Effects of temperature and immersion time on diffusion of moisture and minerals during rehydration of osmotically treated pork meat cubes

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Abstract

The aim of this work was to study the changes in osmotically treated pork meat during rehydration. Meat samples were osmotically treated in sugar beet molasses solution, at temperature of 23±2 °C for 5 h. After being osmotically treated, meat samples were rehydrated at constant temperature (20–40 °C) during different times (15–60 min) in distilled water. The effective diffusivity ($m^2 \cdot s^{-1}$) were between 8.35×10^{-10} and 9.11×10^{-10} for moisture, 6.30×10^{-10}–6.94×10^{-10} for Na, 5.73×10^{-10}–7.46×10^{-10} for K, 4.43×10^{-10}–6.25×10^{-10} for Ca, 5.35×10^{-10}–6.25×10^{-10} for Mg, 4.67×10^{-10}–6.78×10^{-10} for Cu, 4.68×10^{-10}–5.33×10^{-10} for Fe, 4.21×10^{-10}–5.04×10^{-10} for Zn and 5.44×10^{-10}–7.16×10^{-10} for Mn. Zugarramurdi and Lupin's model was used to predict the equilibrium condition, which was shown to be appropriate for moisture uptake and solute loss during rehydration.

Keywords: osmotic treatment, rehydration, sugar beet molasses, pork meat, diffusion coefficient, minerals.

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The knowledge of the kinetics of moisture and solute transfer during the processing is of great technological importance because it allows estimating the immersion time of samples in an osmotic solution to obtain products with determined moisture and solute contents [1–5].

Dehydrated products are usually rehydrated before further processing [6], or prior use to restore the properties of the raw products [7]. Rehydration of food materials also has an important impact on their nutritional and sensorial properties [8].

During rehydration, absorption of water into the tissue results in an increase in the mass [9]. A study of rehydration kinetics can be used to ascertain the net extent of injuries sustained by any material during rehydration and any other processing step prior to it [10]. Rehydration is influenced by several factors, grouped as intrinsic factors such as product chemical composition, predrying treatment, product formulation, drying techniques and conditions and post drying procedure and extrinsic factors such as composition of immersion media, temperature and hydrodynamic conditions [6,11–14].

Two main approaches can be identified. One approach uses the empirical and semi-empirical models like for instance the Peleg and the Weibull equation [15,16]. Azuara proposed a model avoiding the limitations of Fick's diffusion model to estimate moisture loss and solute uptake during OT [17]. Application of the Zugarramurdi and Lupin's model for osmotic treatment has been performed by Corzo *et al*. [18,19]. The other approach employs diffusive models based on Fick's second law of diffusion [20,21]. Some studies using capillary flow approach to model hydration and/or drying of foodstuffs have been reported recently [22,23]. However, the capillary flow approach is still not widely used [8].

Sugar beet molasses is an excellent medium for osmotic dehydration, primarily due to the high dry matter (80%) and specific nutrient content. According to Sauvant *et al*. [24], mineral concentrations in sugar beet molasses are as follows: 3920 mg K/100 g, 680–1300 mg Na/100 g, 100 mg Ca/100 g, 50-320 mg Mg/100 g and 11.7 mg Fe/100 g. The specific chemical composition (approximately 51% sucrose, 1% raffinose, 0,25% glucose and fructose, 5% proteins, 6% betaine, 1,5% nucleosides, purine and pyramidine bases, organic acids and bases) and high content of solids (around 80%) provide high osmotic pressure in the solution, there for molasses appears to be an excellent osmotic medium [25]. In this article, rehydrated pork meat cubes, previously dehydrated in sugar beet molasses solution, are investigated. The final product, being enriched with minerals is intended to be consumed in bakeries. No work has been found dealing with the rehydration of pork meat previously dehydrated in sugar beet molasses solution in the literature.

The aim of this work was to study the influence of the temperature on the effective diffusivities of mois-

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ture and solutes during the rehydration of previously osmotic dehydrated pork meat cubes. Simple regression models were proposed for calculation of the effective diffusivities of moisture and solutes (Na, K, Ca, Mg, Cu, Fe, Zn and Mn), as function of the independent variables, and optimum processing conditions were determined through the use of response surface methodology (RSM).

