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The effect of high hydrostatic pressure on some quality parameters of a traditional tortellini-like Turkish food (mantı) packed with at modified atmosphere

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Abstract

Traditional cereal-based foods need to be thoroughly processed to fulfill the transportation conditions to distant locations. The present study examines the combined use of high hydrostatic pressure (HHP) and modified atmosphere packaging (MAP) processes in mantı, a traditional tortellini-like Turkish food. After the mantı's inner material and dough were separately processed with a HHP treatment at 400 MPa and 600 MPa, the mantı was prepared, and packaged under the modified atmosphere (60% CO_2 + 40% N_2) and stored for 14 days at 4°C. Also, the thermal inactivation was examined of inoculated mantı samples with bacterial cells of *Staphylococcus aureus*, *Escherichia coli* and *Bacillus cereus*. The differences of physicochemical and microbial results were found significant ($P < 0.05$) among the samples, as affected by high pressure at the modified atmosphere package. In case of the consumer sensory evaluation regarding cooking, HHP processed samples (HHPR) were more liked than semi-processed (CR) samples (stored for 14 days at 4°C). Inoculated bacterial cells to mantı samples exhibited varying inactivation responds at different temperatures (55 to 75°C) of heat treatment. As a result, it has been found that the high hydrostatic pressure treatment is a promising process for the mantı packaged in the modified atmosphere, extending the 7-day storage time compared to the untreated control sample.

Keywords: Consumer acceptability studies, Non-thermal processing, High hydrostatic pressure, Modified atmosphere packaging, Mantı

Introduction

In the food and packaging industry, there are many attempts to implement new processing methods for food products. Among these are traditional foods that must be industrialized for both of the domestic and export markets. Mantı consists of a wheat dough (75% w/w of mantı) filled with minced beef, onion, and spices (25% w/w of mantı).

If mantı is to be consumed immediately, then it is cooked in boiling water (200 g mantı in 2 liters of water) for 10-12 mins. Before serving, a sauce is prepared by combining and cooking butter, tomato paste and ground red pepper. If desired, yogurt, garlic, sumac, red pepper and mint are added. When there is a need for storage, mantı is frozen or oven baked before packaging in industrial applications. Packaging is mostly applied in plants by using a vacuum or modified atmosphere (Sitti, 2011). Vacuum and modified-atmosphere packaging extends the shelf life of mantı up to four months (Uzunlu and Var, 2016).

Mantı is a highly perishable product due to its high water activity (>0.87), moisture (>40%) and pH content (6.0-7.0), as well as the fact that its nutrients are beneficial for microorganism growth (Uzunlu and Var, 2016). In the context of cereal-based foods, the standards limit the presence of potential food poisoning risk carrying microorganisms, such as *Staphylococcus aureus*, *Clostridium perfringens*, *Salmonella*

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spp., pathogenic *Escherichia coli*, and spore forming bacteria (Anonymous, 2011).

Previous research has mainly focused on modified-atmosphere packaging. One such study investigated the effects of both heat treatment and modified-atmosphere packaging (MAP) on mantı. Both the wheat dough and filling were first boiled and then baked (dried), followed by modified atmosphere packaging with different gas compositions. A 70% CO_2 + 25% N_2 + 5% O_2 provided a stable mantı product as judged against microbial, chemical and sensorial parameters for 35 days at 4°C (Yücetepe, 2011). Other research has been carried out to determine the refrigerated storage shelf life of modified-atmosphere-packed mantı. The findings shown that both 60% CO_2 and 80% CO_2 with N_2 led to stable storage at 4°C for 4 months (Uzunlu and Var, 2016). Similarly, Sitti et al. (2009) reported that the modified-atmosphere packaging of mantı was found more effective than vacuum packaging in terms of achieving at least one month of stability during refrigerated storage.

As stated above, depending on the processing conditions, heat treatment or freezing may be applied prior to mantı packaging. However, any heat treatment applied to the filling may adversely affect the overall quality of the mantı. For example, heat treatment may cause the leakage of meat lipids from the dough of the mantı, in addition to browning the meat, which, together, may result in poor sensory quality and reduced consumer purchase intent. High hydrostatic pressure (HHP) treatment has been used for over 20 years as a cold pasteurization or non- thermal processing method (Bermúdez-Aguirre and Barbosa-Cánovas, 2011). This treatment is usually applied in the range of 100 and 1000 MPa (Bárcenas et al., 2010). The use of high hydrostatic pressure permits new process development opportunities both for industry and researches (Rastogi et al., 2007).

