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OPTIMIZATION OF FISH OSMOTIC TREATMENT APPLYING FUZZY SYNTHETIC EVALUATION METHOD

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Abstract

Osmotic treatment is used alone or in combination with other drying methods to reduce water content in food and increase its sustainability. Due to the many advantages over traditional drying processes, the osmotic treatment is increasingly being used in the food industry as a preservative method. The complexity of the process causes nonlinear optimization problems and sometimes it is difficult to determine the interdependencies between dependent and independent variables. However, by using improved mathematical models and optimization algorithms, it is possible to technologically improve and plan the production process.

For this experiment three different osmotic solutions (sugar beet molasses (OS_1), aqueous solution of sodium chloride (OS_2) and sucrose and the blend of OS_1 and OS_2 in a 1 : 1 ratio (OS3) were used for osmotic drying treatment of fish meat (Carassius gibelio). The treatment was performed for 5 hours, under atmospheric pressure, at four different temperatures. This work is concerned with determination of the optimum drying conditions by using Fuzzy synthetic evaluation - FSE. The optimization of eight response variables (water loss - WL, solid gain - SG, aw, dry matter content - DM and mineral content (K, Na, Ca, Mg) was based on models already developed by second order polynomial-SOP and artificial neural network - ANN.

The function maximum F represents the optimal values of the dependent variables and for OS_1 was 0.34, 0.36, 0.36, 0.35, for OS_2: 0.52, 0.57, 0.60, 0.62 and for OS_3: 0.69, 0.74, 0.80 and 0.88. Value of this function that is closer to 1 shows that process parameters are optimal.

It can be concluded that by using the FSE method the optimum values of the process parameters for the OS1 were at lower temperatures and at lower concentrations, while for the OS_2 and OS_3 the optimal values were reached at the maximum observed temperature range and concentrations.

***Key words**: Osmotic treatment, Fish, Optimization, Fuzzy.*

1. Introduction

Fuzzy synthetic evaluation was designed in order to describe knowledge and conclusions in a way that can be easily presented on a computer. The founder of the theory phase was Professor Lofti A. Zadeh in 1965, by introducing a new concept based on the fact that mathematics can serve to connect languages and human intelligence [1, 2]. The reality is better described by words than by mathematical formulas, and it is precisely by the phase of logic that through its expressions (phase rallies) provides the possibility of a simpler modelling of reality. Frequent changes and unpredictable situations make the real world a phase (vague, foggy), and the fuzzy synthetic evaluation gives us the ability to successfully manage real situations [1, 3]. Using classical logic, it is possible to use only information that is completely accurate or completely wrong. It is impossible to manage information that is imprecise or incomplete, although such information can sometimes provide a better solution to the problem. Affiliation to a set, in terms of classical logic, is denoted by a value of 0, if the element does not belong to the set, and with a value of 1, when the element belongs to the set. Phase sets are formed by generalizing the classical setup set, since the codename of the characteristic functions of the set is extended from the set {0, 1} to the unit interval. The argument in the fuzzy synthetic evaluation has multiple levels from a fully accurate over half-accurate to completely false. Behind the stage of logic, it stands approximately instead of precise conclusion, and its significance and great potential are reflected in the fact that human thinking by nature is approximate. One of the most important features of the fuzzy synthetic evaluation the ability to express the degree of indeterminacy in human thinking and its subjectivity [4, 5]. There are mechanisms in the field of logic, which find application in defining and finding the phase of functional dependencies in larger databases, which change the function of classical relations, integrating inaccuracy, uncertainty and inequalities negligible in real applications and systems [1, 6]. The importance and role of the functional dependency phase is in providing access to information from the database in a more flexible and accessible way. The goal is not to get as much information as possible, but more useful and more effective knowledge in terms of having filtered information in place of the vast amount of data stored in the observed relationships. Therefore, in practice, when making management decisions, the knowledge obtained by analysing the fuzzy functional dependencies is increasingly applied [1, 7]. Fuzzy synthetic evaluation is applied in cases that are characterized by the lack of a mathematical model or the existence of a model that is too complex. That is why the phase logic has found application in management theory, quantitative analysis, expert systems for diagnostics, planning and prediction, in a wide variety of commercial, information, engineering and industrial systems. Fuzzy synthetic evaluation is also successfully used to optimize the process of osmotic dehydration [8, 9, 10, and 11]. The osmotic dehydration process involves partial removal of water from fresh food material wherein the solutes from the osmotic solution are transported to the treated samples [12, 13]. This is one of the reasons why sugar beet molasses is attracting more attention as an advanced osmotic solution considering the fact that it has high dry matter and specific nutrient content [14, 15]. Molasses solids contains 47 - 48% of total sugar while non-sugar part includes mineral and trace elements such as: potassium, sodium, calcium, magnesium, iron, and copper followed by a range of important bioactive compounds such as crude proteins, non-nitrogen substances, vitamin B complex, biotin, etc. [16]. Osmotically treated fish meat can be used for the production of a variety of fish products such as: fish sticks, pasta, crackers, expanded or extruded fish snacks, etc. [17,18, 19].

