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PHYSICOCHEMICAL AND COLOR EVALUATION OF CONFECTIONERY MOUSSES

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Abstract: *In this study was investigated the effect of raw material and the production process on the physicochemical composition and color of confectionery mousses. For this approach, two different mousses' production procedures were used and the chemical composition (fat, moisture, protein content and soluble substances concentration), physical parameters (overrun, density, specific volume), and color were determined. The dairy cream mousse samples (M_1 and M_3) presented a higher fat content (33.68% and 30.57%), while the protein content varied from 0.9% to 3.42%, being influenced by the raw materials used in the production process. Color measurements indicated that the mousses based on vegetable cream were whiter with a brightness (L*) ranging between 90.04 – 94.25 and a higher whiteness index. The results of one factor analysis of variance — ANOVA showed that the color difference between mousse samples is statistically significant ($p<0.001$).*

Keywords: overrun, color, mousse, density, aeration

1. Introduction

Confectionery represents a class of food products with unique and special sensory properties characterized by a high energy value. The Romanian confectionery market is growing, due to the changes in consumption habits, but on the other hand, the increase of local competition and the international trends also contribute to this growth [1]. Aerated desserts are widespread and show an important market perspective, as a function of consumers' comportment, which has a special interest for lighter and healthier food products [2]. The production of aerated dairy confections is difficult and delicate, demanding thorough acquaintance of the formation and stabilization of food foams, the utilization of functional ingredients such as emulsifiers, stabilizers and also knowledge about the interaction and interference of the process parameters on the characteristics of the finite product [3]. The introduction and fixing of air bubbles or other gases in dairy desserts produce unique texture characteristics or sensory properties, reduces the density of the products [4], and decrease the product's caloric content and the production costs since less raw material are used [5]. Besides mechanical whipping processes in which rotor–stator air dispersing devices are used [6], the aerated structure of dairy desserts can be performed also by mixing the food matrix with gas under high pressure; a suitable pressure being between 2 – 6 bar. This process presents the advantage that the re-coalescence of the air/gas bubbles in the apparatus is reduced.

However, it also has some disadvantages related to the bubble's expansion after leaving the device such as (i) a small interior pressure (Laplace pressure) which leads to a more easily deformable product, the modulus of deformability, and respectively the foam stiffness is reduced, and the aerated product decreases its ability of shape retention; (ii) the products' creaminess decreases due to the fact that large size of the air/gas bubbles reduces the interface of the bubbles thus diminishing the continuous phase immobilization capability and accordingly resulting faster drainage losses; (iii) bubbles expansion can lead to foam lamella rupture resulting even larger disproportionate bubbles, a process also called Ostwald ripening [7]. For the aeration process, in addition to air, it is recommended to use gases without smell, taste, non-toxic and which allow controlled aeration [5]. Among the used gases (air, steam, carbon dioxide, nitrogen or nitrous oxide) [8], the carbon dioxide presents some important features such as a good fat solubility, which makes it less predisposed to escape from the aerated fat - food matrix during cold-stamping, than other gases less soluble in fat, such as nitrogen [5]. The mousses are defined as aerated confectionery products or overrun milk-based products with a stabilized aerated structure that nowadays is produced on an industrial scale and is gaining space in the dessert market [2]. According to Grassler 2001, the overrun food products are understood to be products that have been subjected to an increase in volume by overrunning (from 80% to 120%). Additionally, mousses contain sugar, a flavoring component, cream, and a gelling or a thickening agent [9]. The most popular mousse flavor is chocolate, cocoa followed by orange, strawberry, and lemon [2]. When it comes to overrun food products (aerated products) like Chantilly, mousses, whipped cream, marshmallow, or ice cream an important aspect is represented by the product stability, which is closely connected to the product microstructure, and more exactly, to the gas/air voids dimension, distribution and also volume fraction [10]. The structure of aerated whipped products is primarily affected by the continuous phase properties, like viscosity, density or surface tension and also by the process parameters such as overrun, whipping time, velocity, whipping head geometry, power input, temperature, and static pressure [7]. According to McClements 2016, food foams with the smallest air/ gas bubbles and uniform distribution of them show an improved texture, being creamier and more appealing to consumers and presenting higher stability [11, 12]. Given that aerated confectionery products are complex food systems, represents also a significant category of food materials [13] and diverse types of aerated confections have been designed to develop novel products properly adapted to consumer preferences, using air, as a free ingredient [14]; therefore, this study aims to evaluate the influence of the raw materials and the production process on the physicochemical composition and color of confectionery mousses.