Because of the stated reasons, the current research aimed to assess; (a) the combined effect of HHP and MAP for mantı storage at 4°C, and (b) to determine the thermal death responses of some common food-borne bacteria in mantı.

Materials and Methods

Peptone water (0.1%), tryptic soy broth (TSB), tryptic soy agar (TSA), nutrient agar (NA), 1,2-propanediol (used as a pressure medium) were purchased from Sigma-Aldrich (United Kingdom). Minced beef (fat content <20%, collagen/meat protein ratio <25%) and strong white fine wheat flour (Allinson, UK) were purchased from a local market in Reading, Berkshire (UK).

High Hydrostatic Pressure and Modified Atmosphere Packaging Applications

For this purpose, three sample types were prepared and analyzed. (I) High Hydrostatic Pressured (HHPR) samples, (II) Semi-Processed (CR) samples, and (III) Control samples. High hydrostatic pressure was applied at 400 MPa and 600 MPa to the filling material (minced beef) and the wheat dough for 15 mins at room temperature, respectively. The mantı samples which prepared with dough treated with HHP, and minced beef untreated with HHP was defined as Semi-Processed mantı samples (CR). While HHPR mantı samples were prepared by treating both of the dough and minced beef with HHP. Prior to treatment, samples of beef mince and wheat dough was gently placed in polyethylene (PE) bags, double wrapped, and sealed. Stansted Fluid Power Ltd (UK) high pressure rig was used at the food process center of University of Reading Food and Nutritional Sciences Department's (UK).

Mantı was prepared from wheat flour, minced beef and sterilized distilled water. The dough was prepared by mixing wheat flour and water (35-40% w/v, flour basis) followed by the application of high pressure, as described above. It was then sheeted and cut into equal squares (using a kitchen knife), with an average sheet thickness of 0.19mm (±0.02). Each square of dough (1.125±0.1g) was filled with an equal amount (0.375±0.1g) of beef mince (25% w/w of mantı), and the squares were then folded diagonally by hand to form the distinctive mantı shapes under the hygienic procedures. Mantı samples were placed in PE bags, and were filled as to be with with 60% CO_2 + 40% N_2 gas mixture in a 2/1 gas volume to mantı weight ratio in each bag was applied and sealed using a Multivac A 300 packaging unit (under 2 bar pressure and 75L/min gas flow) at they were put in cold storage at 4°C for 14 days (34% relative humidity).

Physicochemical and Microbial Analyses

From each sample types ten grams of mantı were weighed in a sterile stomacher bag containing 90mL peptone water (0.1%) and homogenized in a stomacher (Seward 400, UK) at 230 rpm for 2 mins. Serial decimal dilutions were prepared and spread onto TSA. Plates were incubated for 24–48h at 37°C in terms of pathogen microorganisms. Each three sample types (HHPR, CR, Control) were stored at 4°C for 14 days and analyzed on each sampling days (0, 2, 4, 7, 14). Color analyses were performed using a ColorLite sph850 instrument (ColorLite GmbH, Germany). Illuminant was D_{65} and observation angle was 10°. For measuring, port was applied force onto the samples, and the size of port was 3.5 mm. Triplicate readings were evaluated for C.I.E. *L*, a*, b** parameters. While, ten grams of samples were homogenized in 90 mL of distilled water and pH value was recorded by using pH meter (SeveneEasy, Mettler Toledo) averaging 3 measurements. The a_w of the mantı samples were measured and recorded using a Pawkit water activity meter (Decagon, WA). Calibration was adjusted to 0.76 a_w with NaCl standard before measurement (Clavero and Beuchat, 1995; AOAC, 2000).

