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COMPARISON OF OSMOTIC MEDIUM OSMOLALITY PROFILES OF CO- AND COUNTER-CURRENT PORK MEAT OSMOTIC DEHYDRATION

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Abstract

One of the potential preservation techniques for producing meat products with low water content and improved nutritional, sensorial and functional properties is osmotic dehydration. Osmolality represents solutions osmotic concentration, or number of dissolved substance particles in mass unit of water. It has been proven than osmotic solution osmolality measurement can be quickly and accurately used for osmotic dehydration process control and management. Goal of this research is to compare osmotic medium osmolality profiles in two different types of osmotic dehydration of pork meat: co- and counter-current process.

Osmolality was measured with VaproR-Vapor pressure osmometer model 5600. Dry matter content (DMC) was determined by convective drying at 105 ^{0}C until constant mass was obtained. DMC of osmodehydrated pork meat has shown that higher values were achieved in counter-current processes in all three osmotic solutions in comparison to the respective DMC values of co-current process.

Results of osmotic solutions DMC change during five hours of the process have shown that there is higher decrease of DMC values of osmotic solutions in co-current processes than in respective counter-current processes. This higher decrease in DMC of osmotic solutions has direct effect in lower obtained DMC of osmo-dehydrated meat in co-current processes. Measurement of osmolality of osmotic solutions has shown that, as in case of DMC change during process, osmolality has also decreased with the duration of the process and increase of DMC of meat. Osmolality of the solutions used in counter-current process were more constant and were less decreased during osmotic process in comparison to the co-current process.

From presented results it can be concluded that osmolality profiles of counter-current osmotic processes are less decreasing than respective co-current processes, indicating on higher efficiency of counter-current osmotic processes, which can be measured and controlled via osmolality measurement.

***Key words**: Osmotic dehydration, Sugar beet molasses, Osmolality, Pork meat.*

1. Introduction

One of the potential preservation techniques for producing products with low water content and improved nutritional, sensorial and functional properties is osmotic dehydration. This technology promotes partial removal of water from food by immersion in a concentrated hypertonic solution. The driving force for the diffusion of water from the plant tissue into the concentrated solution is provided by the high osmotic pressure of the solution. The diffusion of water, as the primary mass transfer, is accompanied by the simultaneous counter-diffusion of solute(s) from the osmotic solution into the meat tissue, which is considered as the secondary mass transfer. Since the membrane responsible for osmotic transport is not perfectly selective, other solutes present in the cells can also be leached into the osmotic solution [1, 2].

Osmotic dehydration is recognized as a pre-treatment step to meat drying processes such as: air-drying, microwave or freeze-drying, to improve the nutritional, sensorial and functional properties of meats, reduce heat damage and minimize their colour and flavour changes [3].

Previous research [4] has shown that the process of osmotic dehydration has positive influence on the microbiological profile and food safety of osmodehydrated pork meat.

Osmotic medium type is a very important factor that determines the rate of diffusion during the osmotic dehydration [5]. Various hypertonic solutions and their combinations have been used for osmotic treatment. The most common osmotic agents are concentrated solutions of sugar (sucrose, glucose, fructose, corn syrup) and sodium chloride [6, 7]. Recent research shows that sugar beet molasses is a highly effective osmotic medium for meat treatment [4, 8].

Sugar beet molasses is an excellent medium for osmotic dehydration, primarily due to the high dry matter (80%) and specific nutrient content. From nutrient point of view, an important advantage of sugar beet molasses use as hypertonic solution is enrichment of the food material in minerals and vitamins, which penetrate from molasses into the plant tissue [9, 10]. The presence of complex solute compositions maintains a high transfer potential favourable to water loss, and at the same time by the presence of sugar, salt impregnation is hindered [11]. High salt concentrations decrease the water holding capacity, which contributes to meat dehydration and shrinkage while there is no swelling of muscle fibres or myofibrils [12, 13].

Sensory analysis has shown that meat processed in this manner has satisfactory characteristics. The use of sugar beet molasses during osmotic dehydration improves the nutritional profile of pork meat. The chemical composition, after the process of osmotic dehydration in molasses is in the optimal range for human health [14, 15].

Osmotic pressure as a functional characteristic of applied osmotic solutions in systems containing concentration gradient between osmotic solutions and dehydrating material, is a measure of a systems' tendency to obtain equilibrium concentration at all locations in the system by diffusion [16].

Osmotic pressure is cogitative properties of the solution, where electrolyte solutions have higher osmotic pressure than non-electrolyte solutions [17].

Osmolality represents solutions osmotic concentration, or number of dissolved substance particles in mass unit of water [18].