2. Materials and methods

Preparation of mousse samples. For experimental mousse samples were used vegetable and dairy cream, white chocolate, sugar, and vanilla; following two different procedures as presented in Figures 1 and 2. The samples aeration was made by the whipping process at 600 rpm [15] for 5 minutes, using a KitchenAid planetary mixer with 6 wire whip attachment [8]. The M_1 and M_2 mousse samples were made by the first procedure (Figure 1), where half of the dairy cream/vegetable cream (62.5 g) was heated to boiling and mixed with chocolate (50 g),

and the other half was whipped, finallybeing combined and put into parallelepiped shapes. The M_1 represents the dairy cream mousse samples, while the M_2 represents the vegetable cream samples.
The M_3 and M_4 mousse samples were made by the second procedure (Figure 2). M_3 represents the dairy cream mousse samples, while the M_4 represents the vegetable cream mousses. A small amount of dairy cream/vegetable cream was heated and infused with vanilla (1g), while the remaining dairy cream/vegetable cream was whipped with sugar and finally mixed together.

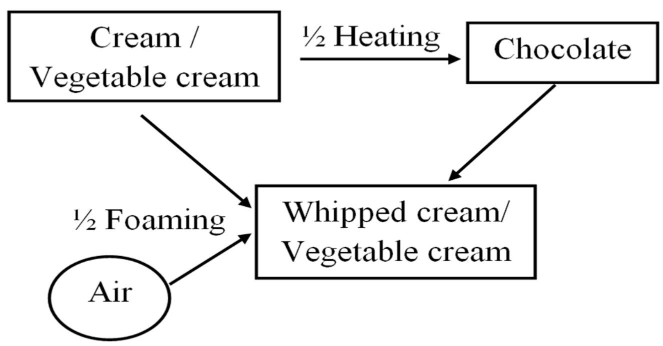

Fig. 1. The process of obtaining the M_1 and M_2mousses samples

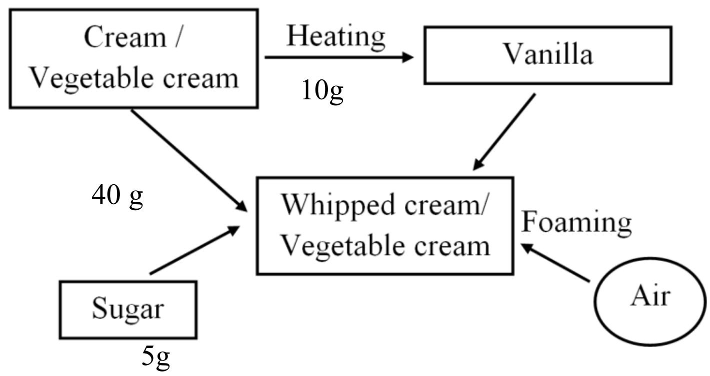

Fig. 2. The process of obtaining the M_3 and M_4 mousses samples

Physicochemical analysis. The moisture content of mousse samples was performed through the oven drying method at 103±2 °C [16], while the protein content was measured using the Kjeldahl assay and a conversion factor of 6.38 (equivalent to 0.156 g nitrogen per gram of protein) [17]. The total fat content of mousse samples was measured by Soxhlet assay, using petroleum ether as solvent [18]. The results of protein and fat analysis were expressed as a percent of wet basis. The acidity was measured by direct titration with 0.1 N NaOH and the results were expressed as Thorner degrees (ºTh) [19]. All reagents used for mousses analysis were of analytical grade. The pH values were measured with a Mettler Toledo pH-meter and the water activity - a_w was determined with AquaLab Lite water activity meter. The soluble substances concentrations (expressed as °Brix) were measured with Leica Mark II Plus refractometer. In addition to chemical composition, the overrun parameter of mousse samples was also calculated. The overrun characterizes the mousse samples in terms of air volume incorporated and fixed in the product structure. Overrun was evaluated for each mousse using the following equation (eq. 1) [20, 12].

$$Overrun = \frac{Wu - Ww}{Ww} \cdot 100 \quad (1)$$

For overrun calculation, the volume corresponding to the weight of unwhipped mousse (Wu) is the same as the volume corresponding to the weight of whipped mousse (Ww). More accessible parameters like density and specific volume were also measured [21].

