective conditions. This method was developed by

Table 2 Pairwise comparison scale for AHP preferences

Ratings of samples	Verbal description
1	Equally preferred
2	Equally to moderately
3	Moderately preferred
4	Moderately to strongly
5	Strongly preferred
6	Strongly to very strongly
7	Very strongly preferred
8	Very strongly to extremely
9	Extremely preferred

Saaty [32] based on mathematics and psychology to prescribe a correct decision according to multiple affecting factors.

AHP method relies on pairwise comparison to observe the levels of each criterion that affects the outcome. The steps of the AHP method to give a decision on multi-parameter conditions are listed by Saaty [32] as:

1. Define the current situation and the problem with the probable goals.
2. Matrix creation for pairwise comparison criteria. Table 2 demonstrates the pairwise comparison scale for AHP method. If one criterion is preferred to the other criteria, numerical rating is selected as 5. In this research, the pairwise comparison matrix was formed based on ten different people's opinion.

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1n} \\ x_{21} & x_{22} & \ldots & x_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ x_{n1} & x_{n2} & \ldots & x_{nn} \end{bmatrix}$$

3. Normalization of the matrix by a factor calculation (normalization is equal to the ratio of the relevant parameter to the sum of the its row. For example, normalized value of x_{11} is equal to $x_{11}/(x_{11} + x_{21} + \cdots + x_{n1})$).
4. Calculation of consistency ratio (CR) to illustrate the consistency of pairwise comparison.
5. Construction of D_i matrix to determine the CR by multiplying X_{ij} matrix and its priority matrix (B_i).

$$D_i = \begin{bmatrix} d_{11} \\ d_{21} \\ . \\ . \\ . \\ d_{n1} \end{bmatrix}$$

The eigenvalue (λ_{max}) is calculated by:

$$\lambda \max = \frac{1}{m} \sum_{i=1}^{m} \frac{di}{i} \quad (1)$$

6. After all the pairwise comparisons have been made, the eigenvalue is used to determine the consistency index CI by: $CI = (\lambda_{max} - n)/(n - 1)$ where n is the matrix size. The judgments consistency can be inspected by CR, equal to the dividing of the CI to the random consistency (RC) value obtained according to the matrix size (n) which is equal to number of criteria. However, the pairwise comparison matrix is acceptable only if the CR value is lower than 0.10 and where higher the judgments matrix is supposed to be accepted as inconsistent. In order to obtain a consistent matrix, judgments should be reviewed and improved where possible.

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \ldots & x_{1n} \\ x_{21} & x_{22} & \ldots & x_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ x_{n1} & x_{n2} & \ldots & x_{nn} \end{bmatrix}$$

7. Alternatives to be formed for each criterion of the pairwise comparison. The present research was based on the determination of ratio between two alternatives for the matrix. If the general acceptability of an alternative (A) is 2 and another alternative (B) is 1, the comparison will be made as $X_{AB} = 2/1 = 2'$ (and $X_{BA} = 1/2 = 0.5$). After the creation of the pairwise comparison, matrix for each criterion and their CR values are calculated [33]. According to the founded CR value (if lower than 0.1), the method will be continued.

$$Y_{ij} = \begin{bmatrix} y_{11} & y_{12} & \ldots & y_{1n} \\ y_{21} & y_{22} & \ldots & y_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ y_{n1} & y_{n2} & \ldots & y_{nn} \end{bmatrix}$$

where Y_{ij} is the pairwise comparison matrix of alternatives for one criterion. That matrix is normalized like step 3.

8. Calculation of the priority vectors for each criterion as follows for Y_{ij} alternative:

$$B_i = \begin{bmatrix} b_{11} \\ b_{21} \\ . \\ . \\ . \\ b_{n1} \end{bmatrix}$$

where $a_{11} = (x_{11} + x_{12} + \cdots + x_{1m})/m$.

Then, the matrix C_{ij} is constructed by combining all of the priority matrices of alternatives for each criterion.

$$C_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ x_{n1} & x_{n2} & \dots & x_{nn} \end{bmatrix}$$

where the first row is the priority matrix of alternatives for criterion 1, and the second row is that of criterion 2.

9. Calculation of the overall score by multiplying priority vectors of the alternatives (C_{ij}) and priority vectors of criterion. The highest overall score owning alternative should be accepted as the best alternative.

Additional benefit of AHP is the calculation of the inconsistency index as a ratio of the decision maker's inconsistency and randomly generated index. This value will assure the consistency of the judgments and the final decision [27].

SAW (simple additive weighting)

This method makes a comparison between each criterion one by one.