In previous research [19], it has been proven than osmotic solution osmolality measurement can be quickly and accurately used for osmotic dehydration process control and management.

Theory background of counter-current osmotic dehydration process predicts higher efficiency of counter-current process in comparison to the co-current process, which is confirmed in the research of Lazarides *et al.,* [20], where it is concluded that counter-current process increased dehydration efficiency of potato due to increasing the rate of water removal while minimizing solid gain.

In the counter-current osmotic dehydration process of carrot and apple, the levels of dry matter content after 1 hour of the process were the same as the levels of dry matter content in co-current processes after 2.5 to 3 hours, which point at the increase of the efficiency of the process and the possibility of reducing the duration of the process and energy savings [21].

Changing technological procedure of the process of pork meat osmotic dehydration from co-current to counter-current process, the responses of the process increased from 14.65% to 19.48%, while the total efficiency of the process was improved by 32.20% [22].

Goal of this research is to compare osmotic medium osmolality profiles during two different types of osmotic dehydration of pork meat: co- and counter-current process.

2. Materials and Methods

Pork meat (*M. triceps brachii*) was purchased at the butcher shop in Novi Sad, Serbia, just before use. Initial moisture content of the fresh meat was 72.83%. Before the osmotic treatment, whole muscle, (*Musculus triceps brachii*, 24 h post mortem, with removed fat tissue), was cut into cubes, dimension 1 x 1 x 1 cm, and then homogenized before the samples were taken for the process. Sugar beet molasses, with initial dry matter content (DMC) of 85.04%, was obtained from the sugar factory Crvenka, Serbia. Both processes, co-current and counter-current, were performed in laboratory jars at temperature of 20 ^{0}C under atmospheric pressure, in constant temperature chamber (KMF 115 L, Binder, Germany).

The sample to solution ratio of 1 : 2 (w/w) was used for both processes co-current and counter-current, since higher sample to solution ratio would suspend excessive dilution of osmotic solutions in co-current process disabling the comparison of co- and counter-process effectiveness. Distilled water was used for dilution of osmotic solutions.

Osmotic solutions were prepared as following:

<u>Osmotic solution 1 (OS1):</u>

Commercial sucrose (in the quantity of 1,200 g/kg water) and commercial NaCl (in the quantity of 350 g/kg water) were dissolved in distilled water [23, 24]. For counter-current process OS1 was diluted in distilled water as following: 45% DMC, 48.75% DMC, 52.5% DMC, 56.25% DMC and 60% DMC for every hour of the five-hour process.

<u>Osmotic solution 2 (OS2):</u>

OS1 and osmotic solution 3 were mixed in mass ratio of 1 : 1. For counter-current process OS2 was diluted in distilled water as following: 52.5% DMC, 56.88% DMC, 61.25% DMC, 65.63% DMC and 70% DMC for every hour of the five-hour process

Osmotic solution 3 (OS3):

OS3 was sugar beet molasses. For counter-current process OS3 was diluted in distilled water as following: 60% DMC, 65% DMC, 70% DMC, 75% DMC and 80% DMC for every hour of the five-hour process. The process of co- and counter-current osmotic dehydration process is performed as described in Filipović *et al.*, [22].

DMC of osmodehydrated pork meat is calculated and presented as mean values and standard deviation of six parallel runs:

$$DMC = \frac{m_f}{m_i} \cdot 100\% \quad (1)$$

where m_i and m_f are the initial and final mass (g).

Osmolality was measured with Vapro^R-Vapor pressure osmometer model 5600.

StatSoft Statistica [25] Software was used for variance analysis, while Microsoft Excel [26] was used for graphics creation.

3. Results and Discussion

Monitoring changes of DMC values of osmodehydrated pork meat is good way to compare and estimate efficiency of osmotic dehydration process. In Table 1, DMC of pork meat dehydrated in three osmotic solutions during 1, 3 and 5 hours of co- and counter-current process are shown.

The highest pork meat DMC values (50.76 ± 2.08% in co-current process and 63.39 ± 0.87% in counter-current process) were achieved in molasses as an osmotic solution, at the end of the five hour process.

From presented results it can be seen that time of the process has statistically significantly influenced on DMC values of all tested samples in all three osmotic solutions and in both types of the process (co- and counter-current process).

Type of osmotic solution has expressed statistically insignificant influence on osmodehydrated pork meat DMC values in different osmotic solutions in co-current processes, where the highest values achieved were in OS3. In counter-current processes type of osmotic solution had statistically significant influence on osmodehydrated pork meat DMC values, and again sugar beet molasses (OS3) as an osmotic medium has produced the highest values of pork meat DMC.

