

Mass transfer and microbiological profile of pork meat dehydrated in two different osmotic solutions

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Abstract

The effects of osmotic dehydration on mass transfer properties and microbiological profile were investigated in order to determine the usefulness of this technique as pre-treatment for further treatment of meat. The process was studied in two solutions (sugar beet molasses, and aqueous solution of sodium chloride and sucrose), at two temperatures (4 and 22 °C) at atmospheric pressure. The most significant parameters of mass transfer were determined after 300 min of the dehydration. The water activity (a_w) values of the processed meat were determined, as well as the change of the microbiological profile between the fresh and dehydrated meat. At the temperature of 22 °C the sugar beet molasses proved to be the most suitable as an osmotic solution, despite the greater viscosity.

Keywords: osmotic dehydration; pork meat from shoulder blade; mass transfer; sugar beet molasses; microbiological profile.

Available online at the Journal website: <http://www.ache.org.rs/HI/>

SCIENTIFIC PAPER

UDC 66.093.48:637.564

Hem. Ind. 66 (5) 743–748 (2012)

doi: 10.2298/HEMIND120130033F

Water is one of the main constituents of fresh meat and plays a key role in many aspects related with its physicochemical, sensory and technological properties [1].

Many traditional techniques and their combinations, such as salting, drying, cooking, smoking and marinating, are used to prevent spoilage of meat and its products by reducing water content. A common step in these processes is placing product (meat) in contact with a concentrated solution (salt, sugar, acids, seasonings, etc.) [2].

Osmotic dehydration (OD) is an environmentally acceptable, material gentle drying method, which received considerable attention due to the low processing temperature, waste material and low energy requirement [3,4].

OD is a water removal process, based on soaking food (fruit, vegetable, meat and fish) in a hypertonic solution. In comparison to other drying treatments main advantages of OD process are water is removed in liquid form, at mild temperatures and osmotic solution can be reused [5,6].

Recent research has shown that use of sugar beet molasses as a hypertonic solution improves OD processes [7]. Sugar beet molasses proved to be excellent as the OD medium due to the high dry matter (80%) and specific nutrient content. Using sugar beet molas-

ses as hypertonic solution is an important part of the food material enrichment in minerals and vitamins, which penetrate from molasses into the plant tissue [8,9]. The presence of complex solute compositions maintains a high transfer potential favorable to water loss, and at the same time by the presence of sugar, salt impregnation is hindered [10]. High salt concentrations decrease the water holding capacity, which contributes to meat dehydration and shrinkage while there is no swelling of muscle fibers or myofibrils [11,12].

Due to its nature as perishable food product, it is important to appropriately store, process, package, and distribute meat as it spoils quickly and becomes hazardous due to microbial growth. Microbial meat contamination is mostly influenced by the conditions prior and subsequent to animal slaughter, meat handling, as well as storage conditions [13].

In literature, although there is a lot of information about OD of plant material, but there is a little information available about OD of meat and none about OD of meat in molasses. Preliminary sensory analysis has shown that meat processed in this manner had satisfactory sensory characteristics.

By processing pork meat from the shoulder blade by means of OD, the initial microbiological profile of the pork meat should be improved due to increasing dry matter content and lowered a_w value of the processed meat.

The objective of this research was to examine the influence of two different osmotic solutions at two different temperatures on the efficiency of OD process characterized by mass transfer and microbiological pro-

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Paper received: 30 January, 2012

Paper accepted: 20 March, 2012

file of the fresh pork meat as a validation of the process efficiency and safety.

EXPERIMENTAL

Fresh pork meat from the shoulder blade was purchased at the local butcher shop in Novi Sad, shortly prior to the experiment. The initial moisture content of the fresh meat was 72.83%. Prior to the treatment, all working areas and tools were thoroughly washed, cleaned and disinfected with pharmaceutical ethanol (70 vol.%). Fresh meat was cut into cubes dimension of approximately 1 cm×1 cm×1 cm. An aqueous osmotic solution (AOS) of sodium chloride and sucrose was made from commercial sucrose and NaCl in the quantities of 1200 and 350 g/kg of distilled water, respectively. Sugar beet molasses was obtained from the sugar factory Pećinci, Serbia. The initial dry matter content in sugar beet molasses was 85.04%. In all experiments, a weight ratio of solution to meat sample of 5:1 was used, which can be considered high enough to neglect the concentration changes during the process. Every 15 min, the meat samples in osmotic solutions were stirred to remove quantities of water that diffused from the center of the meat cube to its surface and allowing better homogenization of the osmotic solutions. The conditions of homogenization (intensity, duration and frequency of stirring) were the same for both osmotic solutions at both temperatures, so the results could be comparable.