1. Construction of pairwise comparison matrix ($m \times n$) based on Saaty's 1–9 scale shown in Table 2.
2. Selection of the important criteria for each comparison and scoring to illustrate how much more important it is.
3. Construction a decision matrix ($m \times n$) including m alternative and n criteria. Normalization of the decision matrix as step 3 in AHP method.
4. Building of the weighted normalized matrix with the following equation:

$$A_i = \sum w_i x_{ij} \tag{2}$$

where x_{ij} is the score of the ith alternative with respect to the jth criteria and w_j is the weight of the criteria [34].

5. Calculating the sum of the weighted normalized vectors to find out the ranking of the alternatives.

ELECTRE

ELECTRE is a methodology used for the determination of the dominant one between the significant relationships and the alternatives. This method has ability to handle discrete criteria of qualitative and quantitative behavior and also to create complete alternative order. In ELECTRE concordance and disconcordance, indices are compared in pairs, and based on these indices, strong and weak relationships can be plotted [21, 25, 27, 35]. The steps of ELECTRE are as follows:

1. Normalization of the decision matrix: The decision matrix is transformed into normalized matrix by the following equation (r_{ij})

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \tag{3}$$

After this normalization process, they are multiplied by its associated weights to observe the weighted matrix.

$$Y_{ij} = \begin{bmatrix} w_1x_{11} & w_2x_{12} & \dots & w_nx_{1n} \\ w_1x_{21} & w_2x_{22} & \dots & w_nx_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1x_{m1} & w_2x_{m2} & \dots & w_nx_{mn} \end{bmatrix}$$

2. Determination of concordance and disconcordance sets. Concordance set C_{ab} of the alternatives $A = \{a, b, c, \dots\}$ and D_{ab} disconcordance sets are calculated with the following equations.

$$C_{ab} = \{j, x_{aj} \geq x_{bj}\} \tag{4}$$

$$D_{ab} = \{j, x_{aj} < x_{bj}\} = J - C_{ab} \tag{5}$$

3. Forming the concordance and disconcordance matrices: The concordance index between Aa and Ab is calculated with the following equation.

$$C_{ab} = \sum_{jeCab} wj \tag{6}$$

Concordance index shows A is more significant than B, and it can be calculated with the following equation:

$$C = \begin{bmatrix} - & c_{12} & \dots & c_{1n} \\ c_{21} & - & \dots & c_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ c_{n1} & c_{n2} & \dots & - \end{bmatrix}$$

4. Construction of the disconcordance matrix: disconcordance index $d(a, b)$ of the probability matrix of deciding A against B condition is calculated.

$$d_{ab} = \frac{\max_{j \in D_{ab}} \left| v_{aj} - v_{bj} \right|}{\max_{j \in J, m, n \in I} \left| v_{mj} - v_{nj} \right|} \tag{7}$$

m and n are used for the calculation of normalized values. Disconcordance index set is then used for the construction of the disconcordance matrix.

$$D = \begin{bmatrix} - & d_{12} & \ldots & d_{1n} \\ d_{21} & - & \ldots & d_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ d_{n1} & d_{n2} & \ldots & - \end{bmatrix}$$

5. Determination of concordance matrix index: To find the favorable condition, concordance index matrix is calculated as follows:

$$\bar{c} = \sum_{a=1}^{m} \sum_{b}^{m} c(a, b)/m(m-1) \tag{8}$$

6. Construction of disconcordance matrix index: To find the unfavorable conditions, disconcordance index matrix is calculated with the following equation.

$$\bar{d} = \frac{\sum_{a=1}^{m} \sum_{b}^{m} d(a, b)}{m(m-1)} \tag{9}$$

7. Calculations of the thresholds value: ca and da are the high and lower values, respectively. ca is favorable for the whole alternatives and summarizes the conditions of the higher and lower condition.

TOPSIS

TOPSIS is an alternative method to ELECTRE, and it was designed by Hwang and Yoon [36]. Selected alternative should have the shortest distance from the negative ideal solution in geometrical media. The preference order of alternatives is yielded through the comparison of the Euclidean distances [27]. The assumption made in this method is each attribute has monotonous increasing or decreasing utility to simplify the process of locating the ideal and negative ideal solutions.