Color evaluation. The color properties were evaluated with aCR-400 Chroma meter from Konica Minolta (Konica Minolta, Japan). Also for color measurements, the Commission Internationale de l'Eclairage (CIE) L*a*b* uniform color space assay was applied, where: L* - represents the mousse brightness (0 represents black and 100 white), a* is the red–green color parameter (+a* represents red and - a* green) and b* is the yellow–blue color parameter (+b* represents yellow and - b* blue). The other color parameters like color difference (ΔE^*), hue angle or tone (h^0), chroma or color intensity (C*), whiteness index (WI), and yellowness index (YI) were also calculated (eq.2-6) [22-24].

$$\Delta E^* = [(\Delta L^2) + (\Delta a^2) + (\Delta b^2)]^{1/2} \quad (2)$$

Where: ΔL^* is the brightness difference between two samples, Δa^* is the difference between red-green color parameters and $\Delta b^*$is the difference between yellow-blue color parameters.

$$h^0 = \tan^{-1}(b^*/a^*) \quad (3)$$

$$YI = \frac{142.86b^*}{L^*} \quad (4)$$

$$C^* = \sqrt{a^{*2} + b^{*2}} \quad (5)$$

$$WI = 100 - \sqrt{(100 - L^*)^2 + a^{*2} + b^{*2}} \quad (6)$$

The mousse samples were stored at 4-6 °C until they were analyzed and the results represent the average of three measurements.

Statistical analysis. The obtained values for mousses analysis were submitted to analysis of variance ANOVA by Statgraphics Centurion XVI (Trial Version). Thestatistical significance was set at $\alpha = 0.05$.

3. Results and discussion

Physicochemical analysis. In Table 1 are shown the physicochemical analysis of moussesamples, respectively the fat content, protein content, moisture, soluble substances concentration, water activity, acidity, pH, overrun, density, and specific volume. The M_1 mousse sample presents a high-fat content (33.68%), followed by the M_3 sample (30.57%); both M_1 and M_3mousses being produced with dairy cream. Unlike M_1 and M_3, the M_2 and M_4 samples showed a lower fat content, ranging between 24 - 28%, due to the use of vegetable cream, which had a lower fat content. The samples' protein content varies from 0.9% to 3.42%, depending on the raw materials used in the production process; the M_1 samples presented the highest values, while the M_4 samples presented the lowest values. The fat and protein content has an important role in food products aeration, initially, the air/gas bubbles being stabilized by the proteins and fixed by fat globules [4, 25]. The moisture contentof mousse samples ranged from 40.84% to 59.98%, for the M_3 and M_4 samples, produced by the second procedure (Figure 2), were observed the highest concentration. In the case of soluble substances concentration and total acidity, it can be observed that M_1 and M_2 samples, produced by the first procedure (Figure 1), had the highest values, whereas the pH values were close to the neutral zone (6.34-6.03). When it comes to confections, water activity has a significant contribution to quality evaluation, product safety, processing, shelf life, texturaland also sensory characteristics [27]. The water activity of mousse samples was in the same range, between 0.93 and 0.97, which is similar to those reported by *Schmidt & Fontana 2020* [28].