MATERIAL AND METHODS

Fresh pork meat (M. *triceps brachii*) (24 h *post mortem*) was bought in local butcher store and transported to the laboratory where it was held for 1–2 h at approximately 4 °C. The muscles were trimmed of external fat and connective tissues and manually cut into approximately 1×1×1 cm^3 cubes with sharp sterile knives.

Meat samples were osmotically treated in solutions of sugar beet molasses (soluble solid content = 80 $kg\cdot L^{-1}$) at 23±2 °C for 5 h. The solution to sample mass ratio was 10:1 to avoid significant dilution of the medium by water removal, which would lead to local reduction of the osmotic driving force during the process [26]. Every 5 min meat samples in osmotic solutions were mixed with hand-held agitator in order to induce sample – solution contact and provide better homogenization of the osmotic solution. After treatment, samples were removed from the osmotic solution and gently blotted.

OT meat samples were rehydrated by immersing the meat cubes in distilled water. The process was performed under atmospheric pressure, in laboratory jars at processing temperature of (20, 30 and 40 °C), with manual agitation on every 5 min. The jars were kept in water bath, in order to retain samples at constant temperature. The samples were removed after different immersion periods (15, 30, 45 and 60 min), blotted with tissue paper in order to remove the excess water and examined for mass change.

Dry matter content of the fresh and treated samples was determined by drying the material at 105 °C for 24 h in a oven to achieve the constant weight (Instrumentaria Sutjeska, Croatia). All weight measurements were carried out in accordance to AOAC (1990) [27]. Soluble solids content of the molasses solutions was measured using Abbe refractometer, Carl Zeis Jenna, Switzerland, at 20 °C.

Minerals composition of the raw pork meat and osmotic dehydrated pork meat in the solution of sugar beet molasses were investigated. A combination of thermal treatment at 350 °C and wet acidic treatment at 160 °C was used for preparation of samples. The dry samples were then processed for minerals determination by wet digestion, where ca. 5 g of dried sample, were weighed exactly to four decimal places, and transferred to vessels, into which 4.5 ml 65% HNO_3 and 10.5 ml 35% HCl were added. The procedure was repeated to obtain the white sediments that were dissolved in 0.07 M HNO_3. The content of minerals present in the corresponding solutions was determined by inductively coupled plasma optic emission spectrometry (ICP-OES). ICP-OES measurement was performed using Thermo Scientific ICAP 6500 Duo ICP (Thermo Fisher Scientific, Cambridge, United Kingdom) spectrometer equipped with RACID86 Charge Injector Device (CID) detector, standard glass concentric nebulizer, quartz torch, and alumina injector. Multi-elemental plasma standard solutions (Multi-Element Plasma Standard Solution 4, Specpure®, 1000 µg/ml) certified by Alfa Aesar GmbH & Co KG, Germany was used to prepare calibration solutions for ICP-OES measurement. Investigation of moisture content and all chemical analyses were conducted in triplicate.

The developed models, based on Fick's unsteady-state law of diffusion, determine the amount of moisture entering the sample and the solutes diffusing out of the sample as a function of time. According to Crank [28], Fick's second law solution for diffusion, for perfect cubes, assuming the diffusion to be perpendicular to the surface of the cube is given by Eq. (1):

$$X_r = \frac{x_t - x_0}{x_{eq} - x_0} = \frac{8}{\pi^2}\sum_{i=0}^{\infty}\exp\left(-i^2\pi^2 D_{ew}\frac{t}{L^2}\right) \quad (1)$$

where X_r denotes the dimensionless values of moisture uptake, or solute loss; x_t, x_0 and x_{eq} are the moisture or the solute contents of a sample at rehydration time t, at the outset and at equilibrium, respectively; D_{eff} (m^2s^{-1}) is the effective diffusivity, L(m) is the dimension of the sample and t(s) is the immersion time.