The aim of the present study was to determine the optimum drying conditions for osmotic treatment of fish *(Carassius gibelio)* by using fuzzy synthetic evaluation-FSE. The optimization of eight response variables (water loss - WL, solid gain - SG, a_w, dry matter content - DM and mineral content (K, Na, Ca, Mg) was based on models already developed by second order polynomial-SOP and artificial neural network -ANN.

2. Materials and Methods

Fish (*Carassius gibelio*) was obtained from a local market in Novi Sad, Serbia, merely before the experiment. The initial moisture content of the fresh samples was 75.34%. Fish samples (1 x 1 x 0.5 cm) were prepared using kitchen slicer and scissors.

Sugar beet molasses was obtained from the sugar factory Crvenka, Serbia with initial dry matter content of 85.04% w/w, with distilled water it was diluted to concentration 80% w/w (solution OS_3). Osmotic solution-OS_1 was a water solution of sodium chloride and sucrose concentration of 70%w/w, while osmotic solution-OS_2 was a mixture of two other osmotic solutions (OS_1 and OS_3) in a mass ratio of 1:1.

After preparation samples were measured and immersed in hypertonic solutions. Sample to solution ratio was 1 : 5 (w/w) which can be considered high enough to neglect the changes of solution concentration during the process. The osmotic dehydration was carried out in laboratory jars under atmospheric pressure at constant solution temperatures of 10, 20, 35 and 50 ^{0}C.The osmotic dehydration was carried out for 5 h as it was described by [16].

The dry matter content of the fresh and treated samples was determined by drying the material at 105 ^{0}C for 24 hours in a heat chamber (Instrumentaria Sutjeska, Croatia). a_w of the osmotically treated samples was monitored by using a water activity measurement device (Testo 650, Germany) with an accuracy of ± 0.001 at 25 ^{0}C. Determination of K, Na, Ca and Mg content was performed using atomic absorption spectrometry (AAS) according to standard [20]. Water loss (WL), Solid gain (SG) and Dry matter content (DM) were calculated as described by [21]. All analytical measurements were carried out in accordance to [22].

The osmotic treatment optimization was performed according to the Fuzzy synthetic evaluation algorithm, using MicroSoft Excel 2007. All mathematical analyses were performed using StatSoft STATISTICA, ver. 10.

3. Results and Discussion

Sustainable industrial production requires optimization not only of products, but of the manufacturing process itself. Using an improved mathematical models and optimization methods, it is possible to technically improve and plan the production process with the aim of reducing energy and raw materials consumption.

The assessment phase can significantly contribute to the reduction of energy consumption.

The selection of the best process parameters (WL, SG, aw, DM, and contents of Na, K, Ca and Mg) for the particular raw material depends on the intended use of the product. Also, if the application of the final product is well known and the optimal values (WL, SG, aw, DM, and content Na, K, Ca and Mg), it is possible to find the optimal process parameters [11, 23, 25, and 26].