Table 1.

Physicochemical properties of mousses samples

Sample	M_1	M_2	M_3	M_4	*F – ratio*	*P–value*
Fat [%]	33.68 (0.57)^a	28.16 (0.42)^c	30.57 (0.38)^b	24.38 (0.81)^d	399.6	$p < 0.001$
Protein [%]	3.42 (0.25)^a	1.90 (0.32)^b	2.04 (0.22)^b	0.9 (0.34)^c	15.2	$p < 0.01$
Moisture [%]	40.84 (0.25)^c	37.58 (0.37)^d	54.29 (1.21)^b	59.98 (1.54)^a	405.5	$p < 0.001$
Brix [°B]	21.50 (0.50)^b	32.00 (0.80)^a	11.50 (0.45)^d	13.00 (0.50)^c	259.1	$p < 0.001$
Acidity [°Th]	23.50 (1.20)^a	20.50 (0.45)^b	15.50 (0.55)^c	11.00 (0.75)^d	97.2	$p < 0.001$
a_w	0.93 (0.02)^c	0.94 (0.01)^{bc}	0.96 (0.02)^{ab}	0.97 (0.01)^a	4.0	$p > 0.05$
pH	6.03 (0.07)^d	6.18 (0.05)^c	6.28 (0.01)^b	6.34 (0.02)^a	91.5	$p < 0.001$
Overrun [%]	17.51 (3.22)^d	89.13 (3.55)^b	59.02 (2.02)^c	236.76 (2.10)^a	2019.8	$p < 0.001$
Density [g/cm^3]	0.997 (0.04)^a	0.618 (0.05)^c	0.641 (0.03)^b	0.311 (0.01)^d	9378.5	$p < 0.001$
Specific volume [cm^3/g]	1.002 (0.04)^d	1.617 (0.05)^b	1.559 (0.03)^c	3.205 (0.01)^a	1865.8	$p < 0.001$

Different lowercase letters (a–d) in a row show significant differences between the groups ($p<0.05$).

The overrun parameter of whipped mousse gives information on the amount of air/gas incorporated in the product [12], and according to *Camacho 1998*[29], the overrun of aerated confectionery products can be improved using hydrocolloids substances like carrageenan, gelatin, or locust bean gum. The highest overrun was recorded by vegetable cream mousses (M_4-236.76% and M_2-89.13%), while the M_1 sample presented the lowest value (17.51%). Furthermore, *Van Aken 2001*[15] reported that the overrun parameter of whipped dairy cream is influenced by fat concentration. According to *Campbell 1999* [20], dairy products such as different types of ice cream, mousses, beating cream, or frozen desserts include commonly from 15% to 60% air, offering a textural variety. The overrun results of analyzed mousses were similar to those reported for whipped cream (70-150%), ice cream (40%), or cake (200-250%), [20]. The introduction of air reduced the mousses' density, which varied between 0.311 g/cm^3 and 0.997 g/cm^3, while de specific volume increased. In the case of mousses' physicochemical properties, the ANOVA analysis highlighted a difference between samples at a level of $p < 0.01$ for protein, fat, moisture, soluble substances concentration, porosity, overrun, density and specific volume, which means that the procedures used as well as the raw materials lead to different samples in terms of physical and chemical composition.

Color evaluation. The ANOVA of color parameter values of the analyzed mousses is shown in Table 2. Color is the quality component evaluated instantaneously by consumers, being decisive to product acceptance or rejection. Foods color is given by the biochemical, chemical, microbial, and physical modifications which occur during processing, growth, ripening process, maturation, heat treatments, postharvest handling, represents an important quality characteristic and determines the consumers choice and preferences [30].

