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Developing a household vacuum cooking equipment, testing its performance on strawberry jam production and its comparison with atmospheric cooking

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Abstract. In this research, the performance of a kitchen appliance cooking equipment prototype, which can operate either under vacuum or at atmospheric pressure, is aimed to be developed and tested on strawberry jam production. Vacuum cooking applications were carried out at two different conditions as 17.5 and 25 minutes at 75 °C. Strawberry jam was also cooked at atmospheric pressure for 5, 10, 15 and 20 min. The effect of cooking conditions under vacuum and atmospheric pressure was determined by the following analysis; brix, color (L*, a*, b*) values, chroma (C*), hue (h°), pH value, titratable acidity, reducing and total sugar content (%), hydroxymethylfurfural content (HMF) and sensorial analysis. When the strawberry jam that is produced at atmospheric pressure is compared to the ones that are produced under vacuum, atmospheric cooked jam got higher Brix and was more viscous depending on the applied elevated temperature. HMF content of jam produced at atmospheric pressure was also found to be excessively high compared to the jam produced under vacuum. As it has been foreseen in the beginning of the study, vacuum cooking has been effective in reducing the HMF content of the strawberry jam due to the low temperature application. Sensorial quality of the vacuum-processed strawberry jam was superior in terms of color, appearance, consistency, taste and overall acceptance comparing to the atmosphere processed jams. This data could be utilized to contribute to the development of a household vacuum cooking equipment and the opportunity to produce with less harmful ingredients in home environment.

Key words: Jam, Strawberry jam, Vacuum Cooking, Evaporation, HMF.

INTRODUCTION

Vegetables and fruits play an important role in our daily diet on account of their rich contents of nutritional compounds (Özel, 2006). Due to the high water contents of fruits and vegetables, their shelf-life is limited by microbial activity (Şahin et al., 1994). One of a/the most famous preserving methods in order to extend the shelf-lives of fruits and vegetables and to obtain various delightful products is called 'jam processing' (Kansci et al., 2003). Jam products are also popular food products due to their low cost, their accessibility all the year around and their organoleptic features (Gałkowska et al., 2010).

Nowadays, besides using modern technologies in jam production at commercial levels, it is still being produced at the household levels (Gałkowska et al., 2010). In home-made jam production, particular proportions of the fruit and sugar are mixed. The fruit and sugar mix is then cooked to obtain a delightful blend which achieves sufficient storage capabilities. In order to acquire the desired final total soluble solid content, the mix is concentrated under excessive thermal treatment (Igual et al., 2013). This process leads to unsavoury colour, flavour and nutritional values of the output. These problems are due to the extreme temperature applications and long processing time (Garcia–Martinez et al., 2002). Also it leads to the formation of undesirable components such as hydroxymethylfurfural (HMF), furfural and melanoidins. Furthermore, producing jam at home is mostly insufficient for achieving the desired consistency. In The Aegean Region of Turkey, it has been observed that jam was kept under sunlight for a while after the heat treatment to thicken the jam's consistency as a traditional homemade method production. All these processes take too long to produce jam at home as well as its being difficult and tiring. On the other hand, keeping the jam under sun is not a hygienic method for food safety and could cause microbial load in the product.

In recent years, vacuum cooking has got remarkable development as an alternative cooking method because of the low-temperature application, the short processing time, the oxygen–reduced cooking environment, the better protection of nutritional value and the physical structure of the food (Garcia-Segoiva et al., 2007). Due to the low temperature and the oxygen content, vacuum cooking helps to protect the natural color and the flavour of the food (Andres-Bello et al., 2009). Whereas the reduction of the nutritional value and the formation of carcinogenic substances in food which is caused by high temperature is minimized, oxidation of the food could also be restricted by reducing the oxygen content of cooking medium with low temperature applications under vacuum. Low oxygen environment in the vacuum cooking process may reduce the formation of enzymatic and non-enzymatic aerobic spoilage reaction which occur during the traditional cooking process and affect the quality of the last product (Martinez-Hendez et al., 2013).