Experimental Design and Protocol of Consumer Study

Sixty healthy consumers were involved in the study. Individual sensory booths at the sensory science center (Department of Food and Nutritional Sciences, University of Reading, UK) were used. All consumers (*N*=60) were recruited from the University campus and provided informed written consent. For both of the high hydrostatic pressured (HHPR) and semi-processed (CR) samples two sample types were prepared and evaluated; raw and cooked mantı. Due to the spoilage on day 7 of the untreated control, this sample was excluded from the consumer study. Raw mantı samples were presented to consumers in their original package, stored for either 4 or 14 days at 4°C. Appearance of raw mantı samples (10g +/- 0.1) was rated using a nine-point hedonic category scale (catego-

ries from dislike extremely to like extremely). For cooked samples, packages (10g +/- 0.1) of mantı (stored for 4 or 14 days) were opened and cooked in a boiling water at min. 75°C for 7 minutes. The temperature was continuously monitored via two copper-constant thermocouples inserted into the core of each mantı piece and held for 7 mins after the core temperature reached above 75°C. Samples were kept warm at 50°C for an hour until served to the consumers. Cooked samples were served plain (without yogurt and spices). Overall liking of cooked mantı samples, followed by liking of appearance, taste and texture, were rated using the nine-point hedonic category scale. Free text comments for each samples were collected. Four batches of samples were served in balanced order in a monadic sequential manner; each session lasting no more than forty-five minutes. Testing was held between 15:00 and 19:00 and consumers were scheduled every hour. Data were collected using Compusense (version 5.5, Ontario, Canada).

Bacterial Inoculation and Heat Treatment

The indigenous microbial flora of both minced beef meat and dough were inactivated prior to inoculation of bacterial cultures to mantı pieces by applying HHP at 600 MPa for 15 mins at room temperature, and checked before the inoculation procedure. *Staphylococcus aureus* NCTC 01803, *Escherichia coli* K12 NCTC 10538, and *Bacillus cereus* NCDO 0578 strains were acquired from the National Collection of Type Cultures (NCTC, England). The preserved strains at -80°C in vials containing TSB were thawed at room temperature in a biosafety cabinet. One ml of the cultures was transferred to 50 ml of TSB in 250 ml flasks, where incubated at 37°C for 24h. Following incubation, the freeze-damaged cells were not used in the thermal treatments. Where, 0.1 ml of each culture were pipetted to 10 ml TSB tubes, and incubated at 37°C for 24h. The cultures were prepared daily in a week basis. Each culture was centrifuged at 5000 *g* for 10 mins at 4°C and washed twice in peptone water (PW). The supernatant was discarded, and pellets were diluted to obtain a final concentration of 3 logs CFU/mL.

Three groups of mantı samples for each bacterial culture were prepared. Each group samples were aseptically placed into the stomacher bags. The bags composed of 15 grams of mantı samples (the weight of one piece is 1.5±0.1g). The mantı bags (contains 10 mantı pieces) were then divided into three groups (four packages were used for each group). 500µL of bacterial cultures of *S. aureus*, *E. coli* and *B. cereus* were separately inoculated with either mantı pieces (50 µL per each) for each bag. Bacterial cultures were pipetted into the distinctive shapes of each mantı pieces. The samples were held at 37°C for 4 h to allow the propagation.

Cultures were then aseptically placed onto sterilized glass lenses (85mm in diameter), and heat treated at 55°C to 75°C for 4 mins in an oven (Gallenkamp, UK). The temperature degrees were continuously monitored. Two copper-constant thermocouples inserted into the core of each mantı piece and held for 4 mins after the core temperature reached above the specified degrees. Bags were then cooled in an ice box and homegenised (Seward 400, UK) in a stomacher at 230 rpm for 2 mins. Peptone water (0.1%) was used for homogenization. Serial decimal dilutions were prepared and spread onto NA for *B.cereus*, and TSA for *S. aureus* and *E. coli*. Plates were incubated at 30°C for *B.cereus* and 37°C for *S. aureus* and *E. coli* for 24-48h, prior to counting the colonies.

Statistical Analysis

Each experiment was repeated twice and duplicate (microbiological and a_w analyses) samples were tested at each sampling time. In order to determine the effect of high pressure treatment, ANOVA was used to evaluate the data, using Statistical Package for the Social Sciences (SPSS) software, version 21 (IBM, USA)). Duncan's *post hoc* test was applied at a significance level of $P< 0.05$. ANOVA was performed to determine the significant differences between samples in consumer liking ratings. To determine whether there were groups of consumers exhibiting similar liking patterns, agglomerative hierarchal cluster analysis (AHC) was carried out using Ward's method and dissimilarity. The mean liking scores of these clusters were then re-analyzed by ANOVA. Multiple pairwise comparisons were determined using Tukey's HSD test. All analysis of consumer data was done using XLStat (AddinSoft, France, 2007).