For long drying periods, Eq. (1) can be simplified to first two terms of the series, and moisture ratio can be expressed in the logarithmic form:

$$\ln X_r = \ln\frac{8}{\pi^2} - \left(\pi^2\frac{D_{eff}t}{L^2}\right) \quad (2)$$

$$D_{eff} = D_0\exp\left(-\frac{E_a}{TR}\right) \quad (3)$$

where the effect of temperature on effective diffusivity is expressed using Arrhenius type relationship. E_a is the activation energy (kJ mol^{-1}), D_0 is the diffusivity value for infinite moisture or solute content, and R represent universal gas constant (kJ mol^{-1}). T is absolute processing temperature (K).

Values of the effective diffusion coefficient (D_{eff}) were obtained by non-linear regression analysis from Eqs. (2) and (3) [29].

The following mathematical model, with an exponential approach to the equilibrium value of moisture and solutes contents, was proposed by Zugarramurdi and Lupin [30]:

$$\frac{\mathrm{d}X_i(t)}{\mathrm{d}t} = k_i\left(X_i^*(t) - X_i(t)\right) \quad (4)$$

$$X_i(t) = \frac{m_i(t)}{m - \sum_{j=1, j\neq i}^{n} m_j}, \; X_i^*(t) = \frac{m_i^*(t)}{m - \sum_{j=1, j\neq i}^{n} m_j} \quad (5)$$

where, i – index of moisture, or mineral content, m_i is mass of i-th component at time t, m_i^* is mass of i-th component at equilibrium, m total mass, k_i is specific rate constant for variation of i-th component.

Eqation (4) can be integrated with the following initial condition (t = 0):

$$X_i(0) = X_i^0 \quad (6)$$

The solution is

$$X_i(t) = X_i^* + e^{-k_i t}\left(X_i^0 - X_i^*\right) \quad (7)$$

It is assumed that the Zugarramurdi and Lupin's model (Eq. (7)) would predict the moisture and solutes content in the kinetics of pork meat cubes including equilibrium solute content during the process.

The considered dependent variables were the concentrations of moisture and minerals (Na, K, Ca, Mg, Cu, Fe, Zn and Mn). The results have been written in Table 1.

The following second order polynomial (SOP) model was fitted to the data. Nine models of the following form were developed to relate nine responses (Y) and two process variables (X):

$$Y_k = \beta_{k0} + \sum_{i=1}^{2}\beta_{ki}X_i + \sum_{i=1}^{2}\beta_{kii}X_i^2 + \beta_{k12}X_1X_2, \; k = 1\text{–}9 \quad (8)$$

where: β_{k0}, β_{ki}, β_{kii}, β_{k12}, are constant regression coefficients; Y_k moisture and observed minerals content (Na, K, Ca, Mg, Cu, Fe, Zn and Mn); X_1 – processing time; X_2 – temperature.

All obtained results were expressed as the mean ± standard deviation (*SD*), analysis of variance (ANOVA) of obtained results was performed for comparison of means, using StatSoft Statistica 10 software (Statsoft Inc., Tulsa, OK, USA).

RESULTS AND DISCUSSION

The study was conducted to determine the rehydration conditions for pork meat cubes. The experimental data used for the analysis were obtained from the experimental design, with 3 temperature and 4 duration time levels, and with 2 parameters (temperature and immersion time).

During rehydration of osmotically dehydrated pork meat cubes in sugar beet molasses, the moisture content (X_w; g water per g of dry solids) and minerals content (X_{Na} – mg Na/g sample; X_{Ca} – mg Ca/g sample; X_K – mg K/g sample; X_{Mg} – mg Mg/g sample; X_{Cu} – mg Cu/g sample; X_{Fe} – mg Fe/g sample; X_{Zn} – mg Zn/g sample; X_{Mn} – mg Mn/g sample) were experimentally determined in samples at different immersion times for all of the experiments. Table 1 shows the response variables as a function of independent variables for the analysis.

