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SUMMARY

The present work aimed to study the use of Ohmic heating in the processing of mango pulp comparing to conventional method. Mango pulp was processed by using Ohmic heating under the studied suitable conditions. The results showed that processing of mango pulp by using either Ohmic heating or conventional method caused a decrease in the contents of TSS, total acidity, total Carbohydrates, total sugars (reducing & non-reducing sugar) and an increase in phenolic content, Ascorbic acid and Carotenoids. Mango pulp processed by Ohmic heating contained more Phenolic compounds, carbohydrates and vit.c and less HMF compared to that produced by conventional one. Total pectin and its fractions had slightly reduced by Ohmic heating and such reduction was increased by conventional method. Results also showed that total plate count and mold& yeast were reduced by processing of mango pulp by using the two methods. However, Ohmic heated mango pulp showed a less total plate count and mold &yeast after processing and during storage compared to that in conventional method. Coliform and thermophilic bacteria were completely inhibited by using both methods after processing and during storage. Results showed a reduction in polyphenoloxidase (PPO) & Polyglacturonase (PG) enzymes activity in mango pulp processed by conventional method. However, Ohmic heating completely inhibited PPO&PG activities due to the affective heating treatment. An improvement in the Organoleptic properties of mango pulp processed by Ohmic heating compared to conventional process was noticed.

Keywords: *Ohmic heating, mango pulp, electric conductivity, total phenolic compounds and carotenoids.*

INTRODUCTION

Ohmic heating is a thermal process that uses the passage of an alternating electric current through food material, which behaves like an electrical resistor, to produce heat. The instrumental design usually consists of electrodes in contact with the food, whereby electricity is directly passed through the medium using a variety of voltage and current combinations. Electrical energy is converted into heat without the use of hot heat transfer surfaces, which results in rapid and uniform heating. Ohmic heating is also termed “electrical resistance heating”, “Joule heating”, or “electro-heating”, and may be used for a variety of applications in the food industry (He, 2012).

In the recent years, the food industry has shown a renewed interest in Ohmic technology with system designs developed since the early 1990’s. Concerning the application of Ohmic heating in food processing, Castro *et al.* (2004) found in their studies on strawberry products that the electrical conductivity increased with temperature for all the products and conditions tested following linear relations. Electrical conductivity depended on the composition of strawberry-based product. An increase of electrical conductivity with field strength was obvious for the strawberry pulps and strawberry fillings but not for strawberry toppings or strawberry-apple sauces. They added that thermal treatments caused a decrease in electrical conductivity of both strawberry pulps tested, but the use of a conventional or Ohmic pre-treatment induces a different behavior of the pulps' conductivity. Ascorbic acid degradation followed first order kinetics for both conventional and Ohmic heating treatments and the kinetic constants obtained were in the range of the values reported in the literature for other food systems. The success of Ohmic heating depends on the rate of heat generation in the system, the electrical conductivity of the food and the method by which the food flows through the system (Leizerson and Shimoni, 2005). And the homogeneity of the food matrix is important for homogeneous heating; inhomogeneity influences the local field strength. Although the technology of Ohmic heating appears to be promising and highly effective, there is limited information regarding its effects on specific quality aspects of food products in comparison to conventional pasteurization (Sun *et al*., 2008).

The advantages of Ohmic heating are summarized as follows: Ohmic heating is a rapid and uniform heating, in which the resulting product is heated rapidly (increase 50 °C in less than 0.1 s) and without temperature gradients. Additionally, it is possible to process large particulate foods (up to 2 cm) as a result of deeper heat penetration compared to other heating techniques. It also reduces oxidation common in heat exchangers. In addition to prolonged shelf life, a small equipment footprint, high energy efficiency (90% of the electrical energy is converted to heat), Optimization of capital investment and product safety as a result of high solids loading capacity, ease of process control with instant switch-on and shut-down and reducing maintenance cost and also reducing fouling (no moving parts) are advantages that have to be considered. Ambient-temperature storage and distribution when combined with an aseptic filling system besides a quiet and environmentally friendly system was attained. Uniformity of heating and improvements in quality with minimal structural, nutritional, or organoleptic changes were recorded. Possible applications include most of the heat treatments such as blanching, evaporation, dehydration, and fermentation as well as pasteurization and sterilization. (Richardson, 2001; He, 2012).

Therefore, the present investigation was carried out to evaluate the quality characteristics and optimal conditions for processing of mango pulp by Ohmic heating which is compared to a conventional heating method.

MATERIALS AND METHODS

1. *Materials:*

Different varieties of fresh mango fruits mix. [Indian (*Mangifera indica L.*), Baladi, Hindi besennara and Bullock's heart] which were harvested in the summer 2011) were processed into mango pulp at "Hero Company", Kalyobia, Egypt. The samples from each processing step were collected filled in jars and stored below -18 ºC until analysis. Except, the final sample aseptic by Ohmic heating which is stored at room temperature.