Results and Discussion

Physicochemical and Microbial Analyses

The semi-processed (CR), pressure processed (HHP) and control group raw samples were analyzed for color at five stages of shelf life (0, 2, 4, 7 and 14 days) and substantially affected by the high pressure; L^* values decreased after day 2, indicating that the samples became darker. L^* values of control and semi-processed samples were lower than for high pressurized samples (Table 1). In terms of a^* and b^* values, high pressurized samples' values were significantly ($P< 0.05$) lower than semi-processed group samples (Table 1) indicating that the samples became less red and yellow in hue. Decreased a^* values lead to the loss of redness in meat. The largest difference among the high pressurized, control and semi-processed samples were observed for a^* values (Table 1) because the redness of the meat was lost due to high-pressure treatment.

Jung et al. (2003) state that the luminosity of the meat can be heightened via HHP. Also, these increased L^* values become steady for pressures around 300–400 MPa. This can be attributed to the denaturation of globin and heme displacement or release; an increase in drip losses, leading to water content changes in the meat; or damage to porphyric rings and protein coagulation (Jung et al., 2003). In case of the wheat dough, Bárcenas et al. (2010) showed that L^* values were not significantly ($P> 0.05$) different between the control (untreated dough) and the treated doughs (50 to 250 MPa).

When the shelf life of the meat increased, the meat assumed a more cooked appearance because actomyosin denatures at about 200 MPa and myoglobin denatures and/or co-precipitates with other proteins at about 400 MPa (Ma and Ledward, 2013). In a research project by Bárcenas et al. (2010), a^* values were found to be significantly decreased in wheat dough (without meat) samples exposed to HHP (50 to 250 MPa) as compared to control (untreated dough) samples. The findings of the current study show that the a^* values of the HHP, control and semi-processed samples decreased during storage due to the lack of oxygen in the package atmosphere. It is well-known

that oxygen maintains the redness of meat (Narasimha Rao and Sachindra, 2002). Similar to *a** values, *b** values increase during the blooming of meat (Young et al., 1999). Generally, an increase in *b** indicates increased yellowness in foods. *b** values increased from day 0 to day 14 in all sample types (Table 1).

Table 1. pH, a_w, color and microbial changes during 14 days of storage at 4°C [1,2]

	Storage days				
	0	**2**	**4**	**7**	**14**
Parameters					
pH					
HHPR	6.29±0.01ax	6.32±0.03ax	6.45±0.01bx	6.60±0.02cx	6.50±0.03bx
CR	6.19±0.04ay	6.18±0.02ay	5.48±0.04by	5.37±0.02cy	4.71±0.01dy
CONTROL	6.24±0.03	5.45±0.03	5.39±0.01	ND	ND
a_w					
HHPR	0.96±0.01abx	0.98±0.00bx	0.93±0.02ax	0.88±0.01cx	0.90±0.00cx
CR	0.91±0.00ay	0.95±0.00by	0.98±0.00cy	0.91±0.01ay	0.88±0.01dx
CONTROL	0.92±0.01	0.90±0.01	0.88±0.01	ND	ND
L*					
HHPR	49.56±0.89ax	51.90±1.16bx	45.42±1.54cx	44.48±2.38cx	32.68±5.23dx
CR	35.11±1.34ay	37.79±0.73by	28.64±5.65cy	29.43±4.36cy	26.20±5.95dy
CONTROL	27.10±1.24	32.58±1.76	22.50±1.39	ND	ND
a*					
HHPR	4.50±0.56ax	4.53±0.46bx	4.95±1.41cx	3.42±1.23dx	2.92±0.63ex
CR	9.70±1.18ay	8.55±1.97ay	8.47±0.83by	8.13±1.16cy	7.75±2.37dy
CONTROL	10.60±1.69	10.40±0.93	8.97±0.69	ND	ND
b*					
HHPR	18.58±1.88ax	17.51±1.38ax	18.78±1.33ax	20.47±2.61bx	21.35±1.64bx
CR	21.05±2.00ay	21.19±2.21ay	24.51±2.09by	22.77±1.51abx	22.57±2.02abx
CONTROL	22.31±0.92	22.67±1.81	23.44±0.14	ND	ND
TAMB					
HHPR	0.1±0.05ax	4.04±0.02bx	5.23±0.04cx	5.69±0.10cx	5.81±0.00dx
CR	3.29±0.04ay	6.66±0.08by	6.49±0.06cy	6.69±0.00cy	7.41±0.00dy
CONTROL	3.73±0.44	5.76±0.9	7.22±0.19	ND	ND