Maximum moisture content observed has been obtained after 60 min of rehydration process (regardless the temperature), while higher moisture content has been noticed at increased temperatures. Quite the opposite, decreasing trend, with the increase of processing time and temperature, has been observed with minerals content. According to developed models, water content gain rate and also minerals content loss

Table 1. Experimental design and data for the response surface analysis

Time, min	Temp., °C	X_w / %	X_{Na}	X_K	X_{Ca}	X_{Mg}	X_{Cu}	X_{Fe}	X_{Zn}	X_{Mn}
			mg/g							
0	-	41.99	375.52	938.91	118.19	33.41	0.23	1.37	1.99	0.37
15	20	50.69	295.06	711.84	93.50	28.63	0.21	1.24	1.88	0.33
30	20	54.36	255.50	673.58	80.59	25.87	0.20	1.22	1.78	0.30
45	20	57.96	235.34	543.14	75.31	24.03	0.19	1.19	1.64	0.26
60	20	58.37	218.61	480.09	71.03	21.96	0.15	1.17	1.58	0.23
15	30	52.45	279.05	659.98	85.46	27.67	0.14	1.22	1.80	0.30
30	30	57.23	246.33	578.20	78.20	24.73	0.13	1.19	1.72	0.27
45	30	60.10	225.02	514.73	73.25	23.65	0.11	1.15	1.58	0.24
60	30	60.43	212.58	461.53	69.05	21.55	0.10	1.10	1.51	0.21
15	40	55.71	253.53	546.15	83.32	25.37	0.13	1.14	1.75	0.25
30	40	58.44	224.16	500.84	76.72	23.74	0.11	1.09	1.61	0.23
45	40	60.12	207.69	455.34	71.41	21.99	0.10	1.07	1.52	0.21
60	40	61.97	193.62	413.67	66.86	20.90	0.09	1.03	1.45	0.18

rate were increased at higher temperatures. As previously stated sugar beet molasses is rich in mineral content, and special care should be concerned to gain optimal mineral content in the final product. Na and K contents have been exceptionally high after osmotic treatment (375.52, for Na and 938.91, for K content). Decreasing of these values can be observed even at mildest temperature treatment, at 20 °C, shortly after rehydration process starts.

Numerous articles discuss various topics concerning the Dietary Reference Intakes [31–33], for the choice of the best process conditions depending on the final product application. Previous research [34–36] has shown that OT positively influenced on improving microbiological profile and food safety of product, and preliminary sensory analysis has shown that pork meat processed in this manner has satisfactory sensory characteristics. Also, the use of sugar beet molasses during OT improves the nutritional profile of meat, which chemical composition after the process of OT is in optimal range for human health.

According to ANOVA, Table 2, X_w as most influenced by duration of rehydration process (statistically significant at $p < 0.05$ level), but the influence of temperature was also observed and statistically significant. Na and K concentration were mostly influenced by linear terms of immersion time and temperature (both statistically significant at $p < 0.05$), while quadratic terms of duration of process in X_{Na} SOP model were found statistically significant. Ca and Mg losses have been most influenced by linear term of process duration, while linear term of temperature was also significant at $p < 0.05$ level. Cu loss was mostly affected by linear terms of temperature and immersion time, while Fe content was mostly influenced by process duration. Zn content was affected by linear terms in SOP model, and Mn content was mostly influenced by linear terms.

The average error between the predicted values and experimental values (calculated by Eq. (1)) was below 10%. Values of average error below 10% indicate an adequate fit for practical purposes. To verify the significance of the models, analysis of variance (ANOVA) was conducted and the results indicate that all models were significant with minor lack of fit, suggesting they adequately represented the relationship between responses and factors.

The two-dimensional graphics have been plotted for experiment data visualization (white colored points) and for the purpose of observation the fitting of regression models (moisture content and Na, K, Ca, Mg, Cu, Fe, Zn and Mn losses) to experimental data, Fig. 1. All plots showed the "rising ridge" configuration, with mineral content decreased due to both temperature and immersion time increasing, while moisture content has been enhanced with temperature and duration of the rehydration process.