2. *Chemicals:*

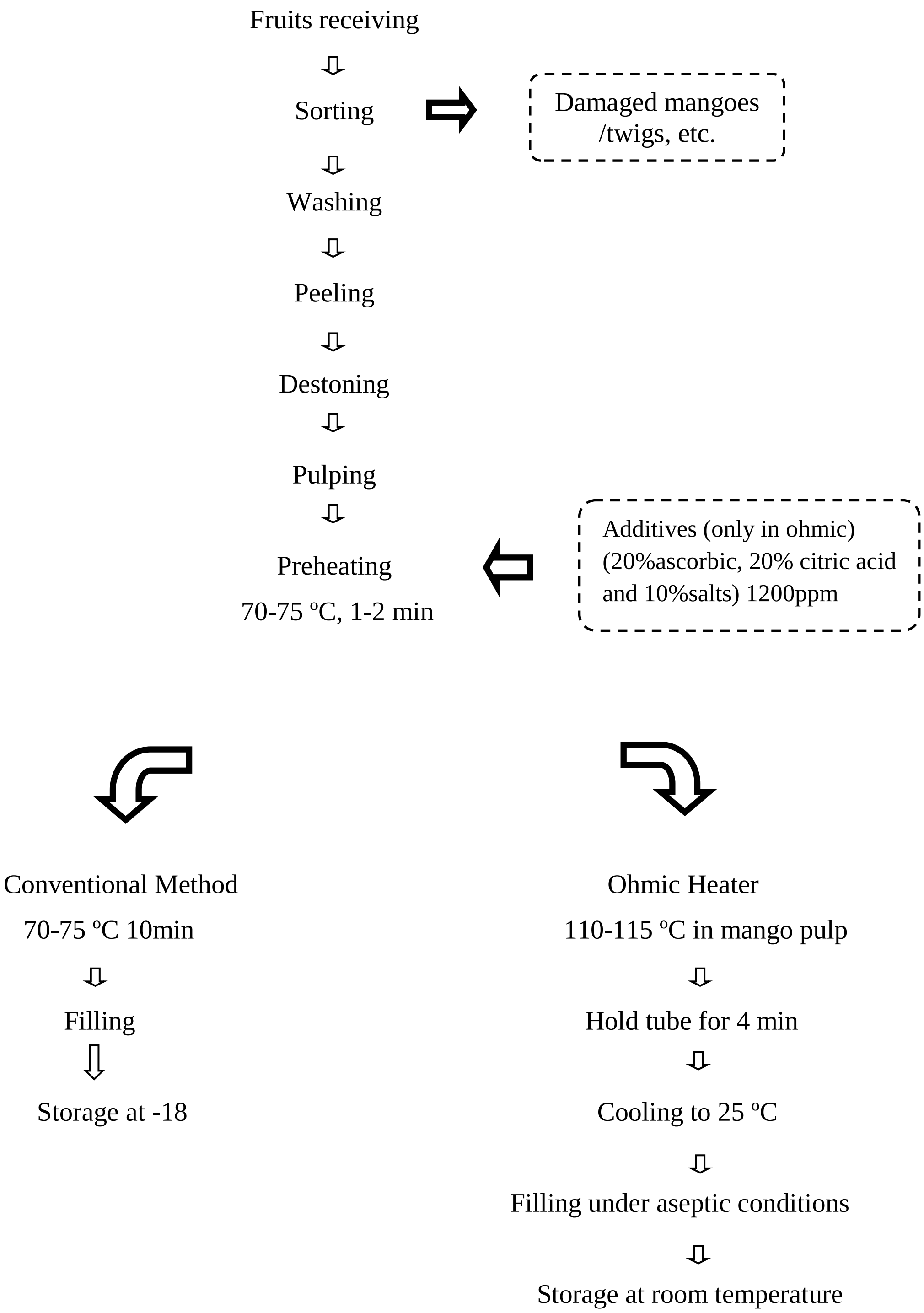
β-Carotene, 3,5-dinitrosalicylic acid, ascorbic acid, galacturonic acid, pectin and catechin (Sigma, St. Louis, USA), gallic acid and Folin-Ciocalteau agent were from Merck, Darmstadt, Germany) and aluminum chloride (Technogen, Egypt) were used. All other chemicals were of analytical reagent grade. For determination of the standard curve for anthocyan analysis cyaninchlorid as well as acetonitrile (HPLC grade) (Roth, Karlsruhe, Germany), methanol (HPLC grade, Wesel, Germany) acetic acid and formic acid both of > 98 % purity from Riedel-de-Haen (Seelze, Germany), potassium chloride and sodium acetate (Merck, Darmstadt, Germany) were from Merck, Darmstadt, Germany).

3. Methods

3.1. Processing of mango pulp:

The fresh mangoes were processed by Ohmic heating as well as conventional methods at the "Hero Company" for food industries as follows:

3.1.1. Mango pulp processing diagram:



3.1.2. Ohmic conditions during processing of mango pulp:

Ohmic heating conditions during processing of mango pulp were AC = 200 A, Frequency = 70 Hz, Voltage = 400 V, Pressure = 1.30 - 1.50 bar, Flow rate was 2170 kg/ hr, Heat generated was 110 - 115 ºC; The temperature of cooling and filling was 25 ºC; the temperature of the hold tube was not less than 104 ºC for 4 min and the temperature of Ohmic heater was 110 - 115 ºC; the temperature of pre-heating was 70 - 75 ºC for 1 - 2 min. The heat treatment in the conventional method was 70 - 75 ºC for10 min.