In the food industry, vacuum cooking method is generally preferred to produce jam, tomato paste and similar food products and the process is carried out in the closed vessels on industrial scale. However household cooking appliance that has a function capable of performing under vacuum is not available on the market. The aim of this study was to develop a kitchen appliance cooking equipment which can operate either under vacuum or at atmospheric pressure and to test its performance on strawberry jam production.

MATERIALS AND METHODS

Materials

Strawberries (*Fragaria x ananassa Duch.*) and sugar were purchased from a local market in İzmir. After strawberries were washed, stems and deteriorated parts were separated. The cleaned strawberries (moisture content, 90%) were weighed 600 g and sugar, which is commercial granulated sugar, was added 400 g on strawberries. Thus, osmotic dehydration and sugar penetration of strawberries were ensured like conventional domestic strawberry jam preparation in which strawberries are put in sugar for an overnight before cooking. In addition, citric acid was added on strawberries and sugar mix just before the cooking process, to ensure the specific acidic flavor and decrease pH in order to provide the gel formation. The citric acid was powder and it was obtained from a local market and stored in dark and refrigerator condition (4 °C)

Design of the vacuum cooking equipment prototype

A kitchen appliance cooking equipment prototype was developed for aiming to work in a wide range of vacuum and precise temperature control as shown in Fig. 1.

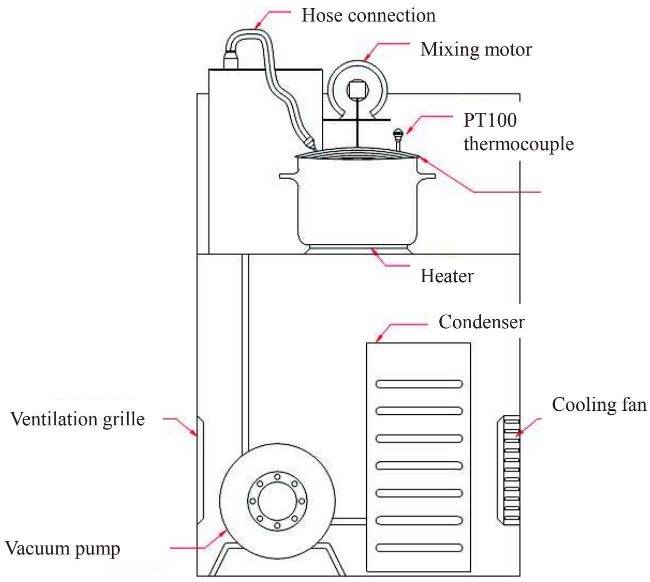

Figure 1. Developed vacuum cooking equipment prototype.

The Vacuum cooking vessel with capacity of 6 L includes a reductor mixer which can operate continuously or batch in the 0–50 Hz range. Electrical heater was used for heating about 1.5 kW also a temperature (PT 100) probe was adapted to system to measure the inside temperature of the vessel. The oily type of pump 0.55 Hp has been preferred to work in a wide range of vacuum. Applied vacuum level was measured inside the vacuum cooking vessel. Between the vessel and the pump, a condenser is needed to collect the water vapor coming from the jam while cooking process. The condenser is 1 kW and includes the refrigerant (R–404a).

Mixer rate, vacuum level and cooking time are controlled by PLC system. Electrical heater is also programed with PID control system. The inside temperature of vacuum cooking vessel, vapor temperature at condenser exit and pressure of vacuum cooking vessel are recorded per each 3 seconds.

Strawberry Jam Production

In this research, the strawberry jam was produced either under vacuum or at atmospheric pressure. Before production of strawberry jam, frozen strawberry and sugar mix (~1,000 g) was thawed in refrigerator (4 °C) during a day. Citric acid (1 g) was added on thawed strawberries and sugar mix. For the vacuum treatment the strawberry jam was cooked at 75 °C and for 17.5 and 25 min under vacuum according to preliminary trial and the data obtained from literature. For the atmospheric treatment, the strawberry jam was cooked for 5, 10, 15 and 20 min at 100 °C in the same equipment without using vacuum pump function. All the cooking experiments were done in duplicate for each operating conditions.