The experiments were conducted under atmospheric pressure at temperatures of 4 and 22 °C, during 5 h. After the process of OD, the meat samples were washed with sterilized water and gently blotted to remove excessive water. The meat samples were weighed and part of the samples were kept in an oven (Instrumentaria Sutjeska, Croatia) at 105 °C until constant weight was attained, and dry matter content calculated from the samples weights before and after drying. Values of dry matter content (DMC), water loss (WL), and solid gain (SG) were calculated as described by Mišljenović *et al.* [14], and presented as a mean value and standard deviation of 6 parallel runs.

Viscosities of both osmotic solutions, prior and after the process of OD and at both temperatures was measured by an Oswald viscosimeter. The values of molasses viscosity were out of reach of the method's range. Literature data [15] was cited.

Analysis of variance (ANOVA) was performed using StatSoft Statistica v10 for Windows software.

Water activity (a_w) of the osmotically dehydrated samples was measured using a water activity measurement device (TESTO 650, Germany) with an accuracy of ± 0.001 at 25 °C.

Determination of the *Salmonella* spp., *Escherichia coli*, the total number of bacteria and *Enterobacteriaceae* was done by the SRPS EN ISO 6579 [16]; SRPS ISO 16649-2 [17]; SRPS EN ISO 4833 [18] and the SRPS ISO 21528-2 [19], respectively.

RESULTS AND DISCUSSION

Based on mass transfer and microbiological profile, the efficiency of the OD process in different osmotic solutions and at different temperatures of the meat was evaluated.

DMC of the fresh pork meat was $26.20 \pm 1.67\%$, and the results of the DMC obtained in the process of OD were varying from 52.85 ± 1.76 to $56.38 \pm 0.83\%$. The data of the WL obtained in the process of OD of the pork meat were between 0.3590 ± 0.0042 and 0.4261 ± 0.0145 g/g i.s (Table 1).

ANOVA has showed the same trends for the examined values of DMC and WL. There was no significant statistical difference ($p < 0.05$) between values of DMC or WL of the meat dehydrated in AOS at 4 °C and the meat dehydrated in molasses at 4 °C. Also, there was no significant statistical difference between value of DMC or WL of the meat dehydrated in AOS at 22 °C and the meat dehydrated in molasses at 22 °C, but there was significant statistical difference between values of DMC or WL in meats dehydrated in the same osmotic solution but at different temperatures.

This indicates that temperature has a significant influence, while the nature of the osmotic solution does not have a significant influence on the DMC or WL of the osmotically dehydrated meat.

Table 1. Average values and standard deviations of dry matter content (DMC), water loss (WL), solid grain (SG) and WL/SG ratio of the dehydrated meat

Parameter	Fresh meat	Meat dehydrated in AOS		Meat dehydrated in molasses	
Temperature of the process, °C	–	4	22	4	22
Dry matter content, %	26.20 ± 1.67^a	52.97 ± 0.64^b	55.73 ± 1.02^c	52.85 ± 1.76^b	56.38 ± 0.83^c
Water loss*, g/g i.s.	–	0.3739 ± 0.0084^a	0.4261 ± 0.0145^b	0.3590 ± 0.0042^a	0.4212 ± 0.0182^b
Solid gain*, g/g i.s.	–	0.1239 ± 0.0211^a	0.1348 ± 0.0074^a	0.1341 ± 0.0328^a	0.1329 ± 0.0141^a
WL/SG ratio	–	2.86 ± 0.71	2.98 ± 0.81	3.16 ± 0.16	3.43 ± 0.42

^{abc} Different letters in the superscript in the same row indicate significant statistical difference between the values, at level of significance $p < 0.05$;

*mass in grams of WL or SG per mass in grams of initial sample

Values of the SG in the pork meat after the OD were similar regardless of the osmotic solutions and temperatures, and varied from 0.1239 ± 0.0211 to 0.1348 ± 0.0074 g/g i.s. ANOVA has showed that there was no significant statistical difference between values of SG in any sample of dehydrated meats.