Moisture and solute contents at equilibrium conditions were determined using Zugarramurdi and Lupin's Equation, Eq. (7), and are given in Table 3. Zugarramurdi and Lupin's equation proved to be suitable for modeling water uptake and minerals loss, as the coefficient of determination was above 0.975 for all treatments. At the beginning of the process there is an initially high rate of water uptake and a quick removal of solutes, followed by a slower rate of water uptake and solute loss in the later stages of the process. Equilibrium moisture content is reached at higher levels for increased temperatures, but the equilibrium content of minerals decreased with the augment in processing temperature.

The effective diffusivities at any given set of conditions were calculated numerically, from the Eq. (2). It is generally assumed that diffusion occurs at a constant rate under the influence of a uniform moisture gradient. However, this does not appear to be true in biological materials, especially after the initial stages of the process, as the physical structure of the material begins to change as the rehydration continues. A non-uniform moisture gradient is developed over the course of rehydration treatment and the effective diffusivity changes with position and time of rehydration [14]. In meat D_{ew} generally shows a decreasing trend over time. Thus it is assumed that in meat materials D_{ew} does not show a pseudolinear correlation with time as also reported by Rastogi *et al*. [14]. Values of effective diffusivity of water, effective diffusivity of nutrients for different combinations of temperature of the osmotic

*Table 2. ANOVA calculation for mineral composition; * – significant at p < 0.05 level, ** – significant at p < 0.10, level 95% confidence limit, error terms were found statistically insignificant, df – degrees of freedom*

Parameter	df	X_w	X_{Na}	X_K	X_{Ca}	X_{Mg}	X_{Cu}	X_{Fe}	X_{Zn}	X_{Mn}
t	1	91.04*	7402.15*	61917.73*	549.40*	53.11*	0.002*	0.016*	0.154*	0.013*
t^2	1	6.15*	284.31*	4.60	15.73*	0.36**	0.000	0.000**	0.001	0.000
T	1	27.60*	1969.09*	30338.00*	61.16*	9.01*	0.013*	0.030*	0.038*	0.008*
T^2	1	0.33	75.08*	452.66	1.94	0.31	0.001	0.001*	0.000	0.000*
t·T	1	0.95	71.05*	3662.44*	8.10**	1.12*	0.000	0.000	0.000	0.000*
Error	6	2.59	26.07	1653.74	11.63	0.55	0.001	0.001	0.002	0.000*
r^2		0.977	0.968	0.999	0.929	0.931	0.976	0.931	0.976	0.943