3.2. Physical and chemical analysis:

Specific gravity and pH determined by the method of (AOAC (2005), electric conductivity (EC) were measured by the method of (Avasoo *et al.,* 2011), total soluble solids as ºBrix were determined with a refractometer (OPTIKA ViaRigla, 3224010 PonteranicaBG- Italy SN 203825) and corrected according to the temperature of the sample. The color was measured using a colorimeter (Model CR-410; Konica Minolta, Japan). Moisture content, ash and fiber were determined by (AOAC, 2005). Total carbohydrates were determined as glucose using the phenol-sulfuric acid method described by (Dubois *et al.,* 1956). Reducing sugars liberated [DNSA method according to Miller (1959)]. 5-hydroxymethyel furfural (HMF) (Husoy *et al.,* 2008). Pectin fraction (*WSP: water soluble pectin, *ASP: ammonium oxalate soluble pectin and* SSP: NaOH soluble pectin) were determined by the method of (Sobotka *et al.,* 1972) and Titratable acidity (% acidity) were determined by the method of (Abd-El Fattah *et al.,* 2010). Total phenol content was determined calorimetrically by using the Folin-Ciocalteau reagent according to the method of Singleton and Rossi (1965). Carotenoids and ascorbic acid were determined as described by the AOAC (2005).

3.3. Enzymes activity

Polyphenoloxidase (PPO) was extracted as described by the (Liu *et al.,* 2005) and its activity was determined according to (Wang *et al.,* 2006). One unit of polyphenoloxidase activity is defined as the increase of 0.001 unit of absorption per min at 420 nm at 25 ºC (Liu *et al.,* (2005). Polygalacturonase (PG) was extracted as described in the method of Pozsar-Hajnal and Polacsek-Racz (1975) and its activity was determined according to the method of Malik and Singh (1980). One unit of PG is defined as the amount of enzyme which catalyzes the release of 1 mg of galacturonic acid per unit time under the specific conditions.

3.4. Microbiological Analysis

Total plate count was determined according to the method of (Harrigan and McCance, 1976), coliform bacteria described by (A.P.H.A., 1976). All plates were incubated at 37 °C for 24 – 48 h, molds and yeasts were determined using potato dextrose agar medium according to the method of (Difco Manual., 1984) and all plates were incubated for 48 h at 30°C. Thermophilic bacteria were determined according to the method of (Kosticová *et al.,* 2004). all plates were incubated at 55°C for thermopiles per 48 hours.

3.5. Organoleptic Evaluation:

Selected samples of each product were evaluated organoleptically for color, flavor and overall acceptability by a panel with 10 trained members. The evaluation was carried out by using a 9-point hedonic scale (Larmond, 1977).

3.6. Statistical analysis

Statistical analysis was carried out according to (Fisher, 1970). Data were analyzed by one-way analysis of variance (ANOVA) and least significant difference (LSD) test at $p < 0.05$ were used to compare the significant differences between means of treatment (Waller and Duncan, 1969).

RESULTS AND DISCUSSION

1. Physical and chemical characteristics of fresh mango juice and mango pulp:

Physical and chemical characteristics (i.e. pH, TSS, electric conductivity (EC), specific gravity, phenol content, ascorbic acid content, carotenoids, carbohydrates, ash, total acidity, (as citric acid), fiber, total sugar (g/100g), reducing sugars, non-reducing sugars and 5-hydroxymethyel furfural (HMF (µg/g)) of mango juice as well as mango pulp processed by using either Ohmic heating or a conventional method were determined, as seen in Table (1).

The results presented in Table (1) showed the changes of the products at different stages of processing, either by Ohmic or by conventional heating. The processing of mango pulp by Ohmic and conventional methods caused a decrease in the contents of TSS, total carbohydrates, total acidity, total sugars (reducing and non reducing sugar) and an increase in, phenol content, ascorbic acid and carotenoids compared to the conventional process. Shaarawy (2004) found that, total sugars (g/100g), reducing and non reducing sugars and fiber were16.41, 3.79, 12.62 and 1.17, respectively.

The increase in electric conductivity of mango pulp during Ohmic heating was due to the addition of some electrolytes (salts) to increase the ions and enhance the process.

Table (1) also showed that total pectin and its fractions were reduced slightly by Ohmic heating with an inverse effect observed using conventional heating. This could be attributed to the effect of the high temperature applied for a short time in Ohmic heating. However, the decrease in pectin fractions could be mainly due to the effect of the long time used during heating. In this respect, it is described that total pectin in mango pulp ranged from 0.26 to 0.53% this results agreement with the results of (Vásquez-Caicedo *et al.*, 2002; Banjongsinsiri, 2003).

The results shown above also indicate that mango pulp processed by Ohmic heating contained more phenols, carbohydrates and vitamin C and less HMF compared to that produced by conventional one. Total acidity increased while the pH decreased during processing due to processing conditions including addition of citric acid or degradation and transformation of polysaccharides or by breakdown of pectic substances. It was reported that pH plaid a dual role in the fruit juices by acting as a flavor promotor and preserving factor. The HMF could be formed and increase at high temperatures, so it could be taken as an indicator for heat stress during processing.

Chien (2007) found that, the total acidity of fresh mangoes was 0.80, while it was 1.16 % for mango pulp processed by chemical preservatives Sosa-Moralesa *et al*. 2009 and Akhtar*et al*. (2010) found that ash and acidity of mango pulp were 0.36 and 0.69, respectively.

