

Predicting the Qualitative Changes of Silver Carp Packed in Vacuum with the Help of Response Surface Method

Forogh Zarif¹, Laleh Roomiani^{2*}, Sorosh Zarinabadi³

- 1- MSc. Student, Department of Chemical Engineering, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran
- 2- Associate Professor, Department of Fisheries, Islamic Azad University, Ahvaz Branch, Ahvaz, Iran
- * Corresponding author (l.roomiani@iauahvaz.ac.ir)
- 3- Assistant Professor, Department of Chemical Engineering, Ahvaz Branch, Islamic Azad University, Ahvaz, Iran

Abstract

In this study, central composite design was used to predict microbial changes, volatile nitrogen basic (TVB-N), sensory analysis and also the freshness factor of silver carp (*Hypophthalmichthys molitrix*) fillet packed in vacuum at 0, 6 and 12 °C for 5, 10 and 15 days optimized for the state-Ease Design Expert software. There was a significant difference between the treatments at time and temperature in the fillets of silver carp ($P < 0.05$). The two parameters of Inosine monophosphate (IMP) and inosine (HxR) showed a decreasing trend with increasing time and temperature ($P < 0.05$). Freshness and sensory analyses were in optimal mode in short time (5 days). In this test, the predicted values were consistent with a satisfactory percentage of 78%. The observations showed a good correlation between the results obtained by the experimental method and the predicted values by the statistical method. The models studied had R^2 and R^2 -adj coefficients of approx. 1, indicating that the experimental model used was able to predict fillet quality changes with low error percentage. The success of this can improve kinetic models in the food industry, so its application can help sustain food products.

Received: 2019.04.09

Accepted: 2019.09.26

Keywords

Hypophthalmichthys molitrix
Quality changes
Response surface methodology
Vacuum packaging

Introduction

Silver carp is one of the most important freshwater species (FAO, 2016) that its fillet, like other aquatic products, is susceptible to corruption due to enzymatic activities, microbial growth, and enzymatic reactions (Zhu, Luo, Hong, Feng, & Shen, 2013). Therefore, storage methods should increase shelf life of the food products. Vacuum packaging limits oxygen access that is the main factor for aerobic bacteria growth, keeps the moisture at an appropriate level, and prevents undesirable pollutants from the external environment (Genç, Esteves, Aníbal, & Diler, 2013).

A large body of information exists about the effect of vacuum packaging on many fish species such as Atlantic Herring (Özogul, Taylor, Quantick, & Özogul, 2000), carp (Křížek, Vácha, Vorlová, Lukášová, & Cupáková, 2004), and salmon (Dondero, Cisternas, Carvajal, & Simpson, 2004), but information about the prediction of the effect of packaging at refrigerator temperature on increasing the shelf life of fillet is very limited (Tsironi, Dermesonlouoglou, Giannakourou, & Taoukis, 2009; Wu, Wang, Luo, Hong, & Shen, 2014).

In addition to packaging, the use of kinetic models is an efficient managerial model that facilitates quality control of aquatic products over the storage period. On the other hand, many studies have shown that by using kinetic models, it is not possible to obtain satisfactory results to predict the quality of many species such as golden carp (Yao, Luo, Sun, & Shen, 2011) and ordinary carp (Bao, Zhou, Lu, Luo, & Shen, 2013), because these models have high deviations. Therefore, more studies are needed to promote the efficiency of the kinetic models (Liu, Qin, & Luo, 2016). The residual errors that indicate the difference between real and predictable values exist in these studies. However, most of these models cannot consider these errors in calculations (Tascikaraoglu & Uzunoglu, 2014). The difference between the logistic model and Arrhenius was studied by Bao *et al.* (2013) to investigate the qualitative changes in the ordinary carp in cold conditions. They concluded that both models are suitable for this purpose and the relative error between the observed values and the predictive values was 5%. The application of the hybrid model to predict qualitative changes and shelf life of the bighead carp was done by Liu *et al.* (2016). They evaluated K-value changes and microbial load at different temperatures and confirmed that this model is suitable to predict qualitative changes of fillet. Hong, Regenstein, & Luo (2017) investigated the predictive qualitative model to study the bighead carp shelf life at different temperatures and introduced it as an efficient tool to predict the freshness index in the temperature range of 3 to 15 °C.