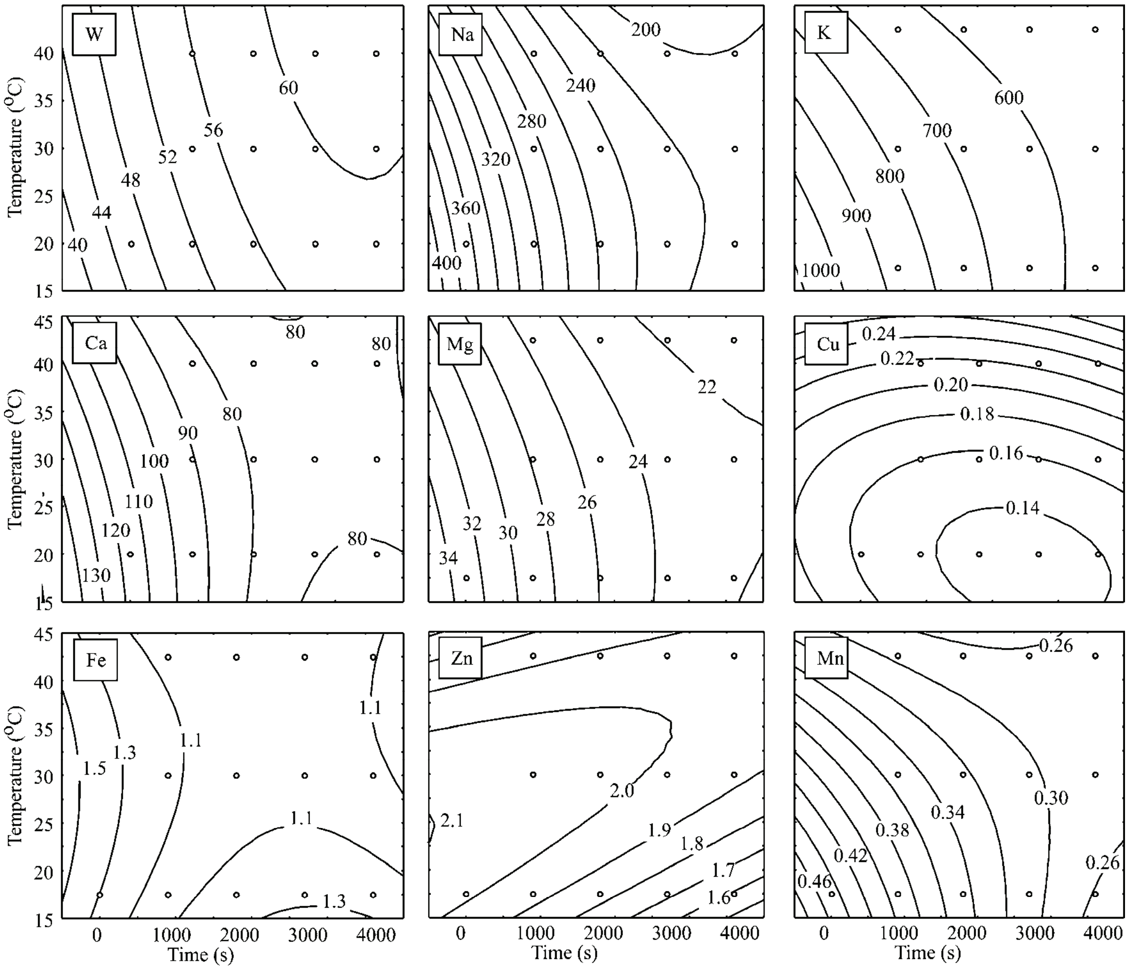

Figure 1. Response surfaces for water content, Na, K, Ca, Mg, Cu, Fe, Zn and Mn contents, as functions of process duration and temperature, during rehydration of meat [mg/100g].

solution, are presented in Table 3. All treatments showed a good fit to the linear equation, giving determination coefficients above 0.98.

The differences between the results of this study and the results found in the literature can be explained by the use of different types of pork meat cubes, and also different degrees of maturation. Another reason for this difference is the use of a sugar beet molasses solution during dehydration process. The presence of the different nutrients in the osmotic solution affects the mechanism involved in the simultaneous flows of water removal and solute penetration and, consequently, affects the diffusivity values. Obtained values for effective diffusivity of moisture, found in this research are in the range of 8.35×10^{-10}–9.11×10^{-10} $m^2\cdot s^{-1}$, which could be compared to the effective diffusivities of moisture in shark filets during brining, found by Mujaffar and Sankat [37], between 0.17×10^{-9} and 0.24×10^{-9} $m^2\cdot s^{-1}$, at temperatures between 20–−50 °C, in NaCl solution.

Several authors have made important model studies on the diffusion coefficients of sodium chloride

Table 3. Experimental data fitted to Zugarramurdi and Lupin's Equation

Temp.	X^*_W	r^2	X^*_{Na}	r^2	X^*_K	r^2	X^*_{Ca}	r^2	X^*_{Mg}	r^2
20	60.05	0.998	209.06	0.998	455.69	0.997	70.18	0.993	21.07	0.975
40	61.63	0.997	207.32	0.997	438.88	0.995	68.46	0.993	20.62	0.980
60	63.28	0.994	191.12	0.999	373.47	0.998	65.11	0.995	18.93	0.993
Temp.	X^*_{Cu}	r^2	X^*_{Fe}	r^2	X^*_{Zn}	r^2	X^*_{Mn}	r^2		
20	0.13	0.996	1.17	0.993	1.35	0.998	0.19	0.994		
40	0.09	0.999	1.09	0.997	1.22	0.994	0.18	0.991		
60	0.05	0.992	1.04	0.999	0.12	0.995	0.17	0.996		

and other solutes in meat [38–42]. The diffusion coefficient is suggested to be affected by changes in mineral concentration, swelling and degree of dehydration [40,41,43].