1. Normalization of the decision matrix: Converting the various dimensional attributes to undimensional version. Normalized decision matrix (r_{ij}) can be calculated as:

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \tag{10}$$

2. Decision maker decides set of weights $W = (w_1, w_2, w_3, \ldots, w_N)$, where $\sum_{i=1}^{n} w_i = 1$ to accommodate to the decision matrix to generate the weighted normalized matrix Y_{ij} as follows:

$$Y_{ij} = \begin{bmatrix} w_1x_{11} & w_2x_{12} & \ldots & w_nx_{1n} \\ w_1x_{21} & w_2x_{22} & \ldots & w_nx_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1x_{m1} & w_2x_{m2} & \ldots & w_nx_{mn} \end{bmatrix}$$

3. Calculation of the performance data for n alternatives over k criteria. Generally, raw measurements (r_{ij}) should be standardized (n_i) by the following formula:
4. Construction of a set of importance weights (w_k) for each criteria. Usually, the basis for the weights is ad hoc reflective of relative importance, but it could be anything. With the standardization by step 1 being successful, scaling will be non-problematic.
5. Positive (A^+) and negative (A^-) ideal solution determination
$A^* = \left\{ v_1^*, v_2^*, \ldots, v_n^* \right\}$ (Maximum values)
$A^- = \left\{ v_1^-, v_2^-, \ldots, v_n^- \right\}$ (Maximum values) v is the weighted normalized values.
6. Calculation of the distance of the alternatives from positive and negative ideal solution

$$D_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^*)^2} \tag{11}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \tag{12}$$

v_{ij}, v_j* and v_j^- are the weighted normalized value, positive and negative ideal solutions, respectively. D_i* and D_i^- are the distance from positive and negative ideal solution.

7. Determination of a ratio of R for each alternative is equal which is obtained by dividing the distance to the nadir by the sum of the distance to the nadir and the distance to the ideal

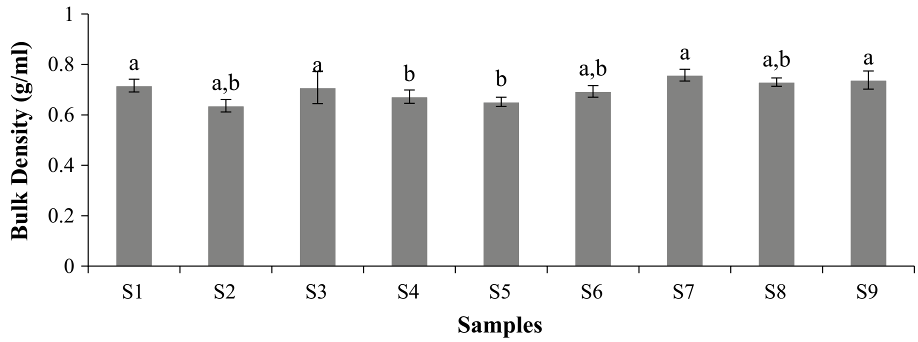

Fig. 2 Bulk density (g/ml) of the instant hot chocolate beverages containing milk and cocoa powder with different fat ratios. Means within a column followed by a different letter are significantly different at $p < 0.05$

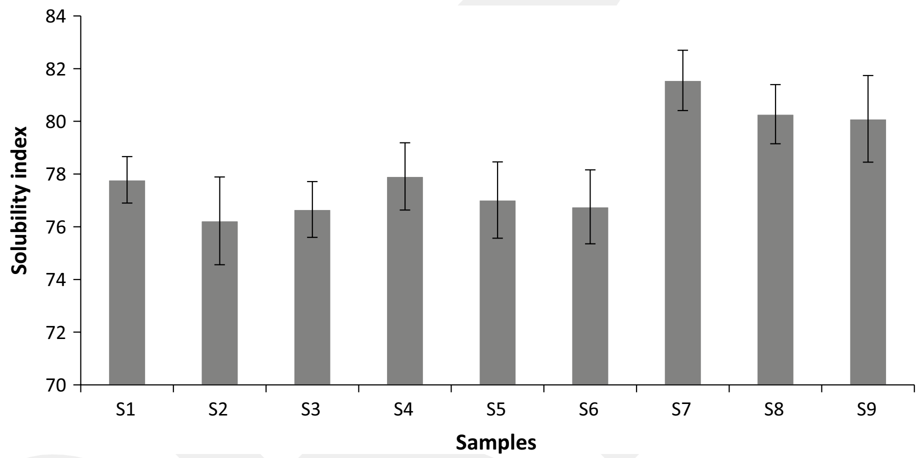

Fig. 3 Solubility index (%) of the instant hot chocolate beverage containing milk and cocoa powder with different fat ratios

$$R_i^* = \frac{D_i^-}{D_i^- + D_i^*} \quad (13)$$

8. Ranking of the alternatives by using the R values [37, 38]. The sample with the highest R value is the best alternative.