From the results for DMC, WL and SG for meat dehydrated in the AOS at 22 °C and molasses at 22 °C, the slight inconsistency of the material balance is evident (mean value of the DMC for the meat dehydrated in AOS at 22 °C is lower than the value of DMC for the meat dehydrated in molasses at 22 °C, while WL and SG mean values are higher for the meat dehydrated in AOS than in molasses). The inconsistency may be the result of the grouping of series of individual values of DMC, WL and SG, from which mean values and standard deviations were derived. By paring mean values of these parameters, slight inconsistency occurs which is noticeable from the difference of the third decimals of WL and SG.

The efficiency of process of the OD was evaluated according to the ratio of WL/SG. Higher values indicate that the process is characterized by higher WL and lower SG, which are favorable. The data presented in Table 1 shows that higher temperatures of the process positively contribute to higher WL/SG ratio in AOS and molasses (WL/SG of 2.98 ± 0.81 at 22 °C in comparison to 2.86 ± 0.71 at 4 °C in AOS, and 3.43 ± 0.42 at 22 °C in comparison to 3.16 ± 0.16 at 4 °C in molasses). Also, the meat dehydrated in molasses had higher WL/SG ratios at the corresponding temperatures in comparison to the meat dehydrated in AOS.

Values of viscosity of the osmotic solutions prior and after OD at both temperatures are shown in Table 2. Values of viscosity of osmotic solutions are highly influenced by temperature, dilution due to the water diffusing from the meat during the process of OD and nature of the osmotic solution. Values of viscosity for the molasses were much higher (even out of range of the applied method of determination) at both temperatures than the values of viscosity of AOS. The reduction of viscosity of the molasses after the process of OD is much greater than the reduction of the viscosity of the AOS (approximately 100 times for molasses, and 2.3 to 2.5 times for AOS).

The average a_w values and standard deviation of the fresh and dehydrated meat in AOS and molasses at 4 °C

and 22 °C are shown in Table 3. Start value of the fresh meat was 0.936 ± 0.01 . It is obvious that process of osmotic dehydration lowered the a_w values of the meat. Meat dehydrated in AOS achieved lower a_w values (0.850 ± 0.003 and 0.841 ± 0.004 at 4 and 22 °C, respectively) in comparison to the meat dehydrated in molasses (0.875 ± 0.025 and 0.871 ± 0.031 at 4 and 22 °C, respectively). Increase of the temperature exerted positive influence on the lowering a_w value of the meat dehydrated in both osmotic solutions.

Very complex composition of molasses, which via solid gain is incorporated in the dehydrated meat, has changed chemical composition of dehydrated meat in much greater extent than the chemical composition of dehydrated meat in AOS. Activity of the present water in dehydrated meat is affected by this complex composition [20], and leads to the inconsistency of the a_w values of meat dehydrated in molasses in comparison to the meat dehydrated in AOS at both temperatures.

Achieved a_w values of the meat dehydrated in both osmotic solutions were lower than a_w values that inhibit growth of the most microorganisms except molds [21].

Microbiological analysis of the fresh and dehydrated meat is presented in Table 4. None of the analyzed samples showed traces of *Salmonella* spp. This indicates that the produced dehydrated semi-product from meat is in accordance with the requirements for food safety criteria of the Serbian National Regulation [22].

The total number of bacteria in the fresh meat cut and prepared for the osmotic dehydration in laboratory was 466667 ± 57735 CFU/g (Table 4).

ANOVA has showed that there was significant statistical difference between the total number of bacteria in all dehydrated meats and the fresh meat, but there was no significant statistical difference between the total number of bacteria in the meat dehydrated in both osmotic solutions and at both temperatures of the process. This indicates that the process of OD has a significant influence on lowering total number of bacteria in the osmotically dehydrated meat.

Temperature of the process of 4 °C has contributed to the higher reduction of the total number of bacteria in the dehydrated meat in AOS, while in case of dehydration meat in molasses, the higher reduction of the total number of bacteria was achieved at the temperature of the process of 22 °C, probably due to the

Table 2. Viscosities of the osmotic solutions (Pa s)

AOS				Molasses			
Prior OD		After OD		Prior OD		After OD	
Temperature of the process, °C							
4	22	4	22	4	22	4	22
0.7179	0.3795	0.3080	0.1482	– ^a	400 ^b	12.3418	4.0486

^aNo literature data for the viscosity of the molasses at the temperatures below 10 °C; ^bliterature data [15]

much higher viscosity of the molasses at the lower temperatures [23], Table 2, which allowed extended retention of the transferred water from the center of the meat sample to its surface.