The effective diffusivities of Na in pork meat cubes, found in Table 4, were estimated and values between 6.30×10^{-10} and 6.94×10^{-10} $m^2\cdot s^{-1}$ have been obtained and compared with other studies. The effective diffusivities of Na in chicken breast cuts found by Schmidt *et al.* [5], were between 2.5×10^{-10} and 2.8×10^{-10} $m^2\cdot s^{-1}$, at 5 °C, under stirring conditions, in solutions of NaCl, between 0 and 20%. Gravier *et al*. [41], gained values between 0.6×10^{-10} and 5.0×10^{-10} $m^2\cdot s^{-1}$, in solutions of NaCl, between 30 and 200 g/l.

The effective diffusivities of K in pork meat cubes were estimated in this article, and values between 5.73×10^{-10} and 7.46×10^{-10} $m^2\cdot s^{-1}$ were found. No data for K diffusivities during rehydration of pork meat have been found to be compared with here presented results.

Also, the effective diffusivities of Ca in pork meat cubes were estimated and values between 4.43×10^{-10} and 6.25×10^{-10} $m^2\cdot s^{-1}$ were gained, but due to the lack of data in the literature, presented results could not be compared.

The effective diffusivities of Mg in pork meat cubes were estimated and values between 5.35×10^{-10} and 6.25×10^{-10} $m^2\cdot s^{-1}$ were found. Mg diffusivities data, during rehydration of pork meat were not found elsewhere in the literature to be compared with these results.

The effective diffusivities of Cu in pork meat cubes were estimated and values between 4.67×10^{-10} and 6.78×10^{-10} $m^2\cdot s^{-1}$ and the effective diffusivities of Fe in pork meat cubes were estimated and values between 4.68×10^{-10} and 5.33×10^{-10} $m^2\cdot s^{-1}$ were found. The effective diffusivities of Zn in pork meat cubes were estimated and values between 4.21×10^{-10} and 5.04×10^{-10} $m^2\cdot s^{-1}$. The effective diffusivities of Mn in pork meat cubes were estimated and values between 5.44×10^{-10} and 7.16×10^{-10} $m^2\cdot s^{-1}$ were found.

Cu, Fe, Zn and Mn diffusivities data, during rehydration treatment of pork meat, were not found elsewhere in the literature to be compared with these results.

These results are in agreement with fundamental theories which state that mass diffusivity strongly depends on the temperature, pressure, and on the components involved. Many investigations require that the effective diffusivity is determined at a range of precise temperatures. Frequently, the relationship between effective diffusivity and temperature follows a first order rate process described by an Arrhenius relationship.

High temperatures cause an increase in membrane permeability (which promotes swelling and plasticization of the cell membranes) and a reduction in the solution viscosity, reducing external resistance to mass transfer. Both these phenomena make water and solute transport easier. However, temperatures above 40 °C reduce the final product quality, changing the structure of cell membranes, resulting in loss of selectivity and leading to greater solute incorporation into the meat. In addition, high temperatures may induce significant changes in texture and nutritional composition of the food as a consequence of the nutrients flow from the product to solution.

Table 4. Effective diffusivities of water and minerals × 10^{10} ($m^2\cdot s^{-1}$) during osmotic rehydration of pork meat

Temp., °C	D_w	D_{Na}	D_K	D_{Ca}	D_{Mg}	D_{Cu}	D_{Fe}	D_{Zn}	D_{Mn}
20	8.35	6.30	5.73	4.43	5.35	4.67	4.68	4.21	5.44
30	8.58	6.52	6.09	6.00	5.61	5.91	5.18	4.76	6.78
40	9.11	6.94	7.46	6.25	6.25	6.78	5.33	5.04	7.16

CONCLUSIONS

The main objective of this article was to provide an adequate model that allows describing the moisture and solute contents during rehydration (in distilled water) of the previously osmotic treated pork meat cubes in sugar beet molasses solution. Different immersion times (15–60 min) and immersion temperatures were used (20–40 °C). Second order polynomial models fitted the experimental data well. According to developed models, water content gain rate and also minerals content loss rate were increased at higher temperatures. Zugarramurdi and Lupin's model was used for equilibrium content evaluation, and coefficients of determination showed good fitting capabilities. During rehydration, equilibrium moisture content increased with the temperature rise, while equilibrium content of observed minerals decreased with temperature enhancement.