Statistical analysis

The statistical analyses were performed using XLSTAT version 2014.3.04 statistical software (Microsoft, Mountain View, CA, USA). Mean values and standard deviation values were calculated. For the comparison of samples, analysis of variance (ANOVA) and Tukey least significant difference (LSD) test were applied to the results at 95 % confidence interval.

Results and discussion

Bulk density

Bulk density measurements are fundamental for the industry in order to adjust storage, processing, packaging and distribution conditions [39]. Particularly, bulk density is an indicative measurement for the packing characteristics of particulate solids. Figure 2 shows that bulk density of instant hot chocolate samples was ranged from 0.64 to 0.76 g/ml. It is known from the literature that bulk density may be changed with the composition of powdered foods and particle size has a direct impact on it [40]. Figure 1 shows that fat content has a statistical impact on the bulk density ($p < 0.01$). It was observed that the high-fat-containing cocoa and milk powder in instant chocolate formulation had the lowest bulk density among these 3 groups of samples. It may be speculated that the density of fat has a lowering effect on the total bulk density of samples.

Solubility

Figure 3 shows the solubility index of the 9 hot chocolate samples ranging from 76 to 82 %. Solubility is an instant property that affects the consumption characteristics and sensory attributes of instant hot chocolate. A similar study done by Dogan et al. [2] claimed that the solubility of the prebiotic hot chocolate samples was very close to each other since the most important factor affecting the solubility of hot chocolate drinks is the sugar content which is the major component of the product. In our study, it was found that there was a significant difference among samples

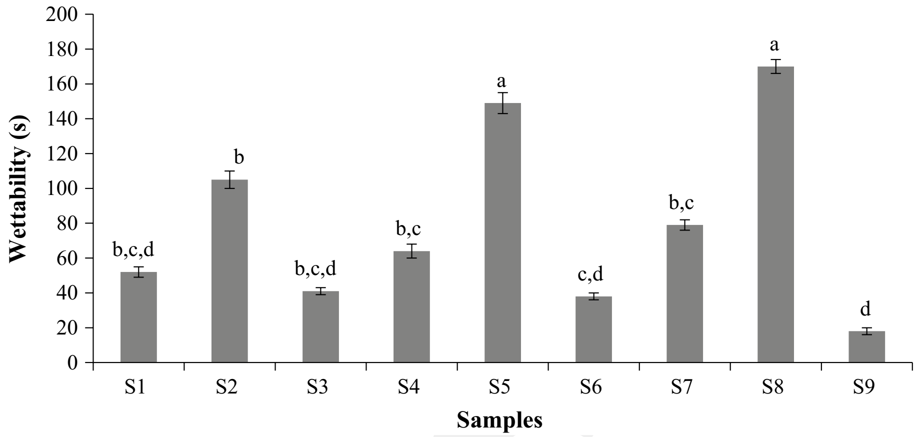

Fig. 4 Wettability of the instant hot chocolate beverages containing milk and cocoa powder with different fat ratios. Means within a column followed by a different letter are significantly different at $p < 0.05$

($p < 0.01$). In addition to the sugar content, fat content may also affect the solubility properties of products. Figure 3 shows that there was a similar pattern of solubility levels until the last 3 samples. However, the best solubility levels in samples were observed in samples 7, 8 and 9 which contained skimmed milk power. Therefore, it can be concluded that less-fat-containing milk powder increases the solubility levels. Because the fat is insoluble in water, it is concluded that the lower the fat content, the higher the solubility index.

Wetting time

Wetting time is the main indicator of the particle size. Figure 4 shows the wetting time of the 9 samples used in this study. The wetting time of the samples was between 18 and 170 s, and the minimum value and maximum value of samples were in sample 8 and sample 9. The difference between these two samples was due to the fat content of the cocoa powder, and they both had milk powder with same fat content. Therefore, it would not be wrong to mention that increase in fat content of the cocoa powder increases the wetting time of the sample. The reason behind this fact was investigated by Fäldt and Bergenståhl [41], and they pointed out that the surface coverage of hydrophobic component may affect the wettability of samples. Because the fat has a hydrophobic character, it imparts poor wetting properties. Similarly, when it was focused on the group 1, it was obvious that the cocoa content was linearly related to the wetting time. Therefore, it could be concluded that the increase in the fat content of cocoa powder increases the wetting time.

Physicochemical properties

The brix values which is an indication of total soluble solid content varied between 10.34 and 10.94 °Brix, being the highest for the S6 and lowest for the S4 samples (Table 3). Generally, the brix values of the samples were similar, because the levels of sugar which was main ingredient in formulation of instant hot chocolate were the same and the soluble solid values were not different statistically ($p > 0.05$).