Table 2.

ANOVA of mousses'colorparameters

Sample		M_1	M_2	M_3	M_4	*F – ratio*	*P– value*
L*		82.72(0.84)^c	90.04(1.05) ^{b}	91.06(0.87) ^{b}	94.25(0.89) ^{a}	46.3	$p < 0.001$
a*		-7.55 (0.10) ^{d}	-6.01 (0.08) ^{b}	-6.63 (0.11) ^{c}	-5.65 (0.12) ^{a}	189.4	$p < 0.001$
b*		25.36(0.28) ^{a}	15.39(0.09) ^{c}	17.25(0.26) ^{b}	9.79(0.12) ^{d}	2828.3	$p < 0.001$
C		26.46(0.24)^a	16.53(0.05)^c	18.48(0.28)^b	11.30(0.17)^d	2732.8	$p < 0.001$
h°		106.57(0.38)^c	111.34(0.39)^b	111.01(0.02)^b	119.97(0.21)^a	1084.6	$p < 0.001$
YI		43.81(0.93)^a	24.42(0.43)^c	27.06(0.15)^b	14.84(0.10)^d	1578.8	$p < 0.001$
WI		68.38(0.66)^d	80.68(0.59)^b	79.45(0.12)^c	87.23(0.70)^a	564.3	$p < 0.001$
ΔE	M_1	-	12.46 (0.30)^b	12.02(1.31)^b	19.53 (1.44)^a	41.9	$p < 0.01$
	M_2	-	-	2.61 (0.92)^b	6.63 (0.79)^a	32.49	$p < 0.01$
	M_3	-	-	-	8.17 (0.98)	-	-

Different lowercase letters (a–d) in a row show significant differences between the groups ($p<0.05$).

For color measurements, the (Commission Internationale de l'Eclairage) CIE L*a*b* method was used and it can be observed that the brightness (L*) of mousses varies from 82.72 to 94.25, the mousse samples with chocolate presented lower values whilethe M_4 sample was the whitest. According to *Pathare 2013,* food color can be associated with other quality characteristics such as nutritional properties, sensory characteristics, some defects and can help to manage them immediately [30].

As the data shows the yellow–blue color parameter - b* had positive values which mean that the samples have a yellowish tint. The samples based on dairy cream and chocolate showed higher values ranged between 25.36 and 15.39; instead, the vegetable mousse samples exhibited lower values for the b*-color parameter and higher values for whiteness index (WI) and hue angle or tone (h^0). According to *Pathare2013,* a higher tone or hue angle value corresponds to a lesser yellow characteristic [30]. In the case of a* color parameter (red–green axis), all values are in the negative zone; lower values being observed for dairy cream-based mousses (M_1 and M_3 samples). The results of one factor analysis of variance - ANOVA showed that the color difference between mousse samples is statistically significant ($p<0.001$). The mousses' chroma value varies from 11.30 to 26.46 and a higher value of chroma corresponds to a more intense color of mousse samples perceived by the human eye. The samples produced by the first procedure with dairy cream presented a high value of chroma and also a high yellowness index (YI 43.81). The total color difference represents a measure of the modulus of the distance vector between the initial color values and the actual color coordinates [31] and indicates the magnitude of color difference between dairy and vegetable cream mousses produced through two different procedures and different raw materials. According to *Adekunte 2010,* if $\Delta E>3$ the color difference isvery distinct, if $1.5<\Delta E<3$ the color difference between samples is distinct, and if $\Delta E<1.5$ the color difference is barely perceptible [32]. As regarding the color difference (ΔE^*) of mousses samples it can be observed that almost all values are greater than 6.63, the color of mousses samples being significantly different ($p < 0.01$). A small color difference (2.61) was recorded between M_2 and M_3 mousses.