Fick's unsteady-state diffusion equation was shown to be suitable for determining the mass effective diffusivity of water and solutes in pork meat cubes. The temperature and osmotic solution composition showed significant effects on all the responses studied. Increases in temperature, and/or molasses concentration led to higher effective diffusivity of water.

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IZVOD

UTICAJI TEMPERATURE I VREMENA NA DIFUZIVNOST VODE I MINERALA TOKOM REHIDRATACIJE OSMOTSKI TRETIRANOG SVINJSKOG MESA

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(Naučni rad)

Cilj ovog rada bio je da se ispitaju promene u osmotski tretiranom svinjskom mesu koje nastaju tokom procesa rehidratacije. Uzorci mesa su bili podvrgnuti osmotskom tretmanu u rastvoru melase šećerne repe, na temperaturi od 23±2 °C, 5 h. Nakon osmotskog tretmana, uzorci mesa su rehidrirani na konstantnoj temperaturi (20–40 °C) pri različitim vremenima potapanja (15–60 min) u destilovanoj vodi. Metoda odzivnih površina je korišćena za predviđanje efektivnog koeficijenta difuzije vode, i minerala, na određenoj temperature, tokom procesa rehidratacije. Numeričko rešavanje Fikovog zakona (Fick) o prenosu mase, pri nestacionarnim uslovima, za idealnu kocku je korišćeno za izračunavanje efektivnog koeficijenta difuzije vode, saharoze i minerala (Na, K, Ca and Mg). Cuguramendijev (Zugarramurdi) i Lupinov (Lupin) model je korišćen za predviđanje ravnotežnih uslova i pokazalo se da je taj model veoma pogodan za izračunavanje gubitka vlage i priraštaja suve materije tokom rehidratacije. Dobijena efektivna difuzivnost ($m^2 \cdot s^{-1}$)je bila između $8{,}35\times10^{-10}$ i $9{,}11\times10^{-10}$ za vlagu, $6{,}30\times10^{-10}$ i $6{,}94\times10^{-10}$ za Na, $5{,}73\times10^{-10}$ i $7{,}46\times10^{-10}$ za K, $4{,}43\times10^{-10}$ i $6{,}25\times10^{-10}$ za Ca, $5{,}35\times10^{-10}$ i 6.25×10^{-10} za Mg, $4{,}67\times10^{-10}$ i $6{,}78\times10^{-10}$ za Cu, $4{,}68\times10^{-10}$ i 5.33×10^{-10} za Fe, 4.21×10^{-10} i 5.04×10^{-10} za Zn i 5.44×10^{-10} i 7.16×10^{-10} za Mn. Korišćenjem ovde razvijenih matematičkih modela dobijaju se bezdimenzionalne vrednosti priraštaja vlage i gubitaka suve materije, sa tačnošću izraženom preko koeficijenata determinacije (r^2), za x_w, x_{Na}, x_K, x_{Ca}, x_{Mg}, x_{Cu}, x_{Fe}, x_{Zn}, i x_{Mn}: 0,977; 0,968; 0,999; 0,929; 0,931; 0,976; 0,931; 0,976 i 0,943, redom. Širok opseg procesnih promenljivih veličina razmatranih u formiranju ovih modela, kao i njihova laka implementacija u tabelarnim proračunima, čini ove modele veoma praktičnim za projektovanje i kontrolu procesa.

Ključne reči: Osmotski tretman • Rehidratacija • Melasa šećerne repe • Svinjsko meso • Koeficijent difuzije • Minerali