To reduce the negative effects of errors, a hybrid model based on accuracy-error technique is proposed to generalize it in food models according to the mathematical models. Since this study is conducted recently and no similar study is conducted in Iran, the purpose of employing a hybrid model according to

error-accuracy technique was to predict some of qualitative changes in the fillet of the silver carp packaged under vacuum.

Materials and methods

Fish preparation

Several silver carps (*Hypophthalmichthys molitrix*) with the initial weight of 1200 ± 2.25 g were prepared from fish farms and transferred to the microbial and chemical laboratory of livestock and poultry in Sari. The fish were cleaned and their organs were removed. Three rectangular fillets with a dimensions of 5×15 cm were selected for each treatment and after vacuum packaging (NPR 200, Iran) at 0, 6, and 12 °C, they were stored for 5, 10, and 15 days, respectively. During storage in the ice, temperature was measured by using digital thermometer and temperature change was ± 1 °C (Liu *et al.*, 2016). To regulate temperature, ice was used and almost every day, ice was added to compensate for the melting ice and keep the temperature constant. In Table (1), the treatments used in this study are presented.

Table 1. Treatments to predict qualitative changes of the silver carp fillet packaged under vacuum

Treatment	Temperature	Day
1	0	5
2	6	5
3	12	5
4	0	10
5	6	10
6	12	10
7	0	15
8	6	15
9	12	15

Qualitative analysis of fillets

Sensory analysis

Sensory analysis was carried out by 20 trained men and women in the age groups of 25 to 27 years. Texture, taste, odor, and color of the samples were investigated with a 9-point Hedonic Scale with slight changes (Nirmal & Benjakul, 2011).

Microbial analysis

Total live bacteria count was done according to Standard 2325 (Iranian National Standardization Organization [ISIRI], 2016). For this purpose, 5 g of the sample with 45 mL of distilled water were transferred to the sterile stomacher bag and homogenized. Then, the solution was diluted to 10^5 mL. 1 mL of each dilution was poured into the pallet containing count agar medium. After several minutes, all pallets were placed in incubator for 48 h at a temperature of 37 °C. Bacteria were counted on days 5, 10, and 15.

Measurement of the freshness index and the related products

The freshness index and the related products were extracted by using the method proposed by Liu *et al.* (2016). 1 g of the muscle tissue was cut and solved with 2 mL of perchloric acid (10%) and mixed with 4000 rpm at a temperature of 4 °C for 5 min. After removing the supernatant, the precipitates were washed with 2 mL of perchloric acid and centrifuged with 4000 rpm at a temperature of 4 °C. This process was repeated for two times. All liquids were mixed and by using NaOH solution (1 mol/mL and 10 mol/mL) they reached 6.35-6.45 pH. Then, they were mixed with 3000 rpm for 3 min. The supernatant was removed and adjusted with 10 mL of perchloric acid (6.40 pH). The resulted solution was filtered by 0.22 μ m filter paper and stored at a temperature of -18 °C. Adenosine triphosphate (ATP), Inosine monophosphate (IMP), HxR (Inosine), and Hypoxanthine (Hx) values included adenosine triphosphate, inosine-5-monophosphate, inosine, and hypoxanthine, respectively (Liu *et al.*, 2016). The essential oil compounds were obtained by using chromatography machine (Agilent Technologies-7890A, USA) connected to mass spectrometry (Agilent Technologies-5975C, USA) with HP-5MS capillary column.

$$K_{value} (\%) = \frac{HxR + Hx \times 100}{ATP + ADP + AMP + IMP + HxR + Hx} \quad (1)$$

Measurement of TVB-N

Measurement of volatile nitrogen basic (TVB-N) was done by Automatic Kjeldahl Analyzer (K1100 Hanon, China). Then, 10 g of the sample was transferred to a 500 mL balloon. Also, 2 g of magnesium oxide was added as catalyzer and finally, 300 mL distilled water was added for dilution. In the next step, 25 mL of boric acid 2% was added to it. After system installation, the Kjeldahl machine was turned on and heated for 45 min until the solution inside the Erlenmeyer became yellow. Then, it was titrated with normal sulfuric acid 0.01 and became purple (AOCS, 1994).

$$TVB-N \text{ (mg/100 g)} = \text{Sample (mL)} - \text{Titrazol content of the control sample} \times 4.1 \times 100 \quad (2)$$

Data Analysis

The resulted data were analyzed by SPSS and State-Ease Design Expert V7 and Central Composite Design (Alpha = 1). The relationship between variables and the results of the tests was obtained as a linear approximate polynomial fitting model (i.e. linear equation, dual cross factor, second-order). Model appropriateness was investigated using analysis of variance and the quality was investigated by coefficient of explanation (R-Squared: R^2).