Brix analysis

The soluble dry matter of the strawberry jam was measured by Abbe refractometer at room temperature (Cemeroğlu, 2010).

Color analysis

The color of the strawberry jam is determined with CIE Yxy, L* a* b* values. Besides, the color intensity (Chroma, C*) and the color tone (Hue, h°) were calculated using equations 1 and 2, respectively (Hunter, 1975; CIE, 1978). Colour measurements were performed with a Minolta Chromameter (Konica Minolta, Osaka, Japan).

Color intensity, Chroma

$$C^* = (a^{*2} + b^{*2})^{1/2} \quad (1)$$

Color tone, hue

$$h^\circ = \arctan(b^* + a^*) \quad (2)$$

pH analysis

pH values of the strawberry jam was measured by digital pH meter ((inoLab pH/Cond 720, WTW, Germany) at room temperature.

Titratable acidity

The strawberry jam was homogenized using a blender. The sample weighed 10 g in 100 ml volumetric flask and was added distilled water. After the sample was filtered by filter paper, 20 ml of filtrate was titrated with 0.1 N NaOH. Fenolftalein was used as indicator (Cemeroğlu, 2010). The titratable acidity which was determined as citric acid % (w/v) was expressed as follows (3):

$$Titratable\ acidity, \% = \frac{V \cdot F \cdot E}{M} \cdot 100 \quad (3)$$

where: V – used 0.1 N NaOH, ml; F – factor of NaOH; E – equivalent acid amount of 1 ml 0.1 N NaOH (citric acid: 0.006404); M – sample amount, ml or g.

Hydroxymethylfurfural (HMF) content

Hydroxymethylfurfural (HMF) content of the strawberry jam was determined by HPLC. The strawberry jam (5 g), which was homogenized with blender, was diluted with 50 ml distilled water. The sample was filtered through a blue filter paper and then was injected into the chromatograph. To prepare the calibration curve, HMF standard was diluted to 10–20–30 mg L^{-1} concentration and peak areas were determined. The amount of HMF in sample was quantitatively determined using the calibration curve. The flow rate was 1 ml min^{-1} and the mobile phase was 80% of distilled water and 20% of methanol. The diode array detector was set at 285 nm and C_{18} (15 cm* 4.6 mm) was used (Vorlová et al., 2006).

Degree of inversion

The degree of inversion of the strawberry jam was carried out by volumetric Lane-Eynon method (Cemeroğlu, 2010).

Sensory evaluation

Sensory evaluation of the strawberry jam included appearance (remaining in all without disintegration), color, consistency in spoon (fluidity), consistency in mouth (being hard or soft for strawberry grains), taste and overall acceptance. Sensory analysis was performed according to Holtz et al. (1984) and Altuğ & Elmacı (2005) with 10 members. All panelists were non-smokers. The intensity of the properties was determined using a 5–point scale (1 being the lowest and 5 the highest).

Statistical analysis

All of the measurements were done in triplicates. Results are shown as mean ± standard deviation.

One-way ANOVA test was conducted to determine the effect of cooking time on the atmospheric pressure cooked and vacuum cooked strawberry jam samples. Also Duncan's multiple range test was evaluated to compare the effect of different processing temperature and times on the quality parameters of the strawberry jam samples. The statistical analyses were performed using SPSS (Statistical Package for the Social Sciences, SPSS Chicago, Illinois, USA) software version 15.0.

RESULTS AND DISCUSSION

The experiments of the strawberry jam carried out under vacuum at 75 °C for 17.5 and 25 min using the developed vacuum cooking equipment prototype were evaluated. The strawberry jam was also produced at atmospheric pressure for 5, 10, 15 and 20 min in comparison with that samples cooked under vacuum. The physical and chemical properties of the strawberry jam produced at atmospheric pressure and under vacuum are given in Table 1 and ANOVA results are given in Table 2.