Similarly, pH values were between 7.4 and 8.2, and the range stayed constant throughout the experiments. It is clear that the fat content of the milk powder and cocoa powder affects the acidic content in the structure. Therefore, as expected the pH value shows fluctuations between the samples ($p < 0.05$).

Color measurements for 9 hot chocolate sample were taken as L^*, a^* and b^* values changed between 4.1–15.3, 4.2–12.9 and 2.6–13.9, respectively. It can be seen that the color measurements had changed drastically between the samples. In particular, L^* value which represents the brightness where lower number indicates darker sample was found to fluctuate according to the fat content of both milk powder and cocoa powder. The less-fat-containing sample was measured to be darker in color. The case was similar for the a^* value where higher number indicates redness. Likewise, higher b^* value indicates increased yellowness. Therefore, the increase in the fat content leads to brighter color looking more red and yellow.

Flow behavior

Rheological properties of hot chocolate beverages can be seen in Fig. 5 as shear stress (Pa) and shear rate (1/s). Also from Table 4, one can observe the consistency index (K), flow behavior index (n), R^2 values of the power law model fitting and the viscosity at 50 s^{-1} shear rate according to Ostwald de Wale model. The determination level of power law model fitting was found to be between 0.93 and 0.99, which is considered as a good fitting. Flow behavior index values of the samples were in a range of 0.19–0.30. This value is an indication of the flowing behavior of the test sample. Since it was <1, it shows that the sample was behaving as a shear-thinning behavior under deformation, or in another expression, increased shearing decreases the

Table 3 Brix, pH and color measurements of the instant hot chocolate beverages containing milk and cocoa powder with different fat ratios

Samples	°Brix	pH	Color values		
			*L**	*a**	*b**
S1	10.87 ± 0.03	7.81 ± 0.01	8.17 ± 0.05	9.5 ± 0.05	7.17 ± 0.04
S2	10.58 ± 0.07	7.48 ± 0.01	14.22 ± 0.38	12.95 ± 0.04	13.87 ± 0.31
S3	10.66 ± 0.02	8.30 ± 0.01	4.13 ± 0.07	4.16 ± 0.02	2.63 ± 0.03
S4	10.34 ± 0.01	7.91 ± 0.01	9.14 ± 0.18	10.28 ± 0.10	8.88 ± 0.23
S5	10.41 ± 0.02	7.58 ± 0.01	14.77 ± 0.04	12.33 ± 0.05	13.83 ± 0.04
S6	10.94 ± 0.02	7.69 ± 0.02	5.79 ± 0.22	6.59 ± 0.22	4.58 ± 0.11
S7	10.71 ± 0.01	7.91 ± 0.01	7.64 ± 0.06	8.22 ± 0.04	6.16 ± 0.03
S8	10.90 ± 0.01	7.39 ± 0.01	15.27 ± 0.04	11.20 ± 0.03	11.63 ± 0.11
S9	10.80 ± 0.02	8.22 ± 0.01	4.02 ± 0.03	4.71 ± 0.04	3.3 ± 0.06

*L** defines the brightness, and *a** and *b** define the redness and yellowness, respectively

apparent viscosity. The consistency index (K) of the samples ranged between 0.19 and 0.30 Pas^n.

The apparent viscosity of the hot chocolate samples is 50 s^{-1}, accepted as mouth shear rate [42]. It ranged between 0.015 and 0.025 Pa s, as can be seen in Table 4. Among the samples, sample 9 had the lowest apparent viscosity and sample 3 had the highest n_{50} value. Sample 9 had the lowest fat content for the milk and cocoa powder throughout the whole sample set. It is not surprising that lower fat content leads to the lower viscosity.

Sensory evaluation

The expectation from hot chocolate is the specific consistency and then the aroma, and these are associated with high overall liking scores. In this test design, authors had tested whether the effect of changing fat content in the milk powder and the cocoa powder had any impact on the sensory testing of the hot chocolates. The rheological tests of the samples showed that the viscosity readings at 50 s^{-1} shear rate did not change drastically. Therefore, the expectation of consistency changes effect on the overall liking score cannot be confirmed in this study. Also statistical tests confirmed that consistency rating of 9 different samples with different fat ratios of milk powder and cocoa powder showed significant difference ($p < 0.05$). Besides, it was observed from the values that the fat content of the milk powder had an effect on the consistency attribute of the samples as expected. Therefore, it can be suggested that decreasing fat content of the milk powder changes the viscosity and the consistency rating, but for our sample range, this cannot be illustrated statistically.