Results and discussion

Investigating the qualitative changes of silver carp fillet packaged under vacuum

Microbial load parameters, K-value, and its related parameters and TVB-N in the fillet of the silver carp packed under vacuum showed a significant difference in nine treatments ($P < 0.05$) and with increased time from 5 to 15 days and increased temperature from 0 to 12 °C, these parameters showed an increasing trend ($P < 0.05$). Accordingly, the highest microbial parameters value, VB-N, ATP,

and Hx were measured in day 15 and a temperature of 12 °C. It should be noted that adenosine-5'-diphosphate (ADP) and IMP values showed negligible values in all treatments and did not show any effect on the freshness index equation. 2 parameters of IMP and HxR showed a decreasing trend with increased time and temperature ($P<0.05$). Accordingly, in

both parameters, the lowest values were measured in day 15 and a temperature of 12 °C ($P<0.05$). Scores given to the sensory parameter showed a significant decrease over time and with increased storage temperature. Qualitative changes of the silver carp fillet packaged under vacuum are shown in Table (2).

Table 2. Investigating the qualitative changes of the silver carp filler packaged under vacuum

Treatment	Microbial load (Log CFU/g)	TVB-N (mg/100 g)	ATP ($\mu\text{mol/g}$)	IMP ($\mu\text{mol/g}$)	HxR ($\mu\text{mol/g}$)	Hx ($\mu\text{mol/g}$)	K (percentage)	Sensory index
1	3.58±0.10	9.43±0.25	0.16±0.007	7.18±0.09	4.46±0.14	0.13±0.02	54.42±2.77	9.23±0.16
2	4.51±0.27	10.59±0.07	0.23±0.01	6.13±0.02	3.18±0.09	0.16±0.01	52.04±1.95	8.80±0.78
3	4.87±0.29	18.33±1.09	0.29±0.02	3.23±0.17	2.30±0.07	1.30±0.07	89.64±3.46	6.05±0.56
4	4.44±0.26	11.73±0.15	0.20±0.007	6.31±0.04	4.15±0.06	0.41±0.00	65.03±1.42	5.88±0.18
5	8.38±0.04	18.00±0.78	0.25±0.007	4.28±0.04	2.61±0.05	0.73±0.02	66.33±1.03	5.49±0.89
6	8.70±0.11	31.47±1.11	0.43±0.02	1.45±0.24	1.59±0.01	2.71±0.04	95.62±0.41	5.21±0.13
7	5.44±0.11	13.10±0.66	0.23±0.007	5.35±0.16	3.58±0.12	0.70±0.10	70.46±2.02	4.35±0.21
8	9.56±0.06	22.25±0.14	0.27±0.007	1.18±0.04	2.21±0.05	2.58±0.03	77.47±3.13	4.23±0.17
9	10.56±0.12	42.07±0.62	0.59±0.02	0.65±0.13	1.48±0.05	3.33±0.31	98.04±0.86	3.91±0.33

Modeling

According to the results of analysis of variance of the effect of different factors including temperature and time on total microbial load and total volatile nitrogen of the fillets under vacuum, F-index is the ratio of model mean square to residual mean squares and its values for total microbial load and total volatile nitrogen

were 154.81 and 411.95, respectively (Fig. 1). These large values show that variance is larger than random error. According to Table (3), the fitted model is completely significant ($P<0.01$). Lack of goodness of fit test was not significant ($P>0.05$) that shows that employed model can show the data process very well.