One of the most important quality parameters of the strawberry jam is an attractive red colour, in addition to its common sweet–sour strawberry flavour and sufficient jam consistency (Wicklund et al., 2005). The color stability of red fruit is affected by temperature, pH, oxygen and sugar content, presence of ascorbic acid and metal ion and undesirable discoloration could be seen in the product as a result of the degradation of color pigment (Withy et al., 1993). Browning reaction of sugar causes darker red color in jam products and this is usually an undesirable color change (Zor, 2007). Significant difference were observed between the L* values of atmospheric pressure cooked jams ($p < 0.05$) and vacuum cooked jam (Table 1).

Table 1. The physical and chemical properties of strawberry jam produced at atmospheric pressure and under vacuum

		Atmospheric cooking			Vacuum cooking	
Temperature (°C)		100			75	
Pressure (atm)		1 atm			0.39 atm	
Time (min)	5	10	15	20	17.5	25
L*	$28.5^{a} \pm 0.0$	$28.7^{a} \pm 0.1$	$28.7^{a} \pm 0.2$	$28.5^{a} \pm 0.0$	$28.2^{b} \pm 0.1$	$28.2^{b} \pm 0.0$
a*	$2.6^{ab} \pm 0.6$	$3.8^{a} \pm 1.2$	$3.8^{a} \pm 1.5$	$3.5^{a} \pm 0.1$	$1.3^{b} \pm 0.0$	$1.2^{b} \pm 0.0$
b*	$1.5^{ab} \pm 0.4$	$1.8^{a} \pm 0.4$	$1.7^{a} \pm 0.5$	$1.7^{a} \pm 0.1$	$0.9^{b} \pm 0.0$	$0.8^{b} \pm 0.0$
C*	$3.0^{ab} \pm 0.7$	$4.3^{a} \pm 1.2$	$4.2^{a} \pm 1.5$	$3.9^{a} \pm 0.2$	$1.6^{b} \pm 0.0$	$1.4^{b} \pm 0.0$
h°	$30.4^{a} \pm 0.3$	$24.6^{b} \pm 1.5$	$25.1^{b} \pm 2.5$	$25.3^{b} \pm 0.2$	$33.2^{ac} \pm 0.1$	$36.0^{c} \pm 1.2$
Brix	$49.0^{a} \pm 1.4$	$51.8^{ab} \pm 2.5$	$56.5^{bd} \pm 2.1$	$65.8^{c} \pm 1.1$	$60.0^{d} \pm 0.0$	$59.0^{d} \pm 1.4$
pH	$3.7^{a} \pm 0.1$	$3.7^{a} \pm 0.1$	$3.7^{a} \pm 0.1$	$3.6^{a} \pm 0.0$	$3.8^{a} \pm 0.1$	$3.7^{a} \pm 0.1$
Titratable acidity (citric acid, %)	$0.5^{a} \pm 0.1$	$0.6^{a} \pm 0.1$	$0.6^{a} \pm 0.1$	$0.6^{a} \pm 0.0$	$0.5^{a} \pm 0.0$	$0.6^{a} \pm 0.0$
HMF (mg kg^{-1})	$49.4^{a} \pm 2.1$	$67.8^{b} \pm 0.8$	$73.0^{b} \pm 2.0$	$129.0^{c} \pm 6.4$	$14.4^{d} \pm 1.5$	$21.4^{d} \pm 1.8$
Reducing sugar (%)	$13.7^{a} \pm 0.5$	$17.9^{b} \pm 2.0$	$21.4^{c} \pm 1.3$	$27.7^{d} \pm 1.0$	$9.1^{e} \pm 0.1$	$11.1^{ae} \pm 0.2$
Sucrose (%)	$30.9^{a} \pm 2.3$	$28.1^{a} \pm 4.5$	$33.8^{ab} \pm 0.2$	$32.8^{ab} \pm 2.1$	$42.2^{c} \pm 3.1$	$39.0^{bc} \pm 0.1$
Total sugar (%)	$44.6^{a} \pm 1.8$	$46.0^{a} \pm 2.5$	$55.2^{b} \pm 1.0$	$60.5^{c} \pm 1.0$	$51.3^{d} \pm 3.2$	$50.1^{d} \pm 0.2$

Results are given as mean ± standard deviation.
The different letter in the same row are significantly different (p<0.05).