In the same time, Ribeiro (2007) found that phenols, ascorbic acid and total carotenoids of mango pulp ranged from 48.40 to 208.70 mg/100 g, from 9.79 to 77.71 mg/100 g and from 1.91 to 2.63 mg/100g, respectively. Manthey *et al*. (2009) found that, the polyphenol content, ascorbic acid and carotenoids in mango pulp were from 21.6 to 107.7, (from 11.5 to134.5) and from (3.08 to 39.02) mg/100g, respectively. Talcott (2009) indicated that, some of mango cultivar such as Haden and Francis contained the highest carotenoids concentration (14.2 and 13.7 mg/100g pulp, respectively), followed by Francis, Kent, Ataulfo and Tommy Atkins (9.6, 6.3 and 5.3 mg total carotenoids /100 g pulp, respectively). Safdar (2012) reported that pH, TSS, total sugar, total acidity and Brix/acid ratio of different mango pulps were from (3.70 to 3.99), (15 to 21), (11.59 to 18.20%), (0.55 to 0.65) and (23.07 to 473.80) mg/100g, respectively. From the results above it can be concluded that fresh mango juice could be processed by Ohmic heating at 110 - 115 ºC for 4 min. The chemical characteristics of mango pulp were found to be of higher quality compared to that of conventional heating.

Table (1). Physical and chemical characteristics of fresh mango juice and mango pulp (on dry weight basis)

Physical & Chemical parameters	Fresh mango juice	After Blanching	Mango pulp		L.S.D at 5%
			Ohmic	Conventional	
pH	3.78 ±0.02[a]	3.41 ±0.4[c]	3.50 ±0.05[b]	3.56 ±0.01[b]	0.07
TSS(°Brix)	18.2±0.26[a]	16.9±0.40[b]	16.1±0.20[c]	16.3±0.36[c]	0.6
EC (ms.cm1)	6.08±0.18[b]	6.45±0.39[b]	8.93±0.07[a]	6.56±0.26[b]	0.53
Specific gravity	1.0654±0.01[a]	1.0556±0.01[a]	1.0398±0.008[a]	1.0424±0.02[a]	0.02
Ash%	3.34±0.07[a]	2.53±0.13[c]	2.64±0.15[c]	2.94±0.20[b]	0.27
Total acidity (citric acid) %	3.14±.20[c]	3.71±0.26[a]	3.62±0.12[b]	3.55±0.24[b]	0.40
Brix/acid ratio	5.80±0.03[a]	4.56±0.11[b]	4.45±0.04[b]	4.59±0.06[b]	0.12
Fiber%	5.44±0.52[a]	5.12±0.36[a]	5.07±0.39[a]	5.18±0.40[a]	0.79
Carbohydrates(g/100gm)	84.18±2.62[a]	83.48±1.72[a]	81.78±2.21[a]	80.47±1.77[a]	3.97
Total sugar (g/100g)	78.66±2.38[a]	76.19±2.03[a]	70.24±0.96[b]	71.81±1.91[b]	3.55
Reducing sugars	31.56±2.48[a]	29.35±3.70[ab]	25.45±4.07[b]	26.02±2.55[b]	6.16
Non reducing sugars	47.10±4.07[a]	46.84±2.63[a]	44.79±4.17[a]	45.79±4.66[a]	7.44
HMF(μg/g)*	0.33±0.09[d]	6.1±0.49[c]	8.14±0.25[b]	12.55±1.43[a]	1.44
Total Phenols (mg/100g)	440.40±2.06[a]	397.36±4.46[b]	354.33±2.15[c]	314.96±2.99[d]	5.78
Ascorbic acid (mg/100g)	154.41±4.16[a]	132.70±3.96[b]	92.69±2.66[c]	65.49±2.94[d]	6.57
Carotenoids (mg/100g)	10.64±0.74[a]	8.34±0.45[b]	8.01±0.51[b]	6.62±0.88[c]	1.25
Total pectin (mg/100g)	2670.80±10.91a	2510.61±19.04[b]	2443.58±16.52[c]	1943.71±34.30[b]	41.36
WSP (mg/100g)*	580.39±68.42[a]	564.75±25.92[b]	540.86±56.82[ab]	449.83±34.25[b]	92.97
ASP(mg/100g)*	553.49±20.58a	477.46±44.72[ab]	447.47±52.91[bc]	375.21±38.22[c]	79.88
SSP(mg/100g) *	1536.93±42.07[a]	1468.39±9.97[b]	1455.25±15.69[b]	1118.67±14.67[c]	45.44
Moisture %	80.15±2.53[a]	81.16±1.54[a]	82.37±1.68a	83.56±1.31[a]	3.42

**HMF: 5-hydroxy methyl furfural, *WSP: water soluble pectin, *ASP: ammonium oxalate soluble pectin and* SSP: NaOH soluble pectin.*

Remark: Yield of mango in Ohmic heating was (20 ton fresh fruits) with its fractions as follows: Pulp 70% (14 ton), Peel 16% (3.2 ton) and Stone 14% (2.8 ton).