Table 3. Analysis of variance of factors affecting the fillet quality of the silver carp

Source	df	Mean of squares							
		Microbial load	TVB-N	ATP	IMP	HxR	Hx	Freshness index	Sensory index
Model	5	49.98**	975.09**	0.15**	44.86**	18.10**	11.98**	4637.30**	435.16**
A-Radiation	1	25.42**	562.60**	0.084**	29.97**	15.19**	8.48**	4242.03**	350.68**
B-Time	1	15.20**	262.28**	0.027**	14.88**	2.53**	1.76**	384.99**	77.62**
AB	1	1.31**	105.78**	0.13**	0.23	0.039	0.82**	9.83	5.44*
A ²	1	5.47**	43.97**	0.018*	0.19	0.33**	0.92**	0.044	0.70
B ²	1	0.35*	3.62*	1.847E-003	0.49	8.403E-003	1.469E-003	0.13	0.72
Residual	7	0.45*	3.31	0.13	3.32	0.23	0.46	88.33	11.19
Lack of Fit	3	0.37 ^{ns}	2.11 ^{ns}	9.086E-003 ^{ns}	2.90 ^{ns}	0.09 ^{ns}	0.40 ^{ns}	26.96 ^{ns}	7.86 ^{ns}
Pure Error	4	0.079	1.20	3.880E-003	0.42	0.14	0.06	61.37	3.33
Cor Total	12	50.43	978.41	0.17	48.17	18.33	12.44	4725.36	446.35

*Significance at 0.05% **significance at 0.01 ns: non-significance

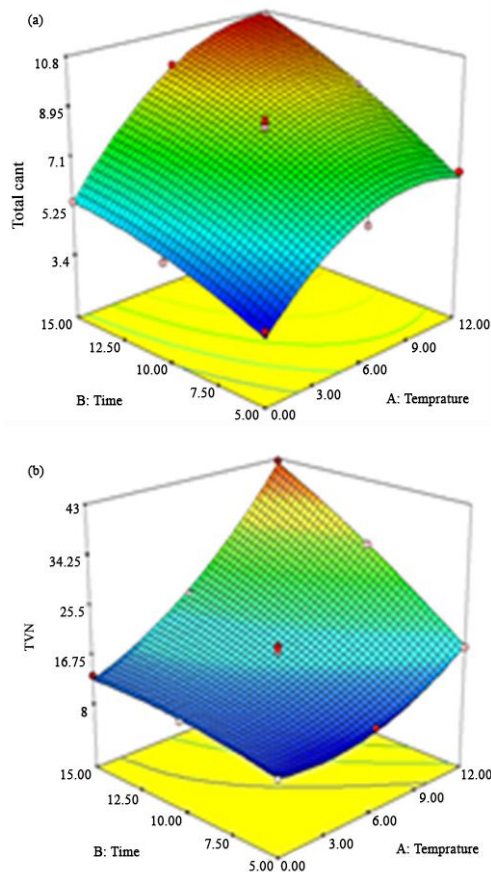


Fig. 1. The effect of input variables on changes a) total microbial load b) total volatile nitrogen

The results of analysis of variance of ATP production are presented in Table (3). The linear effect of temperature with high F-value (45.36) at a confidence level of 99% influenced ATP production. The linear parameter of time with lower curvature slope relative to temperature influenced ATP production ($P < 0.01$). Also, the interaction effect of temperature and time and the power effect of temperature at a confidence level of 95% influenced ATP production ($P < 0.05$). Fig. (2a) shows the 3D space of the effects of temperature and time on ATP production. According to the figure, increased temperature and time increased ATP production (Eq. 3).

(3)

$$Y_{ATP} = 0.23 + 0.12A + 0.067B + 0.058AB + 0.081A^2$$

In adenosine monophosphate test, the linear parameter of temperature and time at a confidence level of 99% influenced

inosine monophosphate ($P < 0.01$). Fig. (2b) indicates that temperature with higher curvature than time influenced IMP production, so that at lower temperatures, higher inosine monophosphate existed in fillets (Eq. 4).