It was found that a* values of strawberry jam cooked at atmospheric pressure and under vacuum were in good agreement with the literature (Kıvrak, 2010). Also C* values of the vacuum cooked jam were compared with the atmospheric pressure ones, a slight increase was determined due to the high temperature exposure of the product at atmospheric pressure. But increase of pigment concentration does not usually have an effect in C* value (Kırca et al., 2007). Because as commented by Wrolstad et al. (2005), a pink and a dark red color could have similar C* values. However hue values of the atmospheric pressure jam were lower compared to the vacuum cooked ones with regard to the change of the red color to darker red color tone with long cooking period. Although a*, b* and C* values of vacuum and atmospheric pressure cooked jams were significantly different (p < 0.05), only 5 min atmospheric pressure cooked jam was not significanly different with vacuum cooked ones (Table 1). Also Hue values of 5 min atmospheric pressure cooked and 17.5 min vacuum cooked jams were not significantly different, however other trials were significantly different (p < 0.05). According to ANOVA results, it was observed that cooking time had no significant effect on L*, a*, b* and C* values of the jams cooked at atmospheric pressure and under vacuum. Relying on the color of the strawberry jam, appearance of the jam products cooked at atmospheric pressure and under vacuum for different cooking periods are given in Fig. 2.

Certain darkenings can be clearly seen from Fig. 2. with the increase of cooking time at atmospheric pressure although no significant changes can be observed between vacuum cooked jams.

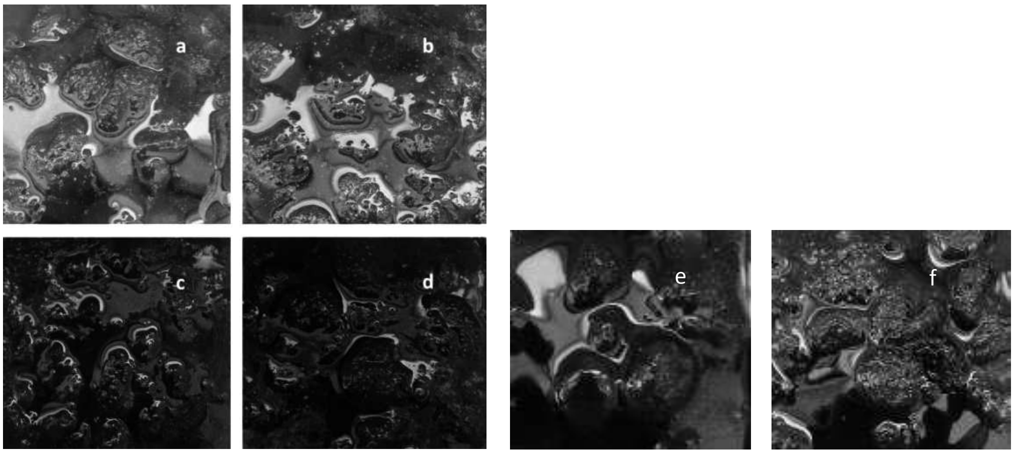

Figure 2. Appearance of the strawberry jam products cooked at atmospheric pressure (5,10,15 and 20 min respectively, a, b, c, d) and under vacuum at 75 °C (17.5 and 25 min respectively, e and f).

The Brix values of the strawberry jam products cooked at atmospheric pressure were found to be in the range of 49 and 65.8% and increased with cooking time (Table 1). It was found that cooking time had significant effect on Hue and Brix values of the strawberry jams cooked at atmospheric pressure ($p < 0.05$), however cooking time had no significant effect on Brix values of vacuum cooked ones (Table 2). No significant difference was observed in the jam products cooked under vacuum at different periods. However 20 min processed atmospheric product had the highest Brix value and were more viscous due to the high temperature application. Brix values of the vacuum and atmospheric pressure cooked jams were significantly different ($p < 0.05$) besides the Brix value of 15 min atmospheric pressure cooked jam was not significantly different to vacuum ones (Table 1).

The pH values of atmospheric pressure jam were determined to be in the range of 3.6 to 3.7. A specified pH range for the jams was stated to be 2.8–3.5 in the Turkish Food Codex. Neither the pH values of the atmospheric pressure jam nor the vacuum jam were in these limits due to insufficient citric acid amount to lower the pH of cooking enviroment and provide gelling. It was observed that cooking time had no significant effect on the pH values of both vacuum and atmospheric pressure cooked strawberry jams ($p > 0.05$) (Table 2).

One of the main purpose of the acidity regulator for jam and marmalade products is to increase specific fruit flavor of the product and the other one is to ensure the formation of the desired gelation (Altuğ et al., 2001). Titratable acidity values (as in citric acid) of vacuum cooked samples were ranged between 0.47 and 0.59%, whereas titratable acidity values of atmospheric pressure jams were found to be in the range of 0.48 and 0.62%. Kıvrak (2010) has reported that titratable acidity values of the commercially produced strawberry jam ranged from 0.34 to 0.57%. Also it was determined that they were slightly lower than García-Viguera et al. (1999) found in their research by using different cultivars of strawberry fruit to produce strawberry jam. The titratable acidity values obtained from this study were in good agreement with literature. Only the titratable acidity of the strawberry jam cooked for 20 min at atmospheric pressure was determined to be slightly higher due to the reactions that began to progress depending on the length of the cooking time. No significant difference ($p > 0.05$) was observed between the pH and the titratable acidity values of vacuum and atmospheric pressure cooked strawberry jam samples (Table 1). However cooking time had significant effect on the titratable acidity values of the vacuum cooked jams ($p < 0.05$) (Table 2).

When the reducing sugar content of the atmospheric pressure cooked strawberry jam was analyzed, it was observed that the amount of reducing sugar ranged between 13.7%. and 27.3%. Also both sucrose % and the reducing sugar % content was increased with the increasing of cooking time. On the other hand, total sugar content of the atmospheric pressure jam products was determined to be in the range of 60.5% and 44.6%.

Also Mohd Naeem et al. (2015) have determined similar total sugar content in strawberry jam products reported in this study. Brix value and amount of reducing sugar and sucrose determine the rate of crystallization. In literature it has been noted that 30–35% of the total sugar should be reducing sugar in the final product to prevent crystallization (Tosun, 1991). Data obtained from the experiments showed that the applied heat treatment was sufficient to provide the inversion in strawberry jam at atmospheric pressure. It was evaluted that cooking time had significant effect on the total sugar content of the jams cooked at atmospheric pressure ($p < 0.05$) (Table 2).

In vacuum cooking reducing sugar content of the jam was increased with the increasing of cooking time. According to ANOVA results, it was determined that cooking time had significant effect on the reducing sugar content of both atmospheric pressure and vacuum cooked jams ($p < 0.05$). When the jam was evaluated in terms of preventing crystallization, inversion was found to be insufficient for jam cooked under vacuum due to the cooking process applied at low temperature and the short-term. Furthermore, vacuum cooked jam products had lower total sugar content % depending on applied lower temperature. It should be also noted that the addition of sugar during jam-making process could cause the remarkable differences (Igual et al., 2013). Reducing sugar content of the atmospheric pressure cooked and vacuum cooked strawberry jams were significantly different ($p < 0.05$) with each other except for the reducing sugar values of the 5 min atmospheric pressure cooked and 17.5 min vacuum cooked jams (Table 1). In addition, total sugar content of the jams cooked under vacuum and atmospheric pressure were significantly different ($p < 0.05$).

Amount of HMF in fruit juice and concentrate products, jam and jelly products, processed sugar-rich products such as molasses and honey, is used as a criteria showing the intensity of heat applied to the product and the suitability of the storage conditions (Telatar, 1985). In 1^{st} class jam products in Turkey, HMF amount is recommended not to exceed 50 mg kg^{-1}, while in 2^{nd} class jam products, it is 100 mg kg^{-1} (Gülpek & Başoğlu, 1989; Bilişli, 1998).

Table 2 .ANOVA results of the physical and chemical properties of strawberry jam produced at atmospheric pressure and under vacuum

	Atmospheric cooking				Vacuum cooking		
	Source	df	Sum of Squares	*p*-value	df	Sum of Squares	*p*-value
L*	Between Groups	3	0.031	0.400	1	0.001	0.817
	Within Groups	4	0.033		2	0.018	
	Total	7	0.064		3	0.019	
a*	Between Groups	3	2.099	0.593	1	0.017	0.069
	Within Groups	4	3.925		2	0.003	
	Total	7	6.024		3	0.020	
b*	Between Groups	3	0.073	0.904	1	0.000	1.000
	Within Groups	4	0.534		2	0.001	
	Total	7	0.606		3	0.001	
Ch	Between Groups	3	1.995	0.647	1	0.011	0.082
	Within Groups	4	4.408		2	0.002	
	Total	7	6.402		3	0.013	
h°	Between Groups	3	43.61	0.048*	1	7.784	0.081
	Within Groups	4	8.554		2	1.434	
	Total	7	52.17		3	9.218	
Brix	Between Groups	3	324.3	0.003*	1	1.000	0.423
	Within Groups	4	13.75		2	2.000	
	Total	7	338.0		3	3.000	
pH	Between Groups	3	0.005	0.885	1	0.005	0.479
	Within Groups	4	0.029		2	0.012	
	Total	7	0.033		3	0.017	
Titratable acidity (%)	Between Groups	3	0.019	0.464	1	0.013	0.008*
	Within Groups	4	0.024		2	0.000	
	Total	7	0.043		3	0.013	
HMF (mg kg^{-1})	Between Groups	3	7077	0.001*	1	48.16	0.053
	Within Groups	4	198.3		2	5.580	
	Total	7	7275		3	53.74	
Reducing sugar (%)	Between Groups	3	212.7	0.002*	1	3.725	0.004*
	Within Groups	4	6.867		2	0.032	
	Total	7	219.5		3	3.757	
Sucrose (%)	Between Groups	3	35.97	0.408	1	10.36	0.286
	Within Groups	4	38.99		2	9.936	
	Total	7	74.95		3	20.30	
Total sugar (%)	Between Groups	3	345.5	0.002*	1	0.053	0.858
	Within Groups	4	11.52		2	2.591	
	Total	7	357.1		3	2.644	

* Significant differences in 0.05 level.

HMF content of atmospheric pressure cooked jam products varied from 49.35 mg kg^{-1} to 129.01 mg kg^{-1}. It has increased with the cooking time as stated by Eichner (1973) HMF formation in food depended on the reducing sugar and amino acid concentration, pH value of food and process conditions in terms of temperature and time. In our study, it was also observed that cooking time had significant effect on the HMF content of the strawberry jams cooked at atmospheric pressure ($p < 0.05$). Ekşi & Velioğlu (1990) reported that reducing sugar content and HMF content (mg kg^{-1}) of jam products was highly corraleted with each other. HMF content of the vacuum cooked jam products was found to be in the range of 14.41 and 21.35 mg kg^{-1}. As stated earlier, HMF content of vacuum cooked strawberry increased slightly with cooking time. Also HMF content of the strawberry jam cooked at atmospheric pressure were excessively high (49.35 to 129.01 mg kg^{-1}) than the jam cooked under vacuum. HMF content of the jams cooked under vacuum and atmospheric pressure were found to be significantly different ($p < 0.05$) (Table 1). Vorlová et al. (2006) reported that high temperature appliance has caused Maillard reaction and caramelization depending on the high carbohydrate content and low pH of the product.

Results of the sensory properties of appearance, color, consistency in spoon, consistency in mouth, taste and overall preferences of the strawberry jam produced at atmospheric pressure and under vacuum were shown in Table 3.