Table 3. Average water activity (a_w) values and standard deviation of the fresh and dehydrated meat at two temperatures

Sample	Temperature of the OD, °C	
	4	22
Fresh meat	0.936±0.01	
Meat dehydrated in AOS	0.850±0.003	0.841±0.004
Meat dehydrated in molasses	0.875±0.025	0.871±0.031

The number of *Enterobacteriaceae* in the fresh meat was 14333±577 CFU/g (Table 4) but after the process of OD it was lowered in all samples dehydrated in both osmotic solutions. The reductions of the numbers of *Enterobacteriaceae* in dehydrated samples in comparison to the initial number of *Enterobacteriaceae* in the fresh meat were 90.70, 98.60, 91.86 and 98.83% for samples dehydrated in AOS at 4 °C, AOS at 22 °C, molasses at 4 °C and molasses at 22 °C, respectively.

ANOVA has showed that there was no significant statistical difference between the number of *Enterobacteriaceae* of the meat dehydrated in AOS at 4 °C and the meat dehydrated in molasses at 4 °C. Also, there was no significant statistical difference between the number of *Enterobacteriaceae* of the meat dehydrated in AOS at 22 °C and the meat dehydrated in molasses at 22 °C, but there was significant statistical difference in the number of *Enterobacteriaceae* in meat dehydrated in the same osmotic solution but at the different temperatures. This indicates that temperature has a significant influence, while the nature of the osmotic solution does not have a significant influence on the reduction of the number of *Enterobacteriaceae* in the osmotically dehydrated meat.

The Serbian National Regulation [21] does not determine reference values for the total number of bacteria or number of *Enterobacteriaceae* for the meat

pieces, but by tracking the change of these parameters it can indicate the level of hygiene of the process and the sustainability of the produced semi product. The results of the reduction of total number of bacteria and number of *Enterobacteriaceae* in any dehydrated meat in comparison to the fresh meat indicate that the process of OD is hygienically safe.

The number of *Escherichia coli* in the fresh meat cut and prepared for the osmotic dehydration in laboratory was 130±26 CFU/g (Table 3). After the process of OD, the number of *Escherichia coli* in the dehydrated meat was lowered in samples dehydrated in both osmotic solutions. ANOVA has showed the same trends of statistical significance in analysis of the number of *Escherichia coli*, as in the analysis of the number of *Enterobacteriaceae*, so it indicates that temperature has a significant influence, while the nature of the osmotic solution does not have a significant influence on the reduction of the number of *Escherichia coli* in the osmotically dehydrated meat.

The reductions of the numbers of *Escherichia coli* in dehydrated samples in comparison to the fresh meat were 63.85, 100, 71.54 and 100% for samples dehydrated in AOS at 4 °C, AOS at 22 °C, molasses at 4 °C and molasses at 22 °C, respectively. Achieved values of the number of *Escherichia coli* in all samples from the dehydrated meats are negligible in comparison to the determined values and are in accordance with the hygiene production criteria of the Serbian National Regulation [21].

CONCLUSION

The data presented in this research indicate that higher temperature of the process of the OD contributes to better results of the technological parameters of dehydrated meat (DMC, WL and WL/SG). Superior results of the technological parameters were obtained in the process of OD of meat in molasses in comparison to the AOS.

Achieved a_w values of dehydrated meat indicate that growth of microorganisms in that environment

Table 4. Microbiological analysis of the fresh and dehydrated meat at different temperatures (average numbers and standard deviation)

Parameter	Fresh meat cut in laboratory	Dehydrated meat in AOS		Dehydrated meat in molasses	
	–	4	22	4	22
Temperature of the process, °C	–	4	22	4	22
	Food safety criteria				
<i>Salmonella</i> spp. (negative/10 g)	0±0 ^a	0±0 ^a	0±0 ^a	0±0 ^a	0±0 ^a
	Production hygiene criteria				
Total number of bacteria, CFU/g	466667±57735 ^a	183333±57735 ^b	216667±76376 ^b	183333±28867 ^b	116667±28867 ^b
Enterobacteriaceae, CFU/g	14333±577 ^a	1333±577 ^b	200±100 ^c	1167±289 ^b	167±115 ^c
<i>Escherichia coli</i> , CFU/g	130±26 ^a	47±6 ^b	0±0 ^c	37±6 ^b	0±0 ^c