(4)

$$Y_{IMP} = 3.97 - 2.24A - 1.58B$$

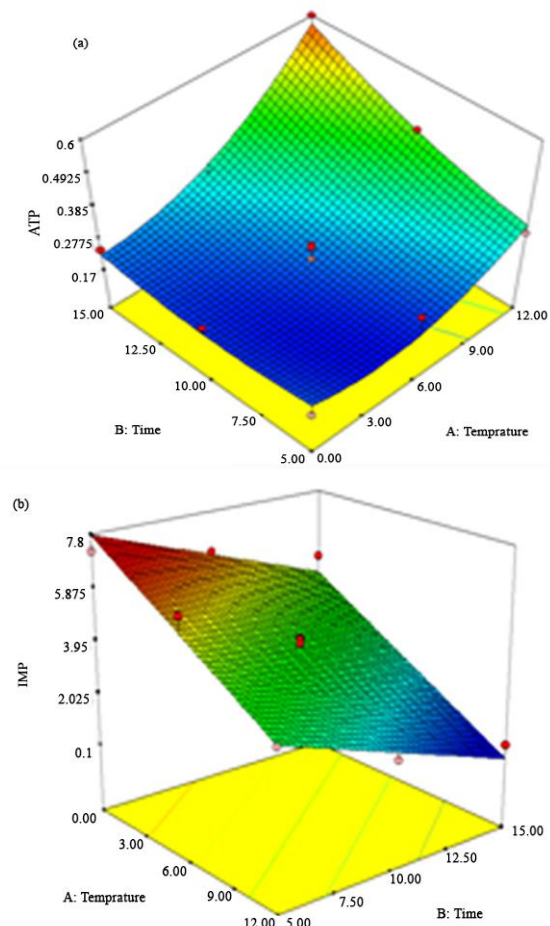


Fig. 2. The effect of input variables in a) ATP production b) IMP production in the fillet of the silver carp under vacuum

According to the response surface test output, the linear parameter of temperature and time significantly influenced inosine production in fillets ($P < 0.01$) (Table 2). Also, temperature at a confidence level of 95% influenced inosine production that indicates the effective role of temperature in inosine production in fillets. In this response, the effect of time on inosine production was not significant ($P > 0.05$). According to Fig. (3a), the temperature factor line was more effective in inosine

production with a higher slope. This figure indicates that fillets under vacuum at lower temperature had shorter time and higher inosine production (Eq. 5).

$$Y_{HXR} = 0.69 + 1.01A + 0.85B + 0.52A^2 \tag{5}$$

The results of the analysis of variance for inosine production in fillets under vacuum are presented in Table (3). In this test, the linear parameter of time at a confidence level of 99% ($P < 0.01$) with F-value of 30.85 had a significant effect on fillet hypoxanthine production. Also, the linear parameter of time with lower slope influenced fillet hypoxanthine production under vacuum. Fig. (3b) indicates that at higher temperature and time, the maximum hypoxanthine level existed in muscles (Eq. 6).

$$Y_{HX} = 0.69 + 1.01A + 0.85B + 0.52A^2 \tag{6}$$

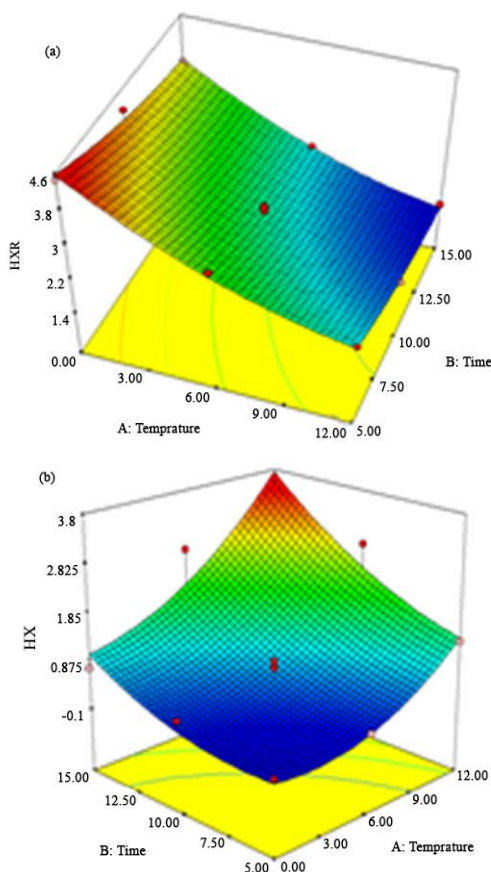


Fig. 3. The effect of input variables on a) HxR production and b) Hx production in fillets under vacuum