The next sensory attribute tested was the color. Subjects verbally commented on the samples that the color showed a strong change within the samples. Likewise, the sensory testing of the color scoring showed that there is a significant difference between the 9 samples ($p < 0.01$). Moreover, the 3 samples that got the highest score in the sensory testing were the sample 3, sample 9 and sample 6, respectively. These 3 samples had the low-fat cocoa powder, and besides, the 3 samples that got the lowest color score were sample 8, sample 2 and sample 5. Not surprisingly, these 3 samples were the one that had a high-fat-containing cocoa powder. Therefore, we can suggest that the fat content of the cocoa powder in instant hot chocolate affects the color liking negatively. Furthermore, the assessors reported verbally that they were not pleased with the appearance of those samples as well.

Table 4 Consistency index (K), flow behavior index (n) and apparent viscosity (η_{50}) values of the instant hot chocolate beverages containing milk and cocoa powder with different fat ratios

Samples	K (Pa s^n)	n	R^2	η_{50} (Pa s)
S1	0.415 ± 0.102	0.280 ± 0.090	0.934 ± 0.015	0.017 ± 0.002
S2	0.314 ± 0.046	0.272 ± 0.025	0.942 ± 0.017	0.016 ± 0.001
S3	0.564 ± 0.121	0.229 ± 0.091	0.978 ± 0.016	0.025 ± 0.005
S4	0.299 ± 0.077	0.302 ± 0.048	0.971 ± 0.011	0.018 ± 0.001
S5	0.453 ± 0.026	0.209 ± 0.009	0.950 ± 0.002	0.019 ± 0.000
S6	0.449 ± 0.141	0.187 ± 0.048	0.933 ± 0.018	0.017 ± 0.003
S7	0.339 ± 0.099	0.273 ± 0.045	0.970 ± 0.020	0.018 ± 0.004
S8	0.315 ± 0.072	0.249 ± 0.053	0.934 ± 0.035	0.015 ± 0.001
S9	0.386 ± 0.056	0.298 ± 0.034	0.997 ± 0.002	0.024 ± 0.000

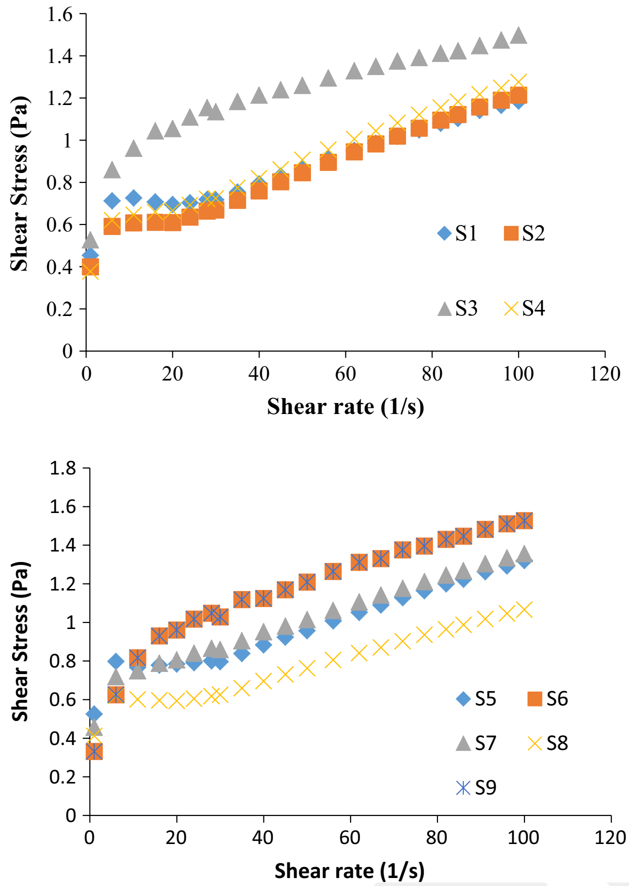

Fig. 5 Flow behavior of the instant hot chocolate beverages containing milk and cocoa powder with different fat ratios