[1]TAMB= total aerobic mesophilic bacteria; ND= not determined owing to the spoilage.

[2] Mean data and standard errors in the same raw bearing different lower-case letters (a, b, c, d) are significantly different ($P<0.05$) from each other. Mean data and standard errors in the same column bearing different lower-case letters (x, y, z) are significantly different ($P<0.05$) among each process.

According to the microbiological analyses, total aerobic mesophilic bacteria counts increased over storage for all the studied samples. As expected, this increase was lower in the high pressurized samples compared to the control and semi-processed samples (Table 1). In fact, high pressurized sample's microbial load was 3 log lower than control and semi-processed samples on day 0. The microbial counts increased in all sample groups, while high pressurized sample's load was 1.6 log colony forming unit/g lower than semi-processed sample on the 14th day. The control sample spoiled after day four, resulting in no available data for days seven and fourteen.

The pH of the high pressurized samples was slightly increased compared to neutral values; however, the pH of the control and semi-processed samples decreased during storage. This finding was correlated with an increase in microbial growth in the semi-processed samples. Microbial cell growth leads to decreased pH values in some foodstuffs (Jay et al., 2005). There were significant ($P< 0.05$) but slight differences in pH between the high pressurized samples. The increase from HHPR0 to HHPR14 was 0.31 (Table 1). However, pH of the control and semi-processed samples decreased from day 0 to day 14 (Table 1). Therefore, differences of the samples were significant ($P <0.05$). The a_w value is a reliable standard parameter that affects the microbial stability of fresh foods (Kong and Singh, 2011). The findings show that a_w values ranged between 0.88 and 0.96, however differences were found significant ($P <0.05$) between semi-processed and high pressurized samples (Table 1). Such values are optimal for the growth of spoilage and pathogenic bacteria (Jay et al., 2005).

As is already well-known, microbial growth limits the shelf

life of foods (Nychas and Panagou, 2011). Such previous research used HHP on cookie dough for preservation and cookie quality. Cookie dough, which had 6 log colony forming unit per gram total aerobic mesophilic bacteria in control samples (untreated with HHP) were subjected to HHP at 100 and 200 MPa for 2 and 4 min. and 400 MPa for 15 min. resulted in 4 log reduction. After HHP treatment in heat-sealed bags, the cookie dough stored at ambient temperature for 7 days did not increase in total aerobic mesophilic counts, while counts of the control samples increased 5 times (Aguirre et al., 2018). Hence, in our study the dough in heat-sealed PE bags after HHP treatment were opened, and immediately used in mantı preparation. The microbial counts were, therefore, increased during cold storage (Table 1).

Microbiological safety of the raw materials to be used in food recipes should be high. One such study applied high pressure to provide microbiological safety to the meat used to prepare Çiğ Köfte, and found a six decimal microbial reduction at 300 MPa at room temperature treatment (Uzunlu, 2019).

Once the meat became discolored, at pressures higher than at 325 MPa, microbiological improvement was achieved. If an improvement in meat color redness for only a few days is needed, then 130 MPa is required. However, this level of pressure is not sufficient to modify the microbial load of the meat (Jung et al., 2003). Taking into account both the meat's location (inside of mantı) and its package without oxygen suggested the use of 400 MPa in the current study, because pressures of ~300–600 MPa are sufficient to inactivate the vegetative cells of microorganisms (Rastogi et al., 2007). Moreover, pressures above 300 MPa cause the irreversible denaturation of enzymes and proteins, leading to the rupturing of the cell membrane and the excretion of internal substances, ultimately causing bacterial death (Huang et al., 2014). It is well-known that MAP extends the shelf life of foods (Narasimha Rao and Sachindra, 2002; Zhang et al., 2016). Using CO_2-enriched atmospheres also extends the shelf life of mantı in refrigerated storage, as previously reported (Yücetepe, 2011; Uzunlu and Var, 2016). While, the use of high pressure and modified-atmosphere packaging provided microbial stability to mantı for 14 days of refrigerated storage in the current findings.