Changes in freshness index at high temperatures were considerable and this indicates the effect of temperature on this parameter ($P < 0.01$) (Table 2). According to the slope of the freshness index line, temperature (Fig. 4a) has a larger impact on this index (Eq. 7).

$$Y_{Kvalue} = 62.25 + 45.25A + 0.41B + 2.32B^2 \tag{7}$$

According to Table (3), the interactive effect of time and temperature indicates the dependency of these factors on sensory changes ($P < 0.05$). According to F-value, temperature factor (150.50) and temperature line slope in Fig. (4b) influenced sensory changes. In this test, the power effect of temperature and time on sensory changes was not significant. The fillets under vacuum at lower temperature and shorter time had larger sensory scores (Eq. 8).

$$Y_{sensory} = 11.10 - 5.01A - 3.60B \tag{8}$$

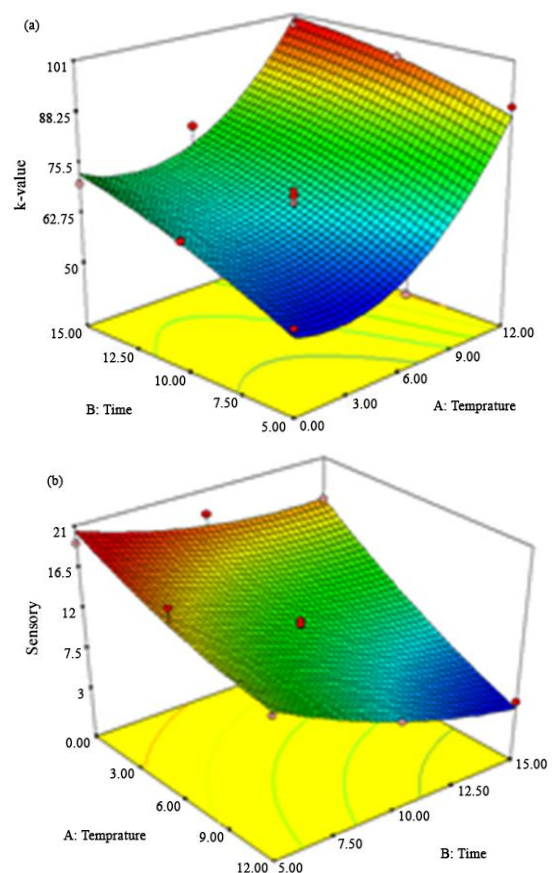


Fig. 4. The 3D diagram of the effect of input variables on a) freshness index b) sensory analysis of fillets under vacuum

In Table (4), the significance level of the fitted variables for fillets under vacuum is indicated. According to this table and R^2 level, the explained models are suitable for predictions.

Table 4. The fitted models for parameters for fillets under vacuum

Measured variable	R^2	R^2 -adj
ATP	0.9216	0.8655
IMP	0.9312	0.9174
HxR	0.9748	0.9569
Hx	0.9006	0.8297
Sensory index	0.9599	0.9312
Freshness index (K_{value})	0.9715	0.9512

In different studies, changes in ATP are used to evaluate freshness and corruption of fish and other aqueous products (Shi *et al.*, 2019). Since this study is an innovative study with high costs, it should be noted that its success is a potential model to improve efficiency of kinetic models and other models in food industry. In the current study, the qualitative changes of the silver carp packaged under vacuum were compared with the predicted conditions through surface response method. In experimental conditions, microbial load, TVB-N, ATP, and Hx with increased storage period from 5 to 15 days and increased temperature from 0 to 12 °C, showed a significant increase ($P < 0.05$). Özyurt, Polat, & Tokur (2007) reported different amounts of TVB-N for different fish as limit. According to this index, fishery products are divided into the following groups: 1) 25 g nitrogen/100 g meat; high quality 2) 30 mg nitrogen/100 g meat; good quality 3) 35 g nitrogen/100 g meat; consumption limitation 4) over 35 mg nitrogen/100 g meat; corrupted. According to Table (2), treatments 1, 0, 4, 5, 7, and 8 that were stored at 0 and 6 °C, showed high quality until day 15 and treatments 3, 6, and 9 that were stored at 12 °C, showed high quality until day 5, consumption limitation until days 10, and corrupted until days 15.