Third sensory attribute tested for these 9 hot chocolate samples was the aroma profile. During the sensory tests, subjects did not made any comment verbally on the aroma of the samples. However, the statistical analysis showed that there is no similarity between the samples (*p* value = 0.003). Sample 2, sample 8 and sample 5 have the highest score of aroma liking. All of these 3 samples had high-fat cocoa powder. The least rated samples were sample 9, sample 1 and sample 7. These 3 samples contained relatively low amount of fat. This finding would suggest that aroma rating has a correlation with fat content of both cocoa and milk powder in a positive way. As a last attribute, the overall likings of the hot chocolate samples were assessed. Statistical analysis showed that the samples were significantly different from each other. Sample 2, sample 4 and sample 8 had the highest score of overall liking. The mutual factor between these three samples all contained high-fat cocoa powder. Moreover, the lowest score of the overall liking was given to the sample 5, sample 6 and sample 9 which contained comparatively low amounts of fat ingredient. Therefore, it will not be wrong to say that the fat content of the cocoa and milk powder has a direct effect on the overall liking of the hot chocolate beverages. This relationship can be classified as positive correlation.

Table 5 Priority matrix for sensory evaluation for analytic hierarchy process (AHP)

	Consistency	Flavor	Color	Overall acceptability	Overall
Weight of the criteria	0.333	0.190	0.047	0.429	–
S1	0.122	0.176	0.098	0.117	0.129
S2	0.151	0.225	0.118	0.174	0.174
S3	0.078	0.054	0.096	0.058	0.066
S4	0.138	0.152	0.098	0.115	0.129
S5	0.149	0.241	0.118	0.166	0.172
S6	0.077	0.082	0.096	0.074	0.077
S7	0.124	0.178	0.098	0.129	0.135
S8	0.147	0.232	0.118	0.159	0.167
S9	0.083	0.061	0.098	0.080	0.078

S1, S2 and S3 samples had the low-fat-containing milk powder; S4, S5 and S6 samples had the whole-fat-containing milk powder; and S7, S8 and S9 samples had the skimmed milk powder

Application of multi-criteria decision techniques to sensory scores of the hot chocolate samples

In this study, 4 different multi-criteria decision techniques (AHP, ELECTRE, TOPSIS and SAW) were used in order to obtain the optimum hot chocolate sample. In the AHP method, the results were directly interpreted from the data. The parameters were required to be scaled as shown in Table 2. During the sensory test, 1–9 scale was used; therefore, it was not necessary to do an arrangement for the dataset. The comparison matrix of the criteria is shown in Table 5. These values were divided to the sum of this column in order to normalize the data. Average of the normalized values of each row was equal to the priority vectors criteria. The pairwise matrices of the alternatives for each criterion were constructed by calculating the ratio of sensory scores to the alternatives among each other. The reliability of the matrices was observed with a consistency ratio (CR) values. Since the CR values for each criterion were lower than 0.1, it will not be a mistake to interpret that the paired comparison matrices were convenient. The alternatives were ranked by calculating the multiplication of the weight of criteria matrix by criteria priority matrices of the alternatives (Table 5), and the results of multiplications can be seen in Table 5 in overall column. This approach shows that the S2 sample was the best alternative when assigned conditions were considered.

Sensory scores of the alternatives were directly used and were normalized by using Eq. 2 for SAW method. The normalized and weighted normalized values of the sensory

Table 6 Pairwise comparison matrix of alternatives based on the criteria and overall score of the alternatives obtained from simple additive weighting (SAW) techniques

	Normalized comparison matrix				Weighted normalized matrix				
	Consistency	Flavor	Color	Overall acceptability	Consistency	Flavor	Color	Overall acceptability	Overall
S1	0.113	0.123	0.104	0.108	0.038	0.023	0.007	0.045	0.112
S2	0.140	0.158	0.125	0.160	0.047	0.029	0.008	0.066	0.151
S3	0.077	0.045	0.104	0.058	0.026	0.008	0.007	0.024	0.065
S4	0.128	0.107	0.104	0.106	0.043	0.020	0.007	0.044	0.113
S5	0.138	0.169	0.125	0.152	0.046	0.032	0.008	0.063	0.149
S6	0.077	0.068	0.104	0.077	0.026	0.013	0.007	0.032	0.077
S7	0.114	0.125	0.104	0.119	0.038	0.023	0.007	0.049	0.118
S8	0.136	0.162	0.125	0.147	0.045	0.030	0.008	0.061	0.145
S9	0.077	0.043	0.104	0.073	0.026	0.008	0.007	0.030	0.071

S1, S2 and S3 samples had the low-fat-containing milk powder; S4, S5 and S6 samples had the whole-fat-containing milk powder; and S7, S8 and S9 samples had the skimmed milk powder

Table 7 Overall *C* (concordance) and *D* (discordance) values of the alternatives for elimination et choixtraduisant la realite—elimination and choice translating reality (ELECTRE) techniques