2. Physical& Chemical characteristics of mango pulp as affected by storage period

The physical& chemical characteristics of mango pulp processed by either Ohmic heating (T1) or conventional method (T2) and stored for 12 months were determined as presented in the Table (2). Table (2) shows slight changes in the physical& chemical characteristics of mango pulp produced either by the Ohmic or the conventional method as affected by storage for 12 months at room temperatures and -18 °C, respectively. An increase in TSS, EC, carbohydrates, total sugar (reducing and non reducing sugars) of mango pulp processed by either Ohmic or conventional method during a storage period of 12 months was recorded. Helmy *et al. (*2001) found that the percentages of total sugars were slightly increased with prolonged storage time. The increase in total sugars (reducing and non-reducing) may be referred to the conversion of non reducing sugars to reducing sugars in the existence of citric acid during heat process and reduction of moisture content. Hussain *et al*. (2003) found an increase in TSS which might be due to the formation of water soluble pectin from insoluble protopectin and reduction of the moisture content. Total acidity was increased while Brix/acid ratio for mango pulp processed was reduced by both methods. Youssed *et al.* (2002) found a reduction in the polyphenol content in mango pulp during storage from 44.2 to 29.1 after 180 days. Sosa-Morales *et al*. (2009) found no difference of the phenols content between the two methods of processing throughout the storage period of mango pulp. The results also indicate that mango pulp processed by Ohmic heating contained more ascorbic acid, carotenoids and less HMF compared to that produced by conventional method along the storage period of 12 months.

Table (2). Physical and chemical characteristics of mango pulp as affected by storage period (on dry weight basis)

Physical & Chemical parameters		Storage period (month) at room temperatures							
		0	3	6	9	12	Mean	%Inc.	%Dec.
pH	T_1	3.50	3.47	3.43	3.41	3.38	3.44^{a}	-	3.43
	T_2	3.56	3.50	3.45	3.42	3.40	3.47^{a}	-	4.49
TSS(°Brix)	T_1	16.1	16.5	17	17.2	17.7	16.90^{b}	9.04	-
	T_2	16.3	16.7	17.1	17.7	18.4	17.24^{a}	11.41	-
EC (ms.cm1)	T_1	8.93	8.95	8.97	9.03	9.14	9.00^{a}	2.30	-
	T_2	6.56	6.61	6.60	6.70	6.77	6.65^{b}	3.10	-
Specific gravity	T_1	1.0398	1.041	1.04415	1.0421	1.0426	1.0413^{b}	0.27	-
	T_2	1.0424	1.0438	1.0443	1.0449	1.0453	1.0441a	0.28	-
Carbohydrates (g/100gm)	T_1	75.78	75.90	76.48	76.76	77.20	76.42^{b}	1.84	-
	T_2	78.47	78.78	78.97	79.14	79.68	79.01^{a}	1.52	-
Total sugar (g/100g)	T_1	70.24	71.58	72.33	72.87	73.43	72.09a	4.34	-
	T_2	71.81	72.59	73.1	73.39	73.79	72.94a	2.68	-
Reducing sugars	T_1	25.45	25.84	26.4	26.82	27.1	26.32a	6.09	-
	T_2	26.02	26.51	26.72	26.92	27.04	26.64a	3.77	-
Non reducing sugars	T_1	44.79	45.74	45.93	46.05	46.33	45.77^{a}	3.32	-
	T_2	45.79	46.08	46.38	46.47	46.75	46.29^{a}	2.05	-
Ash%	T_1	2.64	2.57	2.42	2.41	2.38	2.48^{b}	-	9.85
	T_2	2.94	2.89	2.81	2.76	2.64	2.81^{a}	-	10.20
Total acidity (Citric acid) %	T_1	3.62	3.87	4.12	4.34	4.62	4.11^{a}	27.62	-
	T_2	3.55	3.75	3.96	4.24	4.58	4.02^{a}	29.01	-
Brix/acid ratio	T_1	4.45	4.26	4.13	3.96	3.83	4.13^{b}	-	13.93
	T2	4.59	4.45	4.32	4.17	4.02	4.31^{a}	-	12.42
Fiber%	T_1	5.07	5.02	4.91	4.44	4.07	4.70^{a}	-	19.72
	T_2	5.18	4.96	4.75	4.54	4.17	4.72^{a}	-	19.50
Total pectin (mg/100g)	T1	2443.58	2356.07	2285.36	2234.81	2174.27	2298.82a	-	-
	T2	1943.71	1888.64	1818.77	1756.25	1710.71	1823.62b	-	-
WSP (mg/100g)*	T1	540.86	504.24	484.08	468.95	448.78	489.38a	-	17.02
	T2	449.83	425.21	395.74	373.65	358.44	400.57b	-	17.35
ASP(mg/100g)*	T1	447.47	425.76	400.42	375.07	364.94	402.73a	-	18.44
	T2	375.21	359.87	344.66	324.39	309.18	342.66b	-	19.74
SSP(mg/100g) *	T1	1455.25	1426.07	1400.87	1390.79	1360.56	1406.71a	-	6.51
	T2	1118.67	1103.56	1078.37	1058.21	1043.09	1080.38b	-	6.76

Table (2). Physical and chemical characteristics of mango pulp as affected by storage period (on dry weight basis) (Continuous).