Valuation models are divided into single-criteria and multi-criteria. The common feature of single-criteria models is to evaluate a single criterion, which is their lack, but also an advantage because the process simplifies. The main goal of multicriteria methods is to prioritize between multiple variables or criteria. Solving multicriteria-based decision-making by applying the logic stage provides the possibility of selecting from the set of offered variants the one that is dominated by several criteria, and is most often used for modelling complex systems in which using other methods it is difficult to ascertain the interdependencies between individual variables.

In this study, nonlinear optimization problems were solved by fuzzy synthetic evaluation (FSE) method. The FSE handles all parameters based on pre-defined weights and decreases the dispersion by means of so-called membership function, giving quite high sensitivity in comparison with other valuation techniques [24]. For optimization, Microsoft Excel 2007 was applied based on the proposed SOP and ANN models. Here is the optimization of all 8 outputs based on models developed by SOP and ANN.

When designing a set stage, it is important to choose a particular function of membership A (x). This function shows how many x from set X meets the condition of belonging to set A. In the classical theory of logic, it can have one of two values, 1 and 0, i.e., the element belongs or does not belong to set A. In the theory, the set of attribute function phases can have any value between 0 and 1. If A (x) is larger than there is more truth in the claim that element, x belongs to set A, i.e., the element x is at higher level satisfies the conditions of belonging to set A [24].

Each stage of the set is completely and uniquely determined by its function of belonging. According to the theory phase, the choice of function of affiliation, that is, the form of function and the width of the confidence interval, is usually determined on the basis of subjective assessment or experience, but it is possible (as in this research) and based on the measured values or the mathematical model. The function of belonging to the stage set in this research is trapezoidal. The phase number A obtained from the trapezoidal function is usually determined on the basis of four typical points of the tramp in the abscissa and the ordinate axis. The trapezoidal function of belonging can be presented in the following way:

Table 1. Values of optimal parameters for 100 g of dried material

Consumer group	Parameter	WL	SG	aw	DM	K	Na	Ca	Mg
Extreme values	*a*	0.22	0.04	0.83	35.97	0.15	0.28	0.01	0.01
	b	0.57	0.15	0.93	66.30	0.85	1.30	0.09	0.05
Food for infants	*m*	0.57	0.04	0.83	40.00	0.40	0.12	0.02	0.03
	n	0.57	0.10	0.84	66.30	0.70	0.37	0.08	0.07
Baby food	*m*	0.57	0.04	0.83	40.00	0.30	1.00	0.05	0.08
	n	0.57	0.10	0.84	66.30	0.38	1.20	0.08	0.13
Adult men	*m*	0.57	0.04	0.83	40.00	0.45	1.20	0.10	0.20
	n	0.57	0.10	0.84	66.30	0.47	1.50	0.13	0.42
Adult women	*m*	0.57	0.04	0.83	40.00	0.45	1.20	0.10	0.24
	n	0.57	0.10	0.84	66.30	0.47	1.50	0.13	0.32
Pregnant women	*m*	0.57	0.04	0.83	40.00	0.47	1.50	0.10	0.35
	n	0.57	0.10	0.84	66.30	0.47	1.50	0.13	0.40
Nursing mothers	*m*	0.57	0.04	0.83	40.00	0.51	1.50	0.10	0.31
	n	0.57	0.10	0.84	66.30	0.51	1.50	0.13	0.36
Fitness food	*m*	0.57	0.04	0.83	40.00	0.45	1.20	0.10	0.24
	n	0.57	0.10	0.84	66.30	0.47	1.50	0.13	0.42
Older age	*m*	0.57	0.04	0.83	40.00	0.45	1.20	0.10	0.08
	n	0.57	0.10	0.84	66.30	0.45	1.20	0.10	0.13

$$A(x,a,m,n,b)=\begin{cases} a\le x<m, & \dfrac{x-a}{m-a} \\ m\le x<n, & 1 \\ n\le x<b, & 1-\dfrac{x-n}{b-n} \end{cases} \tag{1}$$

Where: x represents dependent variable and the values of a, b, m and n are function parameters. The interval a - b represents the extent to which the output value of the output variable is shifted, while the m - n is the expected optimum interval of the variable, chosen for certain product groups.

All three osmotic solutions (OS_1, OS_2 and OS_3) were simultaneously tested - Table 1 [23], taking into account that each group of consumers requires a product of the appropriate quality [11, 23].

The objective function (F) is a mathematical function whose maximum is determined by summing the trapezoidal function results. Each set of output parameters (WL, SG, aw, DM, and content Na, K, Ca and Mg) has been equally influenced by function F:

$$F(t,T,c)=0.125\cdot(\overline{WL}+\overline{SG}+\overline{aw}+\overline{DM}+\overline{Na}+\overline{K}+\overline{Ca}+\overline{Mg}) \tag{2}$$

Maximum function F is the optimum process parameters t, T and c, and also the optimal values of dependent variable WL, SG, aw, DM, and contents of Na, K, Ca and Mg, and is determined by equation [2]. Values of affinity function closer to 1 show that process parameters are optimal.

The values of optimization functions (F), optimum process parameters t, T and c, as well as the value of trapezoidal functions associated with the output sizes of the osmotic process are shown in Table 2.

The values of trapezoidal functions are estimated to range from 0 to 1, as shown by equation [1] and that the optimized function F represents the mean value of the calculated estimates for observed osmotic dehydration conditions. The optimal values of the osmotic dehydration process parameters for a first osmotic solution (OS_1) are at lower temperatures and at lower concentrations, while for the other two OS_2 and OS_3 optimal values are at the maximum observed temperature range and concentration. One of the reasons for this trend is high viscosity of sugar beet molasses at lower temperatures that affects the kinetics of the osmotic treatment [27].

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4. Conclusions

- On the basis of these results it can be concluded that by applying the FSE method the optimum values of the process parameters to the OS_1 solution were at lower temperatures and at lower concentration concentrations.

Table 2. Value of optimization functions, optimal process parameters and output value estimates of osmotic dehydration process

Osmotic solution	t	T	c	$\overline{WL}$	$\overline{SG}$	$\overline{a_w}$	$\overline{DM}$	$\overline{Na}$	$\overline{K}$	$\overline{Ca}$	$\overline{Mg}$	F
OS_1	5	10	60	0.7	0.51	0.85	0.5	0.16	0.02	0.01	0.08	0.34
OS_1	5	20	60	0.74	0.46	0.85	0.55	0.16	0.02	0.01	0.07	0.36
OS_1	5	35	60	0.79	0.28	0.85	0.81	0.14	0	0	0.03	0.36
OS_1	5	50	60	0.81	0.15	0.85	0.83	0.17	0	0	0	0.35
OS_2	5	10	70	0.83	0.41	0.85	0.61	0.46	0	0.3	0.52	0.52
OS_2	5	20	70	0.85	0.37	0.82	0.66	0.49	0.46	0.34	0.57	0.57
OS_2	5	35	70	0.88	0.24	0.91	0.88	0.55	0.45	0.34	0.56	0.6
OS_2	5	50	70	0.96	0	0.89	0.97	0.65	0.51	0.38	0.61	0.62
OS_3	5	10	80	0.85	0.41	0.8	0.68	0.72	0.72	0.71	0.69	0.69
OS_3	5	20	80	0.9	0.34	0.86	0.74	0.76	0.77	0.78	0.74	0.74
OS_3	5	35	80	0.92	0.22	0.86	0.93	0.86	0.86	0.87	0.86	0.8
OS_3	5	50	80	1	0.01	1	1	1	1	1	1	0.88

- For the OS_2 and OS_3 solutions optimal values were observed at the maximum observed temperature range and concentration.

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