About microbial load, maximum acceptable total bacteria number for fish

and shrimp is proposed by the International Commission on Microbiological Specification for Foods as 7 Log cfu/g (ICMSF, 1986) that allows storage at 0 °C in days 5, 10, and 15 and for two temperatures of 6 and 12 °C, they were within the permitted range until days 5. According to these indexes, fish fillets under the temperatures of 6 and 12 °C in days 5 showed the best quality.

According to response surface methodology (RSM) analysis, the best treatment in terms of microbial load and volatile nitrogen was related to the silver carp fillets stored in 0 and 5 days and insignificance of the employed model confirmed the data process. Also, comparison of the empirical findings and RSM and the acceptance level (R^2 -adj and R^2) showed the similarity of the results and indicates that the presented model can predict the response of interest very well. Liu *et al.* (2016) studied the application of mathematical models to predict microbial load and TVB-N changes in the fillet of the bighead carp under vacuum and reported that the result of modeling is consistent with experimental findings. Bahramifar, Roomiani, & Askary Sary (2016) in a study on the effect of vacuum packaging on the storage of the grass carp (*Ctenopharyngodon idella*) reported increased microbial load and TVB-N that is due to the bacterial activities and autolytic enzymes available in fish meat. Rahmatipoor (2017) investigated the effect of the microbial load and TVB-N on the shelf life of the silver carp at a temperature of 4 °C with increased microbial load and TVB-N over the storage period. Increased volatile nitrogen loads is due to the aerobic bacteria (Hong *et al.*, 2017). This means that both parameters have similar processes and the parameters of temperature and time have equal effects on them. According to the proposed models and equations, the linear parameter of temperature and time influenced total microbial load and total volatile nitrogen of fillets under vacuum ($P < 0.01$). In a study by Ola & Oladipo

(2004), a strong relationship between total bacterial load and volatile nitrogen in filthy fillets was indicated ($r=0.98$). Moreover, Fazlara, Pourmahdi Brojeni, & Jaferi (2013) reported the consistency between bacterial load and volatile nitrogen. After the species death, ATP undergoes catabolization and becomes ADP, AMP, IMP, HxR and, Hx (Hong *et al.*, 2017). The sum of these parameters form K-value and high Hx values lead to low K-value.

K-value smaller than 20% indicates freshness, smaller than 50% indicates average quality, and over 60% indicates lack of freshness (Saito, Arai, & Matsuyoshi, 1959). According to Tables (2) and (3), with increased temperature and storage time, K-value index increased significantly and except days 5 and temperatures 0 and 12 °C, in other days, it indicates lack of freshness. Liu *et al.* (2016) investigated the effect of vacuum packaging in *Aristichthys nobilis* fillet quality and compared the mathematical model and the empirical model and reported increased K-value index over time as well as increased temperature that is consistent with the findings of the present study. They stated that storage in all times (days 0, 2, 4, 6, 8, 10, 12, 14, 16, and 18) and all temperatures (0, 3, 6, 9, and 12 °C) leads to a significant increase in K-value. Ehira & Uchiyama (1973) introduced K coefficient as the best freshness index that shows stronger relationship relative to other indexes. Mataragas, Bikouli, Korre, Sterioti, & Skandamis (2019) proved that time and temperature indexes are valid to recognize meat products corruption under isothermal and dynamic storage conditions.

About ATP and Hx, in experimental results as well as the production model, temperature and time are effective factors in production process that about ATP and Hx, the increasing trend was observable with temperature and time, so that in high temperature and long durations, ATP and Hx were at their maximum levels. Puchala & Pilarczyk (2005) investigated the effect of freezing on the quality of the ordinary

carp that ATP decomposition to inosine (HxR) in cold conditions and vacuum packaging was too slow, because the enzymes that convert ATP into IMP and then HxR consume oxygen and in cold conditions, their activities is influenced by the lack of oxygen. Moreover, in higher temperatures, ATP release from mitochondria increases (Saito *et al.*, 1959) and its deficiency is accompanied by the breakdown of IMP and HxR (Lougovois, Kyranas, & Kyranas, 2003) and this confirms reduced IMP and increased ATP (Hong *et al.*, 2017). IMP is one of the qualitative parameters of fillet (Lougovois *et al.*, 2003) and its reduction means decreased quality. They reported that hypoxanthine increