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PREVENTING OF PACKAGING EXUDATION IN FRANKFURTER SAUSAGES BY USING MODIFIED POTATO STARCH

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ABSTRACT
The effect of potato starch modified by pre-gelatinization on frankfurter sausage exudation level was investigated. This liquid exuded from the food product may have a negative impact in sensorial properties of packaged food as well as in its microbial quality for consumers acceptance. Modified potato starch caused a decrease in exudation formation vacuum-sealed packages of frankfurter sausages stored at +4 ^{0}C. The juice exuded into the package of the control group was higher than the other groups (P<0.05). Also, some quality characteristics of frankfurter sausages (color, pH, water activity, thiobarbituric acid reactive substance (TBARS), conjugated diene and free fatty acid (FFA) were analyzed during the storage period. Potato starch exhibited a high reducing hydrolysis activity in this study. As a result; it is advisable to use modified potato starch instead of normal potato starch to reduce or delay the exudation level in sausages.
Keywords: Frankfurter sausage, modified potato starch, exudation, TBARS, conjugated diene

MODİFİYE PATATES NİŞASTASI KULLANILARAK ÜRETİLEN FRANKFURTER SOSİSLERDE AMBALAJA SIZINTININ ÖNLENMESİ

ÖZ
Jelatinleşme öncesi modifiye edilmiş patates nişastasının frankfurter sosiste sızıntı düzeyine etkisi araştırıldı. Gıdalardan sızan bu sıvının, paketlenmiş gıdaların duyusal özelliklerinde ve ayrıca tüketicinin kabulü için ürünün mikrobiyolojik kalitesinde olumsuz bir etkisi olabilmektedir. Modifiye edilmiş patates nişastası, vakumlu frankfurter sosislerin depolanması sırasında ambalajda oluşan sızıntı miktarında bir azalmaya neden olmuştur. İstatistiksel olarak kontrol grubunun ambalajına sızan miktar diğer gruplardan daha yüksek olarak tespit edilmiştir (P<0.05). Ayrıca, frankfurter sosislerin (renk, pH, su aktivitesi, tiyobarbitürik asit reaktif madde (TBARS), konjuge dien ve serbest yağ asidi (FFA) bazı kalite özellikleri de depolama süresi boyunca analiz edilmiştir. Sonuç olarak, frankfurter sosislerde oluşabilecek sızıntı seviyesini azaltmak veya geciktirmek için normal patates nişastası yerine modifiye patates nişastası kullanılması tavsiye edilmektedir.
Anahtar kelimeler: Frankfurter sosis, modifiye patates nişastası, sızıntı, TBARS, konjuge dien

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INTRODUCTION

Oil-in-water (o/w) emulsions are dispersed systems composed of an oil phase dispersed in an aqueous phase. Dispersed phase molecules could be stabilized by the proteins, polysaccharides or emulsifiers. Such types of dispersions have a tendency to be thermodynamically unstable. Emulsion instability is linked to two physical processes. The first one is the increase the dimensions of the dispersed phase particles due to flocculation or coalescence; the other is the migration of particles leading to creaming or sedimentation. The visual effect of these processes is a clear phase separation of the emulsion (Dickinson, 2009; Pycia vd., 2018).

Modified starch is obtained through the physical, enzymatic, or chemical processing of starches and the alteration of some properties. The reason for the modification of starch is to improve the properties and performance for different applications. The starch is modified in order to exhibit changes in properties such as acidity, cooling time or freezing resistance, structure, viscosity, and gelatinization time. Modified starch is also used as a thickener, stabilizer or emulsifier in the field of food (Ölçer ve Akın, 2008).

Processed food products, such as meat or poultry, especially vacuum packaged frankfurter sausages are characterized by the generation of exudates during the storage time. This liquid exuded from the food product may have a negative impact on sensorial properties of packaged food as well as on its microbial quality. In this context, exuded liquid allows the proliferation of pathogens or spoilage microorganisms, since this exuded liquid acts as a media, which is rich in macro nutrients, such as carbohydrates, proteins and fats, and micronutrients, micro minerals and water-soluble vitamins that may be divided from food. Deterioration in appearance, bacterial spoilage, and loss of exudates are the main problems in the storage of sausages. The major disadvantages of vacuum package of sausages were compression of the sausage and high drip-loss. Blowing, souring, and formation of exudates were observed in vacuum-packed, frankfurter sausages and associated with high numbers of lactic acid bacteria (LAB), particularly homofermentative lactobacilli (Narasimha Rao ve Sachindra, 2002; Otoni vd., 2016).

Moisture drip absorber pads are commonly placed under packaged fresh meats, fish, and poultry to absorb unsightly tissue drip exudate but these pads are improper to use in vacuum packed sausages. In order to avoid this risk and preserve sensorial characteristics of packaged food products for consumers acceptance, some materials have been used widely by the food industry. Therefore, some materials such as fiber, carbohydrates, soya protein concentrate, soy protein isolate, precipitated milk protein (Na-caseinate), egg white proteins and modified starch can be used for preventing exudation. In this this study, it was aimed to investigate the effects of potato starch modified with pre-gelatinization method on the quality and technological properties of frankfurter sausage. 4% normal potato starch (unmodified) and modified potato starch were added to sausage prepared with beef and chicken meat, and the physical, chemical, and technological properties of the products especially amount of the exudation of the juice into package were examined.

MATERIALS AND METHODS

Materials

Normal potato starch (Migros, Istanbul), beef meat (including 20.36% protein, 4.24% fat, 73.77% moisture, 2.79% FFA, 5.52 pH), animal fat (0.76% FFA) and chicken meat (including 21.67% protein, 4.49% fat, 72.92% moisture, 6.45% FFA, 5.88 pH) were used in sausage production purchased from a local market in Samsun. The beef and chicken meats used were brought to the lab one day before and stored at 24 hours at + 4°C.

Formulation and Sausage Preparation

The formulations of beef and chicken meat sausage with normal (unmodified) potato starch or potato starch modified by pre-gelatinization are summarized in Table 1.

All subcutaneous and intramuscular fat and connective tissue were removed from meat. Meat and fat were ground through an 8 mm plate. Each batch of samples consisted of four (two meat, two chicken meat) meat batters, which differed, in their composition by adding modified and unmodified starch (4 %) (According to Turkish regulations, the level of starch in sausages should not exceed % 4 (Turkish Food Codex Meat, Prepared Meat Mixes and Meat Products Communique Regulation no 2018/522-30670). Four different types of frankfurter were formulated with salt, spices mix, and sodium nitrite (Table 1).

Table 1. Formulation of frankfurters

Ingredients	BC	BM	CC	CM
Beef (g)	2000	2000	-------	----------
Chicken meat (g)	0	0	2000	2000
Cattle fat (%)	20	20	20	20
Ice (%)	25	25	25	25
Unmodified starch (%)	4	0	4	0
Modified starch (PGS) (%)	0	4	0	4
Salt (NaCl) (%)	2	2	2	2
Spice mixture (%)	2	2	2	2
Nitrite ($NaNO_2$) (%)	0.015	0.015	0.015	0.015

BC: Beef control group (beef + normal potato starch), BM: Beef application group (beef + modified starch), CC: Chicken meat control group (chicken meat + normal potato starch, CM: chicken meat + modified starch); PGS; Pre-gelatinization modified potato starch; Spice mixture: white pepper, allspice, coriander, cloves, cinnamon, garlic powder, onion powder, mustard powder, phosphate (E450), ascorbic acid (E300), sodium ascorbate (E301), spice extracts.

Raw meat was homogenized and ground for 1 min in a cutter (MADO Typ MTK 662, Dornhan/Schwarzwald, Germany). NaCl (2.0 %) was then added to the meat mixture and mixed for 1 min. After mixing, the starch (4%), ice (25%), fat (20%), spices were added and batters were homogenized for 1 min. The emulsion was maintained at temperatures <10 ^{0}C and a temperature probe was used to monitor the temperature during this process. After emulsifying, meat batter was stuffed into plastic casing (30 mm diameter, Kalle Nalo Wursthüllen, Weisbaden Germany) using a stuffer (MADO Typ MTK 591, Dornhan/Schwarzwald, Germany). The frankfurters were then heated at 90 ^{0}C for 30 min in a water bath (Microtest Makine, İstanbul, Turkey). The cooked frankfurter was subjected to cooled water (5±1 ^{0}C) bath. Sausages were peeled and vacuum packaged (Multivac, Wolfertschwenden, Germany) then stored at 4 ± 1 ^{0}C for 60 days in refrigerator.

Methods

Chemical Analysis

Samples were diluted 10% with distilled water and homogenized (3000 rpm, 2 min), then pH values were measured with a pH meter (Starter 2100, OHAUS). Total moisture (%) contents were determined by heating at 105°C to a constant weight (AOAC, 2000). Protein quantities of sausage were determined at the beginning of storage according to the Kjeldahl method (AOAC, 2000). The amount of fat in the samples was determined at the beginning of storage using diethyl ether as solvent with the Soxhlet extraction system (AOAC, 2000). The Hunter *L**, a*, and b* values of the samples were determined by colorimetry (Colorflex EZ, USA). Water activity analysis was carried out at 25 ^{0}C using AQUALAB Dew Point Water Activity Meter (USA).

Modified Starch by Pre-gelatinization (PGS)
The Micro Visco Brabender Amylograph (model 8101, Brabender, Duisburg, Germany) was used to prepare modified starch samples with some modifications according to the method of Aktaş ve Gençcelep (2006). Slurries of normal (unmodified) potato starch (15 g of potato starch and 100 mL of water) were poured into the amylograph bowl and loaded into amylograph. The starch suspensions were uniformly heated from 30 to 95 ^{0}C, held at 95 ^{0}C for 3 min, and cooled to 40 ^{0}C. Gelatinized starch was dried at 40 ^{0}C and sieved from 212 μm (Aktaş ve Gençcelep, 2006)

Water and Oil Binding Capacity
Water and oil binding capacity were determined according to the method of Yousif vd. (2012) with a slight modification. 15 mL of distilled water was added to 1 g of the starch sample in a weighed centrifuge tube. The tube was agitated on a vortex mixer for 2 min, and then centrifuged at 6,000×*g* for 20 min. The clear supernatant was removed and discarded. Water binding capacity (WBC) is expressed as the weight in gram of water bound by 1 g of dried sample. For the oil binding capacity (OBC) determination, 15 mL refined corn oil was added to 1 g of starch sample in a weighed centrifuge tube. The tube was agitated on a vortex mixer for 2 min, and then centrifuged at 6,000×*g* for 20 min. The clear supernatant was removed and discarded. Oil binding capacity is expressed as gram of oil bound by 1 g dried sample.

Water Swelling Capacity of Starches
The water swelling capacity of starches was determined with the method by Lecumberri vd. (2007). Firstly, 1 g starch (M, weight) graded cylinder was placed and the volume (V1) was measured. Then, 10 mL of distilled water was added there, followed by agitation until a homogeneous dispersion was formed. The resulting dispersion was allowed to stand at room temperature for 24 hours, so that the powder could completely bind the water. After 24 hours, the volume (V2) of the wetted starch was measured and recorded. Water swelling capacity is calculated according to the formula (WSC) (ml/g)=(V2-V1)/M.

Water Solubility Index of Starches
Analysis of water solubility index of starch samples was determined at 10°C, 20°C, 30°C, 40°C, 50°C, 60°C and 70°C using the method of Anderson et al. (1969). 1% aqueous suspension (S1) of the starch sample was prepared in centrifuge tubes, and the suspension was heated in a water bath at the temperatures mentioned above for 1 h with constant stirring. The resulting mixture was centrifuged at 3.000×*g* for 10 minutes. The supernatant deposited on the surface was removed and the samples were dried at 105°C for 18 h and weighed (S_3). The water solubility index is calculated according to the formula (%) = $S_3/S_1 \times 100$.
(S_1): Sample weight

The Exudation of the Juice into the Package (JEP)
Determination of juice exuded into package samples, according to the method of Bloukas vd. (1997) with a slight modification. Storage period on the 1., 15., 30., 45. and 60th days, the sausage removed from the package was dried with a paper towel. It was weighed and recorded before and after the sausage was wipe dried. In the same way, the weights of the paper towels before and after dampening were weighed. This analysis was performed with 3 packet samples from each group. The exudation value in the package is calculated according to the following formula.

$X = (K2 - K1) + (M1 - M2)/2$
$JEP = X/M1 \times 100$
K1: Initial weight of paper towel
K2: Weight of paper towel after dampening
M1: Weight of sausage sample before wipe dried
M2: Weight of sausage sample after wipe dried
JEP: Juice exuded into the package (%)

Analysis of Conjugated Diene
The formation of conjugated dienes was determined as described by Juntachote vd. (2007). For this purpose, 3 g sausage sample was mixed with 30 mL distilled water and a suspension was formed. Then 0.5 mL of this mixture was taken

and mixed with 5 mL of hexane: isopropanol (3:1) and centrifuged at 2,000×*g* for 5 minutes. At the end of the centrifugation, the absorbance of the upper phase at a wavelength of 233 nm was measured. The absorbance read is expressed as the conjugate diene value (Juntachote et al., 2007).

Thiobarbituric Acid Reactive Substances (TBARS)
To determine the TBARS values, a sample of 10 g sausage was weighed, and 25 mL of 20% trichloroacetic acid (TCA) and 20 mL of purified water were added followed by homogenization for 2 minutes using Ultra Turrax (10,000 rpm). The resulting mixture was filtered through Whatman No: 1 filter paper and 5 mL of filtered capped tubes was removed from the filtrate. The cover was closed by adding 5 mL of 0.02 M TBA (2-thiobarbituric acid) solution and shaken. The shaken tubes were kept in boiling water bath at 93 ºC for 30-35 minutes, then cooled in tap water for 10 minutes and transferred to spectrophotometer tubes to read the absorbance value against the probe at 532 nm wavelength. The absorbance values read were multiplied by a factor of 7.8 and the TBARS values was determined as mg malonaldehyde equivalent substances / kg as an example (Lemon, 1975).

Free Fatty Acids (FFA)
Free fatty acids were determined by according to the Gökalp vd. (1995). 5 g of sample weighed and add 50 mL of a mixture of diethyl ether: ethanol (1:1, v/v) were added to sample. Mixture was stirred for 1 min to dissolve the fatty acids. Mixture was titrated with 0.01 M ethanolic NaOH until a permanent pink color was obtained (at least 15 seconds). The amount of free fatty acid was calculated as the oleic acid.

Statistical Analysis
The data of the study were subjected to variance analysis using the package program, and the sources of variation that were significant in terms of statistics were compared with the Duncan multiple comparison test (SPSS, 2008).

RESULTS AND DISCUSSION
Dependent variables tested for monitoring the effect of functional ingredients on the technological properties directly related to the exudation and quality of beef and chicken meat emulsions were classified as water activity (a_w), color parameters (*L**, *a** and *b**), pH, TBARS, FFA and juice exuded into the package (JEP %).

Mean values of variance analysis results of pH, moisture, water binding capacity (WBC), oil binding capacity (OBC), and water swelling capacity (WSC) of normal (unmodified) potato starch and modified potato starch are given in Table 2, and the results of the water solubility index (WSI) are shown in Table 2. The water binding capacity, oil binding capacity, and water swelling capacity values determined in starch samples were statistically different *(P<0.05).* Modified starch has also been found to have higher oil binding capacity and binding/swelling capacity (at room temperature). The stabilizing effect of modified starches in emulsions is related to their high electrical charge and having more hydrophilic–lipophilic groups within structure, which increase the lipid and water interactions (Alamanou vd., 1996). These groups form a charged layer round fat droplets, causing mutual repulsion, reducing interfacial tension and preventing coalescence. With the modification of starch, technological properties have changed. Similar results were found by Aktaş ve Gençcelep (2006).
As the temperature increased, the water solubility index of the modified starch was measured higher than the normal starch. This could be as a result of the ability of modified starch to form complexes with water that improves water retention. The result of modification could bind more water because of the hydrophilicity groups. Pre-gelatinized modified potato starch performs well in high moisture foods, such as in meat-emulsified products like sausaas the water solubility index, water swelling capacity, water and oil binding properties are much better than normal starch (Table 2). This structure easily reabsorbed most of the extruded water if the water separation was too slow (Table 4).

Table 2. Some composition analysis and water solubility index (WSI) results of normal and modified starches.

Analysis	NPS	MPS
pH	6.44±0. 07^{a}	5.96± 0.02^{b}
Moisture (%)	14.86±0.55^{a}	7.92± 0.46^{b}
Fat (%)	0.20±0.01^{a}	0.28±0.01^{a}
Protein (%)	0.08±0.01^{a}	0.03±0.01^{b}
Ash (%)	0.28±0.01^{a}	0.28±0.01^{a}
WBC	0.846±0.065^{b}	5.665±0.417^{a}
OBC	1.034±0.073^{b}	1.414±0.040^{a}
WSC (mL/g)	0.082±0.020^{b}	5.242±0.027^{a}
L*	93.01±1.07^{a}	91.10±1.25^{a}
a*	-0.1±0.36^{a}	0.22±0.09^{a}
b*	4.25±1.27^{a}	3.52±0.17^{a}
	Water solubility index (WSI)	
Temperature (°C)	%	%
10	1.59±0.14^{eB}	2.57±0.31^{gA}
20	1.67±0.14^{eB}	6.77±1.62^{fA}
30	2.65±0.15^{dB}	8.13±0.47^{eA}
40	3.66±0.43^{cB}	10.19±0.62^{dA}
50	4.01±0.60^{cB}	11.56±1.01^{cA}
60	10.31±1.54^{bB}	14.66±1.06^{bA}
70	13.97±1.82^{aB}	19.13±0.83^{aA}

Values are means ± standard deviation. $^{a-b}$: Means on the same line with different letters are different (P<0.05). NPS: Normal (unmodified) potato starch. MPS: Modified potato starch. WBC: Water binding capacity. OBC: Oil binding capacity. WSC: Water swelling capacity.
$^{a-e}$: Means on the same column with different letters are different (P<0.05) in water solubility index. $^{A-B}$: Means on the same line with different letters are different (P<0.05) in water solubility index.

Table 3. The chemical compositions and colour values (*L**, *a** and **b*) of frankfurter sausages

Samples	Moisture (%)	Protein (%)	Fat (%)	L*	a*	b*
BC	63.75±0.72^{a}	13.43±0.15^{a}	14.01±0.94^{a}	44.83±1.50^{a}	14.99±0.56^{ab}	16.14±0.72^{a}
BM	63.20±0.91^{a}	12.67±0.07^{ab}	14.94±0.73^{a}	44.83±1.41^{a}	15.57±0.42^{a}	16.28±0.41^{a}
CC	64.56±0.16^{a}	14.12±0.94^{a}	12.77±0.83^{b}	62.96±1.53^{a}	14.48±0.23^{ab}	22.30±0.46^{b}
CM	63.89±0.08^{ab}	13.86±0.28^{ab}	13.56±0.50^{a}	62.30±1.71^{a}	14.98±0.30^{a}	24.16±0.33^{a}

Values are means ± standard deviation. $^{a-c}$: The difference between the values with different exponents in the same column is significant for each product types (P <0.05). BC: Control group (beef + normal potato starch), BM: (beef + modified potato starch), CC: control group (chicken meat + normal potato starch), CM: (chicken meat + modified potato starch).

When the values were examined, the moisture content of the sausage was found to vary between 63.20% and 64.56%. There was no statistical difference between sausage control and application groups (P>0.05). Purma (2006) found that the content of moisture changed between 55.3-56.3% and statistically no significant difference (P>0.05) was found between the samples in the study of the dried apricot pulp in sausage production. It was determined that the protein content of sausage changed between 12.67 and 14.12%, the highest amount of protein was in CC and the lowest amount of protein was in BM group. The amount of protein was determined lower in products produced by adding modified starch. This result is probably related to the different protein content in starch. It was determined that the fat contents of sausage changed between 12.77 and 14.94% (Table 3), the highest amount of fat was found in the BM group and the lowest amount of fat was in the CC group (Table 3).

There was no significant difference in the brightness (L^*) values between each chicken groups and beef groups (P>0.05). The mean redness (a^*) values were found different in all groups (Table 3). There was statistically significant difference between the CC and CM groups ($P<0.05$) in the values of yellowness (b^*), but there was no statistically difference between the BC and BM group (P>0.05). The color values of sausage made with chicken meat were found to be quite different from those of beef sausage. The reason is that the amount of myoglobin in chicken meat is lower than the amount of it in beef (Turp, 1999). The result is lighter colored products. The effect of meat difference was also determined in sausages' a^* and b^* values. Ayo vd. (2008) found that the addition of walnuts did not have a significant effect on the L^* value of sausages, but a significant increase in the values of a^* and b^*. L^*, a^* and b^* values of high and low-fat control sausages were found very close to each other and they obtained the result that the amount of fat did not affect the color parameter.

Table 4. Analysis results of frankfurter sausages during the storage periods

Sample type	pH	JEP (%)	aw	Conjugated diene	TBARS (mg MA/kg)	FFA (%)
BC	6.30±0.11^{a}	0.76±0.287^{a}	0.976±0.006^{a}	0.433±0.118^{a}	0.669±0.268^{b}	2.21±0.31^{a}
BM	6.27±0.11^{b}	0.56±0.065^{b}	0.970±0.007^{b}	0.398±0.108^{ab}	0.870±0.314^{a}	1.88±0.18^{b}
Significance	**	**	**	**	**	**
Storage period (day)						
1	6.16±0.017^{d}	0.45±0.10^{b}	0.969±0.007^{b}	0.240±0.039^{c}	0.626±0.043^{b}	1.87±0.18^{b}
15	6.18±0.023^{d}	0.64±0.08^{ab}	0.979±0.003^{a}	0.382±0.016^{b}	0.607±0.153^{b}	1.84±0.28^{b}
30	6.39±0.019^{b}	0.62±0.06^{ab}	0.974±0.007^{ab}	0.418±0.060^{b}	0.633±0.160^{b}	2.04±0.08^{ab}
45	6.29±0.027^{c}	0.82±0.355^{a}	0.970±0.011^{ab}	0.510±0.038^{a}	0.892±0.495^{ab}	2.19±0.23^{ab}
60	6.42±0.021^{a}	0.76±0.22^{a}	0.973±0.001^{ab}	0.528±0.031^{a}	1.091±0.193^{a}	2.30±0.42^{a}
Significance	**	**	**	**	**	**
CC	6.28±0.12^{a}	0.63±0.128^{a}	0.973±0.005^{a}	0.389±0.153^{a}	0.601±0.162^{a}	3.25±0.32^{a}
CM	6.23±0.13^{b}	0.57±0.064^{ab}	0.969±0.007^{a}	0.388±0.143^{a}	0.652±0.153^{a}	3.12±0.25^{a}
Significance	**	**	NS	NS	NS	NS
Storage period (day)						
1	6.11±0.033^{d}	0.45±0.070^{b}	0.968±0.004^{b}	0.234±0.039^{c}	0.540±0.071^{b}	2.93±0.201^{b}
15	6.12±0.028^{d}	0.60±0.081^{a}	0.969±0.008^{b}	0.251±0.031^{c}	0.526±0.026^{b}	2.98±0.047^{ab}
30	6.37±0.037^{b}	0.65±0.074^{a}	0.972±0.004^{ab}	0.371±0.047^{b}	0.572±0.167^{b}	3.35±0.135^{a}
45	6.25±0.031^{c}	0.64±0.074^{a}	0.978±0.008^{a}	0.515±0.060^{a}	0.617±0.055^{b}	3.31±0.467^{ab}
60	6.41±0.021^{a}	0.64±0.098^{a}	0.969±0.005^{b}	0.571±0.030^{a}	0.879±0.067^{a}	3.39±0.156^{a}
Significance	**	**	**	**	**	**