Comparing respective DMC values of osmodehydrated pork meat samples in co- and counter-current processes, it can be seen that type of the process had statistically significant influence on achieved DMC values, generating higher achieved DMC values of osmodehydrated pork meat in counter-current processes, hence higher effectiveness of the osmotic dehydration process.

Concentration gradient between dehydrating material and osmotic solution is drive force for dual mass transfers in osmotic dehydration process, hence from the aspect of process efficiency evaluation it is important to monitor, beside pork meat DMC changes, also osmotic solution DMC changes during the process. Figure 1 shows changes of osmotic solution DMC values in both process types and in all three osmotic solutions during five-hour processes. DMC values of osmotic solutions in counter-current processes are presented as mean value of starting and ending osmotic solution DMC value of corresponding hour of the process, since the method of counter-current process of osmotic dehydration involved the increase of osmotic solution concentration after every hour of the process, simulating counter-current process in laboratory conditions.

From presented results for both types of the process it can be seen that DMC of osmotic solutions in every point of the process were the highest for OS3, than for OS2 and the lowest for OS1, which was influenced by the nature of the used osmotic solutions. These differences in osmotic solution DMC values explain the differences in osmodehydrated pork meat DMC values, Table 1, where the highest values were achieved in OS3 in every hour of the process in comparison to the other two osmotic solutions.

Comparing osmotic solution DMC values of corresponding points of co- and counter-current processes it can be seen that in case of co-current process there is decrease of high starting osmotic solution concentrations which is very prominent in first three hours of the process, while in case of counter-current process there is constant increase of low starting osmotic

Table 1. DMC pork meat values in co- and counter-current osmotic dehydration process during five hours in three osmotic solutions

Time (h)	Co-current DMC (%)			Counter-current DMC (%)		
	OS1	OS2	OS3	OS1	OS2	OS3
1	37.05 ± 2.05^a	37.33 ± 1.54^a	37.36 ± 1.98^a	37.50 ± 1.60^a	40.08 ± 0.85^a	39.84 ± 1.26^a
3	47.15 ± 1.43^b	49.24 ± 0.76^{bc}	49.99 ± 1.86^{be}	48.85 ± 2.84^{bg}	53.26 ± 1.35^{cdefgh}	55.46 ± 0.32^h
5	47.68 ± 2.59^b	50.01 ± 0.99^{bd}	50.76 ± 2.08^{bf}	58.00 ± 1.92^h	62.93 ± 1.60^{hi}	63.39 ± 0.87^i

^{abcefghi} Different letters in the superscript in the table indicate on statistical significant difference between values at the level of significance of p <0.05 (based on post-hoc Tukey HSD test) solution concentrations during the five-hour process. From the graphic presented on the Figure 1, it can be seen that after 3rd hour of the process osmotic solutions DMC were higher in counter-current processes than in respective co-current processes, which directly influenced higher mass transfer and higher efficiency of the osmotic dehydration process.

Figure 2 shows changes of the actual measured osmotic solution osmolality values during counter-current process of osmotic dehydration in three osmotic solutions, indicating on special steps of the process which were undertaken to simulate counter-current process in laboratory conditions (values and lines marked with symbol **). In order to be able to compare changes of osmolality profiles in co- and counter-current processes, mean values of starting and ending osmotic solution osmolality values are introduced, and these values formed trends of osmotic solution osmolality values which then were comparable to the osmotic solution osmolality values of the co-current processes, Figure 3.

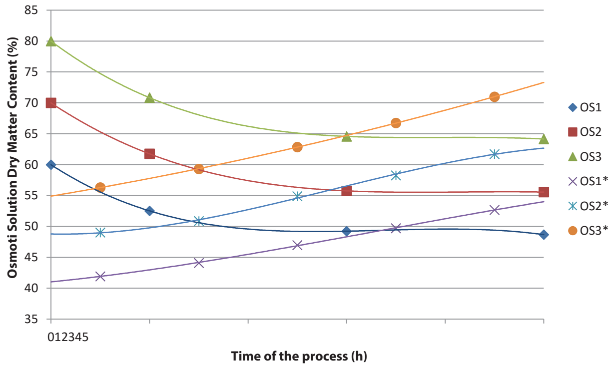
Figure 3 shows changes of osmotic solution osmolality values in both process types and in all three osmotic solutions during five-hour processes.