4. Conclusion

The mousse samples produced with dairy cream showed higher fat and protein content than the vegetable cream mousses. As regarding the amount of air incorporated and fixed in the product it can be observed that vegetable cream mousses presented higher values for overrun parameter and lower values for density measurements, resulting that these samples (M_2 and M_4) had a larger amount of embedded air than those based on dairy cream. Additionally, the mousses produced through the second procedure had the highest concentration of moisture while the highest concentration of soluble substances was observed for mousses made through the first procedure. The color was influenced by the raw materials used, a more yellow tint was recorded for the dairy cream mousse samples, which exhibit higher values of b* color parameter, color intensity (C*) and also yellowness index. Whereas the vegetable cream mousses were whiter with higher values of brightness, of whiteness index and lower b* color parameter.

5. References

[1]. STANCIU, S., Confectionery Sector in Romania: Market Overview, *Education Excellence and Innovation Management through Vision 2020,* 3783-3795, (2020).

[2]. ARAGON-ALEGRO, L. C., ALEGRO, J. H. A., CARDARELLI, H. R., CHIU, M. C., and SAAD, S. M. I., Potentially probiotic and synbiotic chocolate mousse. *LWT-Food Science and technology*, *40*(4), 669-675, (2007).

[3]. CARDARELLI, H. R., ARAGON-ALEGRO, L. C., ALEGRO, J. H., de CASTRO, I. A., and Saad, S. M., Effect of inulin and Lactobacillus paracasei on sensory and instrumental texture properties of functional chocolate mousse. *Journal of the Science of Food and Agriculture*, *88*(8), 1318-1324, (2008).

[4]. ZIMBRU, R. O., PĂDUREŢ, S., and AMARIEI, S., Aerated confectionery: physico-chemical and textural evaluation. *Food and Environment Safety Journal*, *19*(2), (2020).

[5]. GUSTAV, T., CASTRILLON, P. M., and HAUGER, R. U.S. Patent No. 10,178,870. Washington, DC: U.S. Patent and Trademark Office, (2019).

[6]. ZIMBRU, R. O., PĂDUREŢ, S., and AMARIEI, S., Effect of aeration on physicochemical, color and texture characteristics of confectionery foams. *Ukrainian Food Journal*, *9*(1), (2020).