Values are means ± standard deviation. **P<0.01; $^{a-e}$: The difference between the values with different exponents in the same column is significant for each product types (P<0.05). BC: Control group (beef + normal potato starch), BM: (beef + modified potato starch), CC: control group (chicken meat + normal potato starch), CM: (chicken meat + modified potato starch). JEP: Juice exuded into the package; NS: not significant.

Starch modification had a significant effect on pH, JEP, a_w, conjugated diene, TBARS, and FFA in meat frankfurter sausages (Table 4). In chicken frankfurter sausage, starch only had an effect on pH ($P<0.05$). The presence of pre-gelatinization modified potato starch in the beef and chicken emulsion formulation was found to have a statistically significant ($P<0.01$) effect on pH, JEP, aw, conjugated diene, TBARS and FFA values of samples during storage time. When the test results of the averages of the pH values of sausage were examined, the mean pH values of the control groups (BC and CC) was effect to be statistically different from the mean values of BM and CM groups ($P<0.05$).

Control (BC and CC) groups were found to have higher pH values. This may be explained by the fact that the pH value of the normal starch used in the manufacture of control group sausage was higher than the pH value modified starch (Table 2). In Table 4, pH value showed a decrease on the 45th day of storage and increased again on the 60th day both meat and chicken frankfurter sausage. It is thought that this change in the pH values of the 45th day is due to the partial disruption of the proteins to the amino acids and the fatty acids to free fatty acids. However, this effect has not been observed in later stages of storage. When the pH values of all samples were examined, it was found that the pH values tended to increase during storage. During cold storage of emulsified type meat products such as sausage, lactic acid bacteria multiply and decrease pH (Ertaş ve Karabaş, 1998; Şişik, 2008). In this present study, the pH drop was not achieved when compared with other research results. This result is probably regarded to the effect of basic character substances in the structure. Cooked meat products also typically exude a liquid composed of water, fat and protein, which drips to the vacuum packaged sausage in the refrigerator. This liquid accounts for most of the weight lost during the storage and represents a loss of a marketable product, which is not sold and it can also create a sanitation or microbiological development problem in vacuum packed sausages.

As can be observed in Table 4, a high capacity to hold juice exudates was obtained in modified starch sausages. The exudation of the control groups to the package was found to be statistically different from the mean of BM and CM groups ($P<0.05$). Control (BC) group was found to have a higher exudation percent. Even though modified starch exhibited the lowest exudation loss (0.56%) in comparison with the control (0.76%) in meat frankfurter sausage, JEP (%) values were similar in chicken group statistically. Juice exuded into the package was increased during the storage period of sausages (Table 4). Despite the high percent loss of juice, moisture, the water activity levels remained close to those of the other formulations. During the storage period, the data of the percent of juice exuded into the package in control sausages found that was 0.45% to 0.82% in meat frankfurter and 0.45% to 0.65% in chicken frankfurter for which there was the significant difference between the means. Grizotto vd. (2012) reported that the values found for the percent loss of juice exuded in the package that was 1.24% to 1.42%, for which there was no significant difference between the means either in the study using okara flour at the different ratio (1.5%-4%).

During storage, the lower JEP value than meat frankfurter was determined in chicken frankfurter. This can be explained by protein proportion found in chicken sausages (Table 3). The amount of water held in foods increases as the protein content increases. This can be explained as the rate of water solubility index, water and oil binding capacity and water swelling capacity of modified starch were more than normal starch (Table 2). Also, amylopectin may govern the interactions between water and pregelatinized starches. It has stabilizing effects, whereas amylose forms gels and has a strong tendency to form complexes with lipids and other components (Hermansson ve Svegmark, 1996). While potato starch has about 72–75% amylopectin, and phosphate groups covalently linked to amylopectin in potato starch increase its hydrophilic nature.

The highest levels of exudation occurred in the control sausage (BC and CC) compared to modified potato starch (Table 4). This indicates that modified potato starch has better hydration/binding properties. Modification might increased these interactions. Water can bind to starch and its modified derivatives by capillary effects, hydrogen bonds, ionic bonds and/or hydrophobic interactions, and by surface tension in the pores of the matrix (Colmenero vd, 2005; Thebaudin vd, 1997). Alamanou vd. (1996) and Hughes vd. (1997) also observed that increasing the percentage of added hydrocolloid reduced total expressible fluid. This might be attributed to the better absorption by modified starches of the water added during formulation. The stabilizing effect of modified starches in emulsions is related to their high electrical charge and having more hydrophilic–lipophilic groups within the structure, which increase the lipid and water interactions (Alamanou vd. 1996). These groups form a charged layer round fat droplets, causing mutual repulsion, reducing interfacial tension, and preventing coalescence. The extent of hydration may have increased due to starch gelatinization as starch-water systems heated to higher temperatures released less water suggesting that more water molecules are absorbed into the polymer matrix after subjecting it to the higher temperature. Previous studies (Tananuwong ve Reid, 2004) have shown a significant reduction in granule crystallinity at higher temperatures. As the granule structure becomes increasingly disrupted, more starch polymers, especially amylopectin, disentangle, which exposes more hydroxyl groups to water, resulting in increased starch–water interactions. Sausages in packages produced with modified starch and containing modified starch had lower drip loss than the normal starch using in sausages.

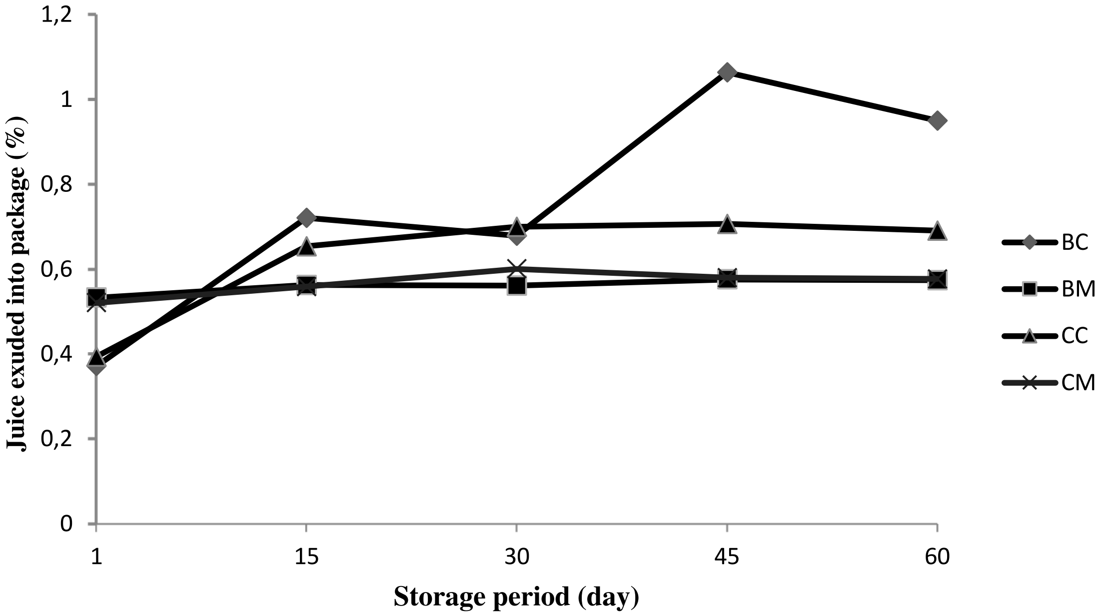

Fig. 1. Sausage samples on the values of leakage in the package x the effect of the storage time interaction

As can be understood from Fig. 1 (sausages and storage time interaction), on the first day of storage, the control group (BC and CC) showed a lower JEP (juice exuded into the package) rate than the sausages application group but showed faster JEP as storage time progressed. During the storage period of sausage, the average juice exuded into the package with beef meat, which was 0.45% on the first day of production, increased to 45 days (0.76%). These values in chicken meat were found between 0.45-0.64. On the 60th day of the storage period in all groups, it showed a slight decrease. It was determined that the control group (BC and CC) was higher in sausages after the 15th day of the storage period of the JEP value. The juice exuded into the package of sausage samples produced with normal starch during storage was higher than sausage samples produced using modified starch and these differences were found statistically significant ($P<0.05$). Claus ve Hunt (1991) 3.5% reported that wheat starch and modified corn starch reduced the juice exuded into the package level. In the study of the use of extruded wheat flour in the production of sausages, the fat rate and extruded wheat flour on the value of juice exuded into the package of sausages were determined to be effective Uysal (2011) ($P<0.05$).

According to the test results of averages of water activity (aw) values given in Table 4, the mean aw values of the BC and CC control groups were higher than the mean values of the BM and CM group frankfurters. This difference was statistically significant in beef frankfurter group ($P<0.05$).