Physical & Chemical parameters		Storage period (month) at room temperatures							
		0	3	6	9	12	Mean	%Inc.	%Dec..
Total Phenolics (mgs/100g)	T_1	354.33	336.93	333.27	330.53	317.71	334.55[a]	-	10.33
	T_2	314.96	308.55	303.47	295.73	283.83	301.31[b]	-	9.88
Retention (%)	T_1	100	95.09	94.06	93.28	89.67	-	-	-
	T_2	100	97.96	96.35	93.89	90.12	-	-	-
Ascorbic acid (mg/100g)	T_1	92.70	83.41	69.84	58.94	49.76	70.93[a]		46.32
	T_2	65.49	59.80	51.49	41.32	32.73	50.17[b]	-	50.02
Retention (%)	T_1	100	89.98	75.34	63.58	53.68	-	-	-
	T_2	100	91.31	78.62	63.09	49.98	-	-	-
Carotenoids (mg/100g)	T_1	8.01	7.82	6.71	6.32	5.65	6.90[a]	-	29.46
	T_2	6.62	5.93	4.78	4.31	3.48	5.02[b]	-	47.43
Retention (%)	T_1	100	97.63	83.77	78.90	70.54	-	-	-
	T_2	100	89.58	72.21	65.11	52.57	-	-	-
HMF(µg/g)	T_1	8.14	8.64	9.14	9.57	9.89	9.08[b]	17.69	
	T_2	12.55	12.95	13.51	13.78	14.12	13.38[a]	11.12	-
Moisture %	T_1	82.37	81.23	80.04	79.33	78.64	80.32[b]	-	4.53
	T_2	83.56	83.21	82.64	82.59	81.05	82.61[a]	-	3.00

*T_1: Ohmic heating, T_2: conventhonal method, HMF: 5-hydroxy methyl furfural, *WSP: water soluble pectin, *ASP: ammonium oxalate soluble pectin and* SSP: NaOH soluble pectin.*

Khalil *et al*. (1979); Riaz*et al*. (1988); Hussain (2003) and Bajwa (2007) reported an increase in TSS in communited lime squash and communited fruit bases during storage of mango pulp. Hussain, (2003); Akhtar *et al. (*2010) reported that total acidity of different mango pulps ranged from 1.29 to 1.59 after 270 days of storage and Helmy *et al. (2001)* reported a decrease in total sugars during storage of mango pulp. However, a reduction of the due to the increase in titratable acidity along the storage time of the mango pulp was observed (Helmy*et al*., 2001; Hussain *et al*., 2008; Abbassi *et al*., 2009; Sosa-Morales *et al*., 2009; Akhtar, 2010) and vitamin C by oxidation during heat application (Lee *et al.*, 2000; Gil *et al*., 2006).

From the results above it could be concluded that the physical and chemical characteristics of mango pulp processed by Ohmic heating were only slightly affected and retained more vitamin C, polyphenols and carotenoids. In addition, they showed a reduced increase in HMF compared to that processed by the conventional method. Such effect might be due the use of heat treatment in conventional method. Moreover, Ohmic heating of mango pulp could also be a potential alternative to conventional heating processes because in many situations particles heat as fast as or even faster than liquids.

The results in Table (3) showed the changes in the color of mango pulp after processing by either Ohmic or conventional method compared to the fresh mango juice. The processing of mango pulp by the conventional method caused a higher reduction of L, a, and b compared to Ohmic heating. A decrease in the color values (L, a, and b) in both mango pulps processed by Ohmic heating and conventional method during storage was also recorded. However, the reduction of color in mango pulp processed by Ohmic heating was not so pronounced as compared to the conventional process. This might be due to the effect of heating (used in conventional) and oxygen on the carotenoid content during storage.

Van den Berg *et al*. (2000) found that the β-carotene content was responsible for the development and retention of color in the mango pulp. They observed that pasteurization of pulp caused degradation in colored pigments. Other nutrients were also negatively affected. Marx *et al*. (2003) showed that the time and temperature of application had a significant influence on the carotenoids contents. Benjar and Arhapol (2006) reported that the browning of pineapple puree could be prevented by thermal inactivation of polyphenoloxidase at different temperatures between 40 - 90 °C depending on the exposure time. Chien (2007) found that the color of sliced mango during storage at 6 ºC (L, a, and b) was 66.76 ± 1.09, 10.27 ± 0.56 and 15.37 ± 0.31, respectively. These findings also indicated that Ohmic heating of mango pulp caused a lower reduction in color of the final product compared to the use of conventional method.

Table (3). Color measurement of fresh mango juice and mango pulp.

Parameters	L*	a*	b*	Chroma(C*)	Hue(h*)	ΔE	Browning index
Fresh mango juice	61.73±2.48^{a}	11.09±2.23^{a}	27.46±2.69^{a}	29.61±2.23^{a}	75.56±3.56^{a}	-	70.58±3.08^{a}
After Blanching	58.43±3.31^{a}	9.07±2.01^{ab}	24.18±1.86^{ab}	25.82±1.60^{ab}	77.15±2.06^{a}	5.07±0.11^{c}	63.52±1.96^{b}
T_1	56.52±3.28^{a}	8.88±2.06^{ab}	24.92±3.49^{ab}	26.45±2.89^{ab}	78.20±3.05^{a}	6.20±0.20^{b}	68.23±2.44^{ab}
T_2	50.79±1.57^{b}	6.69±0.59^{b}	21.92±0.70^{b}	22.92±2.31^{b}	73.02±3.41^{a}	13.03±0.16^{a}	64.90±2.50^{b}
L.S.D at 5%	5.18	3.47	4.55	4.33	5.78	0.29	4.75
T_1Storage period (month)Zero time	56.52	8.88	24.92	26.45	78.20	6.20	68.23
3	55.02	6.31	23.8	24.61	83.52	9.01	63.52
6	53.87	5.47	20.1	20.81	83.29	12.15	52.94
9	50.35	4.74	18.3	18.99	83.99	15.93	50.58
12	50.02	3	18.1	18.34	89.54	17.03	48.23
Mean	53.16^{a}	5.68^{a}	21.04^{a}	21.84^{a}	83.71^{a}	12.06^{b}	56.70^{a}
T_2 Storage period (month) zero time	50.79	6.69	21.92	22.92	73.02	13.03	64.90
3	50.22	5.81	20.65	21.45	74.28	14.38	60.33
6	47.20	5.10	18.5	19.19	74.58	18.09	56.68
9	46.37	3.72	16.4	16.82	77.21	20.31	48.68
12	44.18	2.43	14.18	14.39	80.27	23.65	41.97
Mean	47.75^{b}	4.75^{b}	18.33^{b}	18.95^{b}	75.87^{b}	17.89^{a}	54.51^{a}