Thermal Inactivation of Inoculated Bacteria

The effect of high hydrostatic pressure on the indigenous microbial flora of raw materials of mantı were as follows.

Total microbial cells in dough and minced beef were inactivated in 15 mins at 600 MPa. N_0 (initial load) was 4 log CFU/g in dough and 3.65 log CFU/g in minced beef. In terms of the thermal treatment in mantı samples, no inactivation was recorded at 55°C for all the inoculated bacterial cells (*S.aureus*, *E.coli*, *B.cereus*). *S.aureus* was inactivated by 1.1 log CFU/g to 1.81 log CFU/g at 60°C to 75°C. No inactivation at 60°C was recorded for *E.coli*. And the cells were inactivated by 0.23 log CFU/g to 0.51 log CFU/g at 65°C to 75°C in mantı samples. This was similar for *B.cereus*. No inactivation was observed at 60°C. 0.3 log CFU/g inactivation was recorded at 65°C, while a total inactivation was recorded at 70°C and 75°C.

As a sum, *E.coli* was found more resistant than *S.aureus* and *B.cereus*. Heat treatment at 75°C for 4 mins to inactivate 3 log of the *S.aureus* and *B.cereus* cells was found adequate, while this was found inadequate for *E.coli* cells. This finding should be taken into account for providing food safety of this product. Because, currently industry is using heat or freeze treatment in mantı production. We studied several combinations of heat (55 to 75°C) and time (1 to 6 mins) treatments in mantı samples (Uzunlu, 2013; Uzunlu and Var, 2014).

When mantı held in the oven in increasing periods, it resulted in leaking meat lipids from the dough of mantı and browning the mantı pieces. For this reason, the mantı retention time in the oven was determined optimum 4 minutes at max. 75°C.

As stated by Rastogi et al. (2007) HHP should be combined with heat treatment, to avoid the risk of spore germination in foods. Because, evaluating HHP as an alternative to heat treatment might lead to have the risk of spore resistant bacterial presence in the products. Where, very high resistance to increased levels of high pressure, such as 1000 MPa, was reported for bacterial spores (Rastogi et al., 2007).

Consumer Acceptability

When the consumer acceptability of high hydrostatic pressure processed mantı was evaluated we could say that, there was no significant difference between for appearance liking scores of the high hydrostatic pressured raw samples (HHPR) and semi-processed raw samples (CR) of mantı whether stored for 4 or 14 days at 4°C. There was a significant difference in taste liking scores between the cooked high pressure processed (HHPC14) and semi-processed samples CC14 (P=0.001), with the HHPC14 samples being more liked than semi-processed samples CC14, where both had been stored for 14 days at 4°C. However, consumers found no significant difference in taste liking between the high pressure processed (HHPC4) and semi-processed samples (CC4) when cooked after storage for 4 days at 4°C. In addition, there was no significant difference between the processed and semi-processed samples, whether for 4 or 14 days of storage at 4°C, for the parameters of overall liking, liking of appearance and texture (Table 2).

Taking the consumer evaluation into account, the consumers preferred raw HHPR14 to CR14 in terms of appearance (Figure 1A). Therefore, consumers preferred high pressurized samples stored for 14 days at 4°C to semi-processed samples stored in the same way. Similar results were found for the cooked mantı samples. Consumers preferred HHPC14 and HHPC4, shown at Figure 1B, 1C, 1D, and 1E, to CC14 and CC4 regarding all of the tested parameters (overall liking, taste, texture and appearance). Although not all consumers had the same liking trends (as shown by the cluster analysis), the overall conclusion is that at both 4 and 14 days of storage at 4°C, the high pressurized samples were preferred to the semi-processed samples.