The conjugate dienes determined during storage of sausage were examined, the number of conjugate dienes increased from 0.240 on the first day of production as the storage time progresses in meat sausages, and the increase after the 30th day was further accelerated. In the study of Sağır (2011), it was determined that the number of conjugated dienes in all of the products was increased regularly during storage (180 days). Conjugated diens were determined as 0.41-0.46 (μmol/mg) at the beginning of storage and as 0.81-0.90 (μmol/mg) at the end of storage.

There was a statistically significant difference ($P<0.05$) between the BC group and BM, but no significant difference between CC and CM groups ($P>0.05$).

As can be seen table 4, the lowest TBARS value of meat sausage was determined at 15th day and the difference between 30th day and 1st day was not statistically significant ($P>0.05$). After day 30, the TBARS value of sausage was increased and the highest TBARS value was determined at 1.091 to 60 days. In chicken meat sausages, no results were found different from 1st to 45th days. Şişik (2008) found that the use of corn oil and broccoli on sausage production the TBARS value increased in all groups as storage time progressed. In researches carried out by Ertaş and Karabaş (1998) and Bloukas and Paneras (1997) it has been reported that the TBA values of frankfurters produced using both vegetable oils and animal fats increased along with the storage time. In the study conducted by Wilfred Ruban vd. (2008) the TBARS values of sausage during storage for 30 days at 4ºC increased with storage time from 0.22 to 1.14 mg MA/kg.

As the free fatty acid values of sausage given in Table 4 were examined, the mean FFA value of the control group of beef group sausage was found to be statistically different from the mean of the BM group ($P<0.05$). This may be due to the fact that raw potato starch hydrolysates have high anti hydrolysis activity and could be used as a food antioxidant agent (Wu vd., 2017). Nieto vd. (2009) investigated the effect of potato protein hydrolysate on oxidation reactions in meat emulsions and reported that 2.5% of the hydrolysate added to the mixture reduced TBARS value (9.55 mg MDA/kg in the control sample, 3.19 mg MDA/kg in the hydrolysis potato starch sample). There was no statistically significant difference ($P>0.05$) between the chicken meat group sausage of control group (CC) and the CM group. As indicated in Table 4, the FFA value has continuously increased as the storage duration progresses. The FFA values increased significantly ($P<0.05$) in all of the sausage groups till the 60th day of storage. The FFA (%) values on days 1, 15, 30 and 60 were similar in beef sausages ($P>0.05$). The FFA value rose to 2.30% at the highest 60th day. Zalacain et al. (1996) have identified the amount of FFA in the final product as 3.31g oleic acid/100 g fat in traditional dry fermented sausages produced by adding *L. plantarum* and *S. carnosus*. Jezek ve Korobova (2016) found that selected cooked sausages FFA amount from 1.40 to 3.31% as oleic acid in the Czech Republic. In this study, the FFA amounts were found lower than other similar studies. Chicken meat group (CC, CM) had a higher mean FFA value than beef group sausage (BC, BM). This may be due to the fact that the FFA value of chicken meat from raw materials used in production is higher than the FFA value of beef. It might be due to the presence of unsaturated fatty acid in chicken meat than beef because unsaturated fat is more prone to hydrolysis. Free fatty acids content in both group sausages increased with storage study, but the values remained in the acceptable limit (maximum 4%).

Exudation reduces flavor, texture, microbiological quality and nutrient quality, thereby reducing consumer's acceptance of the product. Pre-gelatinization modified starch sausages showed a high capacity to hold water and fat exudates and consequently, had the highest emulsion stabilization parameters. Incorporation of modified starches into a meat batter improved the emulsion stability and reduced the exudation rate, probably due to the formation of a more stable complex. The water solubility index, water swelling capacity, water and oil binding properties of modified starch are much better than normal starch. This structure easily reabsorbed most of the exuded water if the water separation was too slow during the storage period. The addition of modified starch significantly decreases the exudation value both meats types of sausages. From the results of exudation, we concluded that modified potato starch is better than normal potato starch for meat and chicken sausages. Also, modified starch was affected the FFA values. The use of pre-gelatinization modified starch did produce significant changes in lipid oxidation levels in beef sausages in comparison with normal potato starch sausages excluding conjugated diene values. However, modified starches can be successfully used to control juice exuded into the package properties of meat batters. These results suggest that the addition of pre-gelatinized potato starch at 4% will have a positive effect on the quality of stored the heat-treated sausage stored at + 4 °C. Pre-gelatinized modified potato starch is suitable in high moisture foods, like emulsified meat products such as bologna type sausages and frankfurters.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of İnterest regarding the publication of this article.

AUTHOR CONTRİBUTİONS

Hüseyin Gençcelep is a Supervision (Organising and supervising the course of the project and writing the article and taking the responsibility). Maliyanmu Saimaiti is a Data Collection and Processing (Taking responsibility in execution of the experiments, data management and reporting)

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