[7]. MÜLLER-FISCHER, N., and WINDHAB, E. J., Influence of process parameters on microstructure of food foam whipped in a rotor–stator device within a wide static pressure range. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, *263*(1-3), 353-362, (2005).
[8]. PĂDUREŢ, S., ZIMBRU, R. O., and AMARIEI, S., Texture and rheological evaluation of aerated confectionery, Ovidius University Annals of Chemistry, Volume 31, Number 1, pp. 60 - 65, (2020).
[9]. GRASSLER, W., and WILD, M, U.S. Patent No. 6,231,902. Washington, DC: U.S. Patent and Trademark Office, (2001).
[10]. MIQUELIM, J. N., LANNES, S. C., and MEZZENGA, R., pH Influence on the stability of foams with protein–polysaccharide complexes at their interfaces. *Food hydrocolloids*, *24*(4), 398-405, (2010).
[11]. MCCLEMENTS, D. J., *Food emulsions: principles, practices, and techniques*. CRC press. New York, USA, (2015).
[12]. DUQUENNE, B., VERGAUWEN, B., CAPDEPON, C., BOONE, M. A., De SCHRYVER, T., VAN HOOREBEKE, L., andDE BLOCK, J., Stabilising frozen dairy mousses by low molecular weight gelatin peptides. *Food hydrocolloids*, *60*, 317-323, (2016).
[13]. MEZZENGA, R., SCHURTENBERGER, P., BURBIDGE, A., and MICHEL, M., Understanding foods as soft materials. *Nature materials*, *4*(10), 729-740, (2005).
[14]. NARCHI, I., VIAL, C., and DJELVEH, G., Effect of protein–polysaccharide mixtures on the continuous manufacturing of foamed food products. *Food hydrocolloids*, *23*(1), 188-201, (2009).
[15]. VAN AKEN, G.A., Aeration of emulsions by whipping, Colloids and Surfaces A: Physicochemical and Engineering Aspects 190,333-354, (2001).
[16]. NIELSEN, S.S., (Ed.), Food analysis New York: Springer, pp. 139-141, (2010).
[17]. SR EN ISO 8968-2:2002, Determination of nitrogen content. Block digestion method.
[18]. AOAC International, Official methods of analysis, 20th Edn., AOAC International, Rockville, MD, 2016.
[19]. TYL, C., SADLER, G.D., pH and Titratable Acidity. In: Nielsen S. (eds), Food Analysis, Food Science Text Series, Springer, Cham, pp. 389–406, (2017).
[20]. CAMPBELL, G. M., and MOUGEOT, E., Creation and characterisation of aerated food products. *Trends in food science and technology*, *10*(9), 283-296, (1999).
[21]. SERENO A. M., SILVA M. A., MAYOR L., Determination of particle density and porosity in foods and porous materials with high moisture content. International Journal of Food Properties, 10(3), 455-469, (2007).
[22]. JUNG H., SATO T., Comparison between the Color Properties of Whiteness Index and Yellowness Index on the CIELAB. Textile Coloration and Finishing, 25(4), pp. 241–246, (2013).
[23]. PĂDUREȚ S., OROIAN M., GUTT G., AMARIEI S., Evaluation of strawberry texture in close relation with their anisotropy, *International Journal of Food Properties*, 20(2), pp. 247–259, (2017).
[24]. HSU, C. L., CHEN, W., WENG, Y. M., and TSENG, C. Y., Chemical composition, physical properties, and antioxidant activities of yam flours as affected by different drying methods. Food chemistry, 83(1), 85-92, (2003).
[25]. RODRIGUEZ-AGUILERA, R., OLIVEIRA, J. C., MONTANEZ, J. C., and MAHAJAN, P. V., Effect of modified atmosphere packaging on quality factors and shelf-life of mould surface-ripened cheese: Part II varying storage temperature. *LWT-Food Science and Technology*, *44*(1), 337-342, (2011).
[26]. SHAHIDI, F. (Ed.)., *Bailey's Industrial Oil and Fat Products, Edible Oil and Fat Products: Processing Technologies* (Vol. 5). John Wiley and Sons, (2005).
[27]. FONTANA, A., Water activity for predicting quality and shelf life. *Manufacturing Confectioner*, *85*(11), 45, (2005).
[28]. SCHMIDT, S. J., and FONTANA Jr, A. J. E., Water Activity Values of Select Food Ingredients and Products. *Water activity in foods: Fundamentals and applications*, 573-591, (2020).
[29]. CAMACHO, M. M., MARTINEZ-NAVARRETE, N., and CHIRALT, A., Influence of locust bean gum/lambda-carrageenan mixtures on whipping and mechanical properties and

stability of dairy creams. *Food Research International*, 31, 653e658, (1998).

[30]. PATHARE, P. B., OPARA, U. L., and AL-SAID, F. A. J., Colour measurement and analysis in fresh and processed foods: a review. *Food and bioprocess technology*, *6*(1), 36-60, (2013).

[31]. PATRAS, A., BRUNTON, N. P., TIWARI, B., and BUTLER, F., Stability and degradation kinetics of bioactive compounds and colour in strawberry jam during storage. Food and Bioprocess Technology, 4, 1245–1252, (2011).

[32]. ADEKUNTE, A. O., TIWARI, B. K., CULLEN, P. J., SCANNELL, A. G. M., and O'DONNELL, C. P., Effect of sonication on colour, ascorbic acid and yeast inactivation in tomato juice. *Food Chemistry*, *122*(3), 500-507, (2010).