There were three patterns of overall liking of the cooked mantı; the largest two clusters were of similar size (35% and 38.3%). Cluster 1 liked both high pressure processed (HHPC) mantı samples significantly more than semi-processed (CC) samples, however cluster 2 gave lower scores to all cooked mantı and particularly disliked the HHPC sample that had been stored for 4 days. When comments of cluster 1 were analyzed, consumers encountered that the dough was opened and the meat had come out in some of the samples, for both HHPC and CC. The lower

scores of the CC samples compared to the HHPC samples were due to shape, tastelessness and moist texture. However, cluster 2 consumers mostly gave lower scores to HHPC4 samples, similarly for the reason that filling had come out of the dough when cooked.

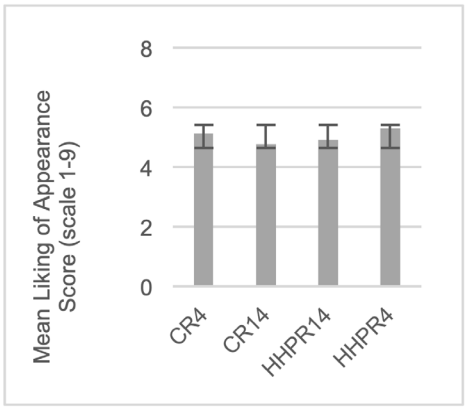
Table 2. Mean liking scores for clusters of consumers following hierarchical cluster analysis [1,2]

Appearance liking scores of raw mantı						
Cluster	N (%)	Samples				
		CR4	CR14	HHPR14	HHPR4	Significance of sample (P-value)
1	5 (8.3)	2.6	2.2	2.4	3.0	n/a
2	23 (38.3)	6.3	5.9	6.3	5.7	<0.0001
3	32 (53.4)	4.6	4.3	4.2	5.3	<0.0001
Overall liking scores of cooked mantı						
Cluster	N (%)	Samples				Significance of sample (P-value)
		CC4	CC14	HHPC14	HHPC4	
1	21 (35.0)	5.6	5.4	6.0	6.2	<0.0001
2	23 (38.3)	4.2	4.8	4.7	3.3	<0.0001
3	16 (26.7)	2.5	2.6	3.2	3.6	n/a
Appearance liking scores of cooked mantı						
Cluster	N (%)	Samples				Significance of sample (P-value)
		CC4	CC14	HHPC14	HHPC4	
1	19 (31.7)	4.8	3.5	5.1	4.2	<0.0001
2	17 (28.3)	3.0	6.6	4.9	3.9	<0.0001
3	11 (18.3)	2.0	2.5	2.7	2.6	n/a
4	13 (21.7)	6.3	5.9	5.3	6.3	<0.0001
Taste scores of cooked mantı						
Cluster	N (%)	Samples				Significance of sample (P-value)
		CC4	CC14	HHPC14	HHPC4	
1	39 (65)	3.9 ^{a,b}	3.6 ^{a}	4.6 ^{b}	4.3 ^{a,b}	0.001
2	9 (15)	2.3	1.7	2.4	2.1	n/a
3	12 (20)	6.8 ^{a,b}	6.0 ^{a}	6.9 ^{b}	6.0 ^{a,b}	<0.0001
Texture scores of cooked mantı						
Cluster	N (%)	Samples				Significance of sample (P-value)
		CC4	CC14	HHPC14	HHPC4	
1	16 (26.7)	5.1	5.7	3.6	5.3	<0.0001
2	31 (51.7)	3.3	2.9	4.4	3.4	<0.0001
3	13 (21.6)	6.3	6.1	6.5	6.1	<0.0001

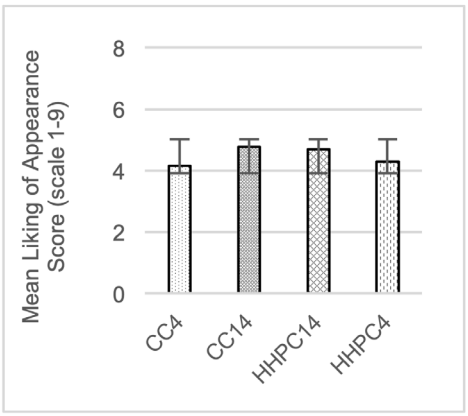
[1] CR4= semi-processed (dough treated with HHP, but with untreated filling) raw samples stored for 4 days; CR14= semi-processed raw samples stored for 14 days; HHPR4= high hydrostatic pressured raw samples stored for 4 days; HHPR14= high hydrostatic pressured raw samples stored for 14 days; CC4= semi-processed samples stored for 4 days served as cooked; CC14= semi-processed samples stored for 14 days served as cooked; HHPC4= high hydrostatic pressured samples stored for 4 days served as cooked; HHPC14= high hydrostatic pressured samples stored for 14 days served as cooked; n/a= ANOVA was not analyzed on these clusters due to their small size.