T_1: Ohmic heating, T_2: conventional method

3. Microbiological load of fresh mango juice and mango pulp:

The microbiological load (i.e. total plate count (TC), mold and yeast, coliform bacteria and thermophilic bacteria) of mango juice as well as mango pulp processed by using either Ohmic heating or conventional methods were determined and the results are presented in the /Table (4).

Results in Table (4) show changes in the microbiological load of mango pulp after processing by either Ohmic or conventional method compared to the fresh mango juice. The processing of mango pulp caused a decrease in TC (total plate count), mold and yeast, coliform bacteria and thermophilic bacteria. The obtained results (Table, 6) show an increase in TC (total plate count) and (mold and yeast) while coliform bacteria and thermophilic bacteria were completely inhibited in mango pulp processed by conventional method during storage. However, TC, mold and yeast, coliform bacteria and thermophilic bacteria in mango pulp processed by Ohmic heating were completely inhibited after processing and also during storage.

In this respect Helmy *et al. (*2001) found that, yeast and mold count of fresh Alphonso and Zebda mango pulp were 2.2 ×10^4 Cfu/g and 3.1×10^4 Cfu/g, respectively. During a storage of 9 months the molds and yeasts increased from 0.90 ×10^2 Cfu/g to 1.52×10^2 Cfu/g in Alphonso and from 1.01×10^2 Cfu/g to 1.83×10^2 Cfu/g in Zebda. The total bacterial count of Alphonso fresh mango pulp was 3.4 ×10^5 Cfu/g and 8×10^5 Cfu/g in Zebda. During a storage of 9 months molds and yeasts increased from 1.70 ×10^3 Cfu/g to 7.10×10^3 Cfu/g and 1.80×10^3 Cfu/g to 7.19×10^3 Cfu/g in Alphonso and Zebda, respectively. Younis *et al.* (2011) found an increase in the total bacterial count of mango pulp during storage.

Table (4). Microbiological load of fresh mango juice and mango pulp as affected by storage period.

Microbiological analysis	fresh mango juice	After Blanching	Ohmic heating Storage period (month)					Conventional heating Storage period (month)				
			0	3	6	9	12	0	3	6	9	12
TC (total plate count) CFU. ML⁻¹	5.8×10^5	4.2×10^5	N	2×10^1	4×10^1	6×10^1	12×10^1	1.4×10^3	4.2×10^3	6.48×10^3	8.24×10^3	11.65×10^3
Mold and yeast CFU. ML⁻¹	3.3×10^4	2.6×10^4	N	N	N	N	N	1.2×10^2	2.15×10^2	2.24×10^2	3.21×10^2	3.8×10^2
Coli form bacteria CFU. ML⁻¹	N	N	N	N	N	N	N	N	N	N	N	N
Thermophilic bacteria CFU. ML⁻¹	N	N	N	N	N	N	N	N	N	N	N	N

** N=<100 ESPC. ML⁻¹*

Table (5). Enzymes activity of fresh mango juice and mango pulp.

Enzyme	Fresh mango juice	Ohmic heating 111º Cfor 4 min	Conventional 70-75 ºC for 10 min	Conventional Residual activity%	L.S.D at 5%
PPO(unit/gm/ min)	361.29 ± 8.35^a	0^c	96.136 ± 5.20^b	26.61	11.35
PG(unit/gm/ min)	1.336 ± 0.078^a	0^c	0.367 ± 0.021^b	27.4	0.093

PPO: polyphenoloxidase; PG: Polyglacturonase

From the results above it could be concluded that the Ohmic heating completely inhibited TC as well as yeasts and molds after processing or during storage which is not the case in conventional heating.

4. Enzymatic activities of fresh mango juice and mango pulp

The enzymatic activities (polyphenoloxidase (PPO) and PG (Polyglacturonase) of mango juice as well as mango pulp processed by using either Ohmic heating or conventional method were determined and the results are presented in Table (5).

Results in Table (5) show the changes in the enzymatic activity of PPO (EC1.14.18.1) and PG (EC 3.2.2.15) of mango pulp after processing by either Ohmic or conventional method compared to the fresh mango juice. The obtained results (Table, 5) showed a decrease in PPO and PG activity in mango pulp processed by conventional method. However, Ohmic heating completely inhibited the enzymes activities due to the effective heating treatment.

In this respect, Labib *et al.* (1995) found that the activity of PG in mango pulp was 4.5 and 0.55 units/100 g. Wang *et al*. (2006) found that PPO activity was reduced at high temperatures (e.g. 70 – 75 ºC and 100 ºC and the relative activity (%) decreased by 75 % and 100 %, respectively. Chutintrasri and Noomhorm (2006) found that the thermal inactivation of pineapple PPO, at 40 - 60 ºC for 30 min reduced the enzymatic activity up to 60 %. They added that denaturation increased rapidly above 75 ºC. Thus, residual activity was about 7% after 5 min at 85 ºC and 1.2 % after 5 min at 90 ºC. Gui *et al. (*2007) found that, strawberry PPO was also thermosensitive and its activity was reduced by 50 % after 10 min of heating at 55 ºC. The enzyme was almost completely inactivated at 65 ºC after 10 min.