^{abc}Different letters in the superscript in the same row indicate significant statistical difference between the values, at level of significance $p < 0.05$

would be inhibited. Results of the microbiological analysis of the fresh and dehydrated pork meat confirmed the assumption made on the basis of measured a_w values.

OD of meat in molasses contributed to better reduction of the present microorganisms in fresh pork meat in comparison to the OD of meat in the AOS at the corresponding temperatures.

Dehydrated pork meat in molasses experienced higher reduction of the present microorganisms from the fresh meat at temperature of 22 °C, probably due to the high viscosity of the molasses at temperature of 4 °C.

The microbiological profile of the osmotically dehydrated meat has shown that the OD is hygienically safe process and semi products are safe for further technological production.

OD of the fresh pork meat in molasses as osmotic solution at the temperature of 22 °C has contributed to the better technological and microbiological parameters in comparison to the process at the temperature of 4 °C, without the need of extra input of energy. OD, as an environmentally acceptable process, contributes to the extended usage of the by-product of sugar beet production.

Acknowledgement

These results are part of project supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, TR-31055.

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IZVOD

PRENOS MASE I MIKROBIOLOŠKI PROFIL OSMOTSKI DEHIDRIRANOG SVINJSKOG MESA U DVA RAZLIČITA RASTVORA

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Osmotska dehidracija kao metod sušenja materijala je u poslednje vreme sve aktuelnija zbog karakteristika niske procesne temperature, niskih energetske zahteva procesa kao i male količine otpadnog materijala. Osmotska dehidracija je proces uklanjanja vode iz materijala potapanjem sirovine u hipertonične rastvore, gde je glavna prednost ovog procesa uklanjanje vode iz materijala u tečnoj fazi, pri umerenim temperaturama, kao i mogućnost ponovne upotrebe osmotskih rastvora. U ovom istraživanju ispitivani su uticaji procesa osmotske dehidracije na prenos mase i promenu mikrobiološkog profila s ciljem određivanja upotrebljivosti ove tehnike kao pred-tretmana u procesu obrade mesa. Proces je ispitivan u dva osmotska rastvora (melasa šećerne repe i vodeni rastvor natrijum hlorida i saharoze), na dve temperature (4 i 22 °C) pri atmosferskom pritisku. Najznačajniji parametri prenosa mase su određeni nakon 300 min osmotske dehidracije. Određene su i a_w vrednosti dehidriranog mesa kao i promena mikrobiološkog profila mesa nakon dehidracije. Ispitivanjem je utvrđeno da temperatura ima značajan statistički uticaj, dok priroda osmotskog rastvora nema značajan statistički uticaj na sadržaj suve materije i gubitak vode iz mesa. Takođe je utvrđeno da nema značajne statističke razlike između vrednosti prirasta suve materije između ispitivanih uzoraka mesa. Postignute a_w vrednosti u dehidriranom mesu u oba osmotska rastvora su niže od graničnih a_w vrednosti koje inhibiraju rast većine mikroorganizama. Ispitivanjem promene mikrobiološkog profila mesa nakon osmotske dehidracije utvrđeno je da dobijeni poluproizvodi od dehidriranog mesa zadovoljavaju kriterijume bezbednosti hrane i higijenske kriterijume definisane Pravilnikom o opštim i posebnim uslovima higijene hrane u bilo kojoj fazi proizvodnje, prerade i prometa (Službeni glasnik R.S., 72/2010). Bolji rezultati tehnoloških parametara i poboljšanja mikrobiološkog profila dobijeni se u procesu osmotske dehidracije svinjskog mesa na temperaturi od 22 °C uz upotrebu melase šećerne repe kao osmotskog rastvora u poređenju sa vodenim rastvorom natrijum-hlorida i saharoze.

Ključne reči: Osmotska dehidracija • Meso svinjske plećke • Prenos mase • Melasa šećerne repe • Mikrobiološki profil