Alternative	*C*	*D*
S1	−0.8086	1.1420
S2	7.1440	−7.1029
S3	−6.7160	7.8820
S4	−0.7144	0.1783
S5	6.3806	−6.6876
S6	−4.6191	4.0000
S7	1.0967	−1.3203
S8	4.4754	−4.2095
S9	−6.2385	6.1180

S1, S2 and S3 samples had the low-fat-containing milk powder; S4, S5 and S6 samples had the whole-fat-containing milk powder; and S7, S8 and S9 samples had the skimmed milk powder

Table 8 Distance from positive (D^+), negative (D^-) and ratio values of each alternative for technique for order preference by similarity to ideal solution (TOPSIS) techniques

Alternative	D^+	D^-	*R*
S1	0.0735	0.0825	0.5290
S2	0.0059	0.1525	0.9625
S3	0.1544	0.0012	0.0076
S4	0.0750	0.0843	0.5290
S5	0.0097	0.1466	0.9382
S6	0.1306	0.0271	0.1716
S7	0.0611	0.0940	0.6063
S8	0.0174	0.1386	0.8886
S9	0.1400	0.0189	0.1192

S1, S2 and S3 samples had the low-fat-containing milk powder; S4, S5 and S6 samples had the whole-fat-containing milk powder; and S7, S8 and S9 samples had the skimmed milk powder

scores are shown in Table 6. Equation 2 was used for calculating weighted normalized values. According to the SAW technique, S2 sample had the highest value meaning that S2 was the best sample.

Another multi-criteria decision technique was the ELECTRE method. The sensory scores of the samples were calculated by using Eq. 3. The normalized values were multiplied with weight of the criterion to obtain weighted normalized matrix. The overall C and D values of the alternatives for the ELECTRE method are shown in Table 7. The S2 sample had the highest C and lowest D value, which means that it was the best sample.

The TOPSIS has similar normalized and weighted matrices to the matrices of ELECTRE. In order to acquire the normalized values, Eq. 12 was used, while they were multiplied with the weight of the criterion to have the values of weighted normalized matrices.

The calculations of Eqs. 12–13 were made through the negative (D^-), positive and (D^+) ideal solution values of the alternatives as shown in Table 8. With the aim of arranging the alternatives, Eq. 13 was used to acquire *R* value. When compared to other methods, it was shown that the best sample was S2. Table 9 demonstrates how the results were achieved using TOPSIS, SAW, ELECTRE and AHP.

Whereas the hot chocolate beverage which had a poor content of fat (S3) can be seen as the worst alternative, the optimal alternative for hot chocolate was the sample which contains relatively high amount of fat (S1) with respect to all the MCDM techniques. The findings showed that the most ideal way of obtaining hot chocolate beverage was increasing the fat content which was caused by cocoa and milk powder. The weights of the criterion were the most influential element in the findings of the study.

Table 9 Evaluation scores of the samples on the sensory alternatives with different multi-criteria decision techniques

Samples	AHP	SAW	ELECTRE	TOPSIS
S1	6	6	6	5
S2	1	1	1	1
S3	9	9	9	9
S4	5	5	5	6
S5	2	2	2	2
S6	8	7	7	7
S7	4	4	4	4
S8	3	3	3	3
S9	7	8	8	8

S1, S2 and S3 samples had the low-fat-containing milk powder; S4, S5 and S6 samples had the whole-fat-containing milk powder; and S7, S8 and S9 samples had the skimmed milk powder

The variation in the weights affects the results as well and general acceptability scores showed that the weights were consistent. The results acquired by the MCDM techniques indicated that the sample which had the highest score in general acceptability can be regarded as the best sample.

Conclusions

In this present study, the effect of fat content in the composition on the rheological and sensory properties of instant hot chocolate was examined. It was seen that the consistency index and apparent viscosity of a product were the major quality factors affecting the consumer preferences. The findings showed that fat content of the milk and cocoa powder changed the viscosity and the consistency rating rheologically, and the same effect was also observed in sensory evaluation. All hot chocolate samples with different fat contents behaved as shear-thinning behavior under deformation, or in another expression, increased shearing decreases the apparent viscosity. To conclude, lower fat content had a decreased effect on the viscosity. Multi-criteria decision techniques (AHP, SAW, ELECTRE and TOPSIS) were performed to compare the samples according to sensory scores. S2 sample which contained relatively high amount of fat content was found as the best alternative for hot chocolate as a result of multi-criteria decision techniques.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Compliance with ethics requirements This article does not contain any studies with human or animal subjects.

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