5. Organoleptic characteristics of the processed mango pulp

The results are presented in Table (6). The results in Table (6) show changes in the organoleptic properties of mango pulp after processing by either Ohmic or conventional method. An improvement in the organoleptic properties of mango pulp processed by Ohmic heating compared to conventional process was noticed. In this respect, Akhtar *et al*. (2010) found that color, flavor, taste, and acceptability were 7.67±0.139, 7.50±0.129, 7.33±0.116 and 7.17±0.096), respectively. They added that the organoleptic properties decreased during storage of 90 days.

Table (6). Organoleptic characteristics evaluation of the processed mango pulp by either Ohmic heating or conventional method.

Treatment	Organoleptic score			
	Color (10)	Oder (10)	Taste (10)	Acceptability(10)
Fresh fruits	8.31±0.47^a	8.84±0.40^a	8.54±0.44^a	8.77±0.14^a
T_1	8.27±0.55^a	8.50±0.30^a	8.78±0.34^a	8..58±0.33^a
T_2	7.17±0.29^b	7.11±0.19^b	7.06±0.59^b	7.25±0.22^b
L.S.D at 5%	0.90	0.62	0.93	0.48
T_1 Storage period (month) 0	8.27	8.50	8.78	8..58
3	7.67	7.33	7.63	7.71
6	6.80	6.60	6.77	6.88
9	6.33	6.00	6.36	6.22
12	5.58	5.87	5.71	5.91
Mean	6.93 ^{a}	6.86 ^{a}	7.05 ^{a}	7.06 ^{a}
T_2 Storage period (month) 0	7.17	7.11	7.06	7.25
3	6.64	6.58	6.78	7
6	6.22	6.25	6.24	6.25
9	5.64	5.84	5.94	5.84
12	4.87	4.74	4.64	4.74
Mean	6.11 ^{b}	6.10 ^{b}	6.13 ^{b}	6.22 ^{b}

T_1: Ohmic heating, T_2: conventional method

The above results indicated the availability of using Ohmic heating under the studied conditions in the processing of mango pulp and compared to conventional one. The Ohmic heated mango pulp contained more phenolic compounds, carbohydrates and vitamin C and less HMF compared to that produced by conventional one. Results also show that such a product was free from TC and molds and yeasts in case of Ohmic heating while the microorganisms were not completely eliminated during the conventional process (TC: 1.4×10^3 and molds and yeasts: 1.2×10^2). The results also show a complete inhibition of coliform and thermophilic bacteria. The organoleptic characteristic of Ohmic heated mango pulp was also improved compared to the conventional heating method.

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تكنولوجيا التسخين بالتيار العالي التردد(الاومي) وخصائص الجودة للب المانجو

صبحي محمد محسن[1] و محمد محمد النقيطي[1] و مايكل ماركوفيتش[2] و طارق جمال عبد المقصود[1]

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تهدف هذه الدراسة الي استخدام تكنولوجيا التسخين الأومي[كأحد طرق الحفظ الحديثة(غير تقليدية) في حفظ الاغذية] في معاملة لب المانجو ومقارنته بالطريقة التقليدية. حيث تم تصنيع لب المانجو بأستخدام التسخين الأومي تحت الظروف المناسبة للدراسة.أظهرت النتائج أن معاملة لب المانجو باستخدام التسخين الأومي أو الطريقة التقليدية تسبب انخفاضا في كلا من المادة الصلبة الذائبة و الحموضة الكلية والكربوهيدرات الكلية و السكريات الكلية (السكريات المختزلة وغير مختزلة) و ايضا زيادة في الفينولات وحمض الاسكوربيك والكاروتينات والذي تم معاملتة عن طريق التسخين الأومي كان اكثرفي محتواه من المركبات الفينولية والكربوهيدرات والهيدروكسي ميثيل فورفورال (HMF) وفيتامين c وذلك بالمقارنة مع الطريقة التقليدية .وايضا حدث انخفاض طفيف للبكتين الكلي وجزيئاته عن طريق التسخين الأومي ولكن الانخفاض كان اكثر في الطريقة التقليدية. كما أظهرت النتائج انخفاض في العدد الكلي للبكتريا والفطر والخميرة عن طريق معاملة لب المانجو باستخدام الطريقتين .ولكن أظهر التسخين الأومي انخفاض كبير في العدد الكلي للبكتريا والفطر والخميرة بعد المعاملة وأثناء التخزين مقارنة بالطريقة التقليدية .وايضا بكتريا القولون والبكتيريا الثرموفيلية حدث لها تثبيط كلي باستخدام الطريقتين .وأظهرت النتائج ايضا انخفاض النشاط الأنزيمي لكلا من بولي فينول اوكسيديز (PPO) والبولي جلاكتيورنيز(PG) في لب المانجو التي تم معاملتها بواسطة الطريقة التقليدية .امافي طريقة التسخين الأومي حدث لها تثبيط كلي للانزيمين بسبب تاثير الحرارة.وقد لوحظ تحسن في الخصائص الحسية للب المانجو عن طريق التسخين الأومي مقارنة بالطريقة التقليدية .