From the presented results it can be seen that results of osmolality for co- and counter-current processes have shown that the highest values of osmolality were achieved for OS1, than for OS2 and the lowest for OS3 for every hour of the process. This is the opposite trend from DMC values. It is direct consequence of cogitative properties of osmolality which is directly influenced by number of dissolved particles in unit volume. The number of dissolved particles in unit volume is higher in OS1 than in OS3, opposite from DMC values. However the osmolality changes measurement allows monitoring different osmotic dehydration processes containing the same osmotic solution [19].

Comparing osmolality values of corresponding points of co- and counter-current processes, the same as in case of osmotic solution DMC values, it can be seen that in case of co-current process there is high decrease of high starting osmotic solution osmolality values in first three hours of the process, while in case of counter-current process there is constant increase of low starting osmotic solution osmolality values during the five-hour process.

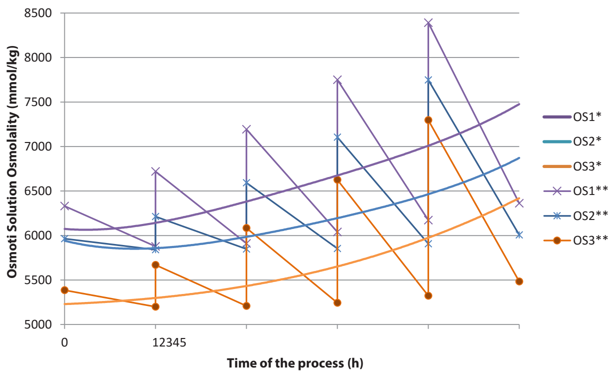
Analysing osmolality values of OS1 in co- and counter-current processes, it can be seen that point of interception where osmolality values reached the same values, was close to 3.5 hours from the beginning of the process, and after that point higher osmotic solution osmolality values were in osmotic solutions of counter-current process indicating higher process efficiency.

In case of OS2 osmolality values, point of interception where osmolality values reached the same values, was



* - OS1, OS2 and OS3 marked with symbol * are DMC values of solutions in counter-current processes

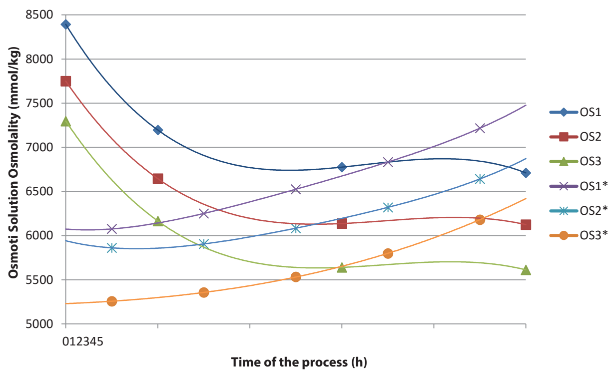
Figure 1. Changes of osmotic solution DMC during co- and counter-current process of osmotic dehydration in three osmotic solutions



* - OS1, OS2 and OS3 marked with symbol * are mean osmolality values of solutions in counter-current processes

** - OS1, OS2 and OS3 marked with symbol ** are actual osmolality values of solutions in counter-current processes

Figure 2. Changes of osmotic solution mean and actual osmolality during counter-current process of osmotic dehydration in three osmotic solutions



* - OS1, OS2 and OS3 marked with symbol * are osmolality values of solutions in counter-current processes

Figure 3. Changes of osmotic solution osmolality during co- and counter-current process of osmotic dehydration in three osmotic solutions

before 3 hours from the beginning of the process. The position of the interception was earlier on time scale than in case of OS1, indicating on higher process efficiency of the counter-current process for longer period of time than in case of OS1, which is also noticeable from the greater difference in achieved osmodehydrated pork meat DMC values at the end of the process (difference between pork meat DMC values in co-current and counter-current process in OS1 was 10.32% and in case of OS2 12.92%).

Point of interception in case of OS3 was positioned at 3 hours after the beginning of the process. There is, as in case of OS2, significant difference of the osmotic solution osmolality trends in the processes after the point of interception indicating on more effective process in latter phases of counter-current process. This is also noticeable from the difference between achieved pork meat DMC values in co-current and counter-current process at the end of the five-hour process which was 12.63%, insignificantly lower than in case of OS2, as the position of the interception point indicated.

4. Conclusions

- From presented results it can be concluded that sugar beet molasses, used as an osmotic solution provides better process efficiency than other, commonly used osmotic solutions. Comparison of the products of co- and counter-current processes has shown that counter-current process has produced significantly better end products.

- Comparing osmotic solution osmolality profiles of co- and counter-current osmotic processes have explained the mechanisms which lead to the higher efficiency of the counter-current osmotic processes, and provided a fast responsive tool for measurement and control of the process of osmotic dehydration via osmotic solution osmolality measurement.

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