[2]Data was analyzed by one-way ANOVA for comparisons between mantı samples of within each cluster of consumers followed by Tukey's post hoc test. Different superscript letters within the same row indicate significant differences between mantı samples at $P < 0.05$.

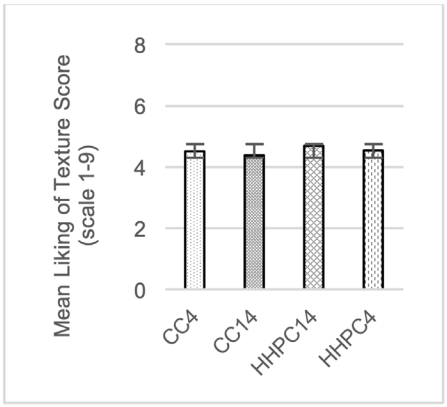
1A. Raw Mantı Appearance Liking



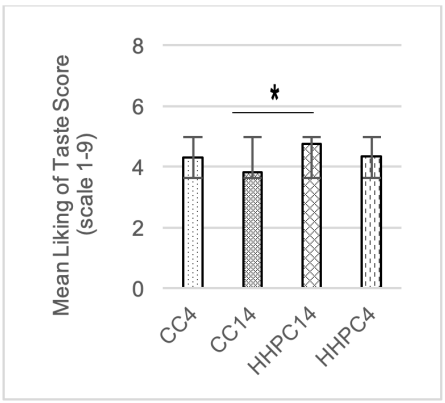
1B. Cooked Mantı Appearance Liking



1C. Cooked Mantı Texture



1D. Cooked Mantı Taste



1E. Cooked Mantı Overall Liking

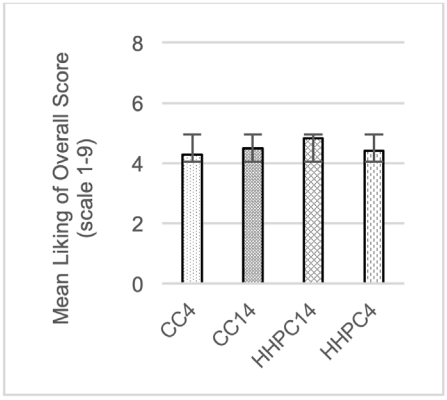


Figure 1. Mean liking scores for clusters of panelists following hierarchical cluster analysis of liking scores.[1,2]

[1] CR4= semi-processed (dough treated with HHP, but with untreated filling) raw samples stored for 4 days; CR14= semi-processed raw samples stored for 14 days; HHPR4= high hydrostatic pressured raw samples stored for 4 days; HHPR14= high hydrostatic pressured raw samples stored for 14 days; CC4= semi-processed samples stored for 4 days served as cooked; CC14= semi-processed samples stored for 14 days served as cooked; HHPC4= high hydrostatic pressured samples stored for 4 days served as cooked; HHPC14= high hydrostatic pressured samples stored for 14 days served as cooked.

[2] Values are means ± SD. * indicates significant difference at $P < 0.05$.

Conclusion

Combined use of HHP and MAP substantially improved the microbiological and sensorial parameters of both raw and cooked mantı samples compared to semi-processed and control untreated samples, and was extended refrigerated storage from 7 days to 14 days. However, the need for studying rheology of the HHP processed dough is apparent, in further studies. Because, for instance, while serving cooked mantı the important problem was filling material had come out of the dough. As a conclusion, when all data evaluated it can be said that the results can contribute to new processing conditions of high hydrostatic pressure and modified atmosphere packaging treatments.

Compliance with Ethical Standards

Conflict of interest

The authors declare that for this article they have no actual, potential or perceived the conflict of interests.

Author contribution

The contribution of the authors is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Not applicable.

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Data availability

Not applicable.

Consent for publication

Not applicable.

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