Table 3. Sensorial evaluation results of the atmospheric pressure and vacuum cooked strawberry jam

	Atmospheric pressure cooking				Vacuum cooking	
Temperature (°C)	100				75	
Pressure (atm)	1 atm				0.39 atm	
Time (min)	5	10	15	20	17.5	25
Appearance	3.6 ± 0.6	3.8 ± 0.3	3.8 ± 0.3	3.2 ± 0.1	4.2 ± 0.1	4.2 ± 0.1
Color	3.9 ± 0.4	4.3 ± 0.0	4.0 ± 0.1	3.8 ± 0.3	4.4 ± 0.2	4.4 ± 0.1
Consistency in spoon	3.6 ± 0.4	4.1 ± 0.2	3.8 ± 0.3	3.8 ± 0.5	4.3 ± 0.3	4.3 ± 0.1
Consistency in mouth	3.7 ± 0.3	4.1 ± 0.1	3.9 ± 0.1	3.7 ± 0.5	4.2 ± 0.1	4.2 ± 0.4
Taste	3.8 ± 0.4	4.0 ± 0.3	3.8 ± 0.3	3.3 ± 0.9	4.3 ± 0.1	4.0 ± 0.1
Overall preference	3.8 ± 0.2	4.1 ± 0.1	3.8 ± 0.1	3.5 ± 0.5	4.3 ± 0.3	4.2 ± 0.3

Whereas consistency in spoon specifies the fluidity of the strawberry jam, the consistency in mouth was associated with being soft or hard of strawberry fruit in jam. While consistency in spoon scores was decreased due to highly viscous structure of jam and consistency in mouth scores was decreased due to being very soft of fruit after 10 min cooking. With the increase in cooking time, color of the jam have darkened, strawberry grains are scattered and had an undesirable appearance. These changes have affected the taste of the jam and has led to low scores given by the panelists. Sensory analysis results showed that the jam cooked for 10 minutes at atmospheric pressure had the highest overall preference score in terms of color, consistency in spoon, consistency in mouth and taste. As seen in Table 2, whereas 17.5 min at 75 °C cooked jam got the highest score in terms of consistency in mouth, taste and overall acceptance, 25 min at 75 °C cooked jam got the highest scores in terms of appearance, color, and consistency in spoon. No significant difference was observed between the sensory properties of vacuum cooked jam except for the taste results. When vacuumed jam products are compared with atmospheric ones, vacuum cooked ones got the highest scores with regard to apperance, color, consistency in spoon, consistency in mouth, taste and overall acceptance.

CONCLUSION

In this research, a vacuum cooking equipment prototype was designed to work both under vacuum and atmospheric pressure. Brix value indicates the microbiologically resistance and sensorial consistency of the product . Only the Brix of the strawberry jam produced at atmospheric pressure for 20 min was higher (> 60) and were more viscous depending on the applied high temperature compared to the other jam products. It was observed that vacuum process was sufficient to acquire the similar Brix value to atmospheric process with a moderate heat treatment. Hue (h°) values of the vacuum cooked jam products were higher compared to atmospheric cooked jams. This result shows that strawberry jam cooked under vacuum protected the color of red fresh strawberry fruit better whereas high temperature applications at atmospheric pressure caused discoloration in the product. Hydroxymethylfurfural (HMF) content of the strawberry jam produced under vacuum was found to be ensured the limit range for 1st class jam products in the literature (< 50 mg kg^{-1}). Although the HMF content of the atmospheric processed jam for 5 min was under 1st class jam limit (< 50 mg kg^{-1}), HMF content of the other atmospheric processed jam was found to be exceeding the limit. As it was foreseen at the beginning of the study, vacuum cooking process has been succesfully reduced the HMF content of the strawberry jam due to the low temperature application and oxygen free environment. However it was determined that vacuum cooking application found to be insufficient in providing the inversion compared with atmospheric cooking application. This could lead to crystallisation problems in jam when stored for a long time. Vacuum cooked strawberry jam had the highest overall preference scores by the panelists in terms of attractive fresh strawberry fruit color and less crushed strawberry grains.

In conclusion, this study has shown that appearance and color were better protected, formation of the harmful components such as HMF was decreased and soluble dry matter content was found to be close to the jam produced at traditional ways by vacuum cooking application. Vacuum cooking could be an alternative way to traditional methods at home and this could improve the properties of strawberry jam. This developed prototype could meet the consumers' demand on preparing food with healtier method under their own control at home environment. Furthermore, these findings could also be utilized to improve and develop more household cooking equipment to address the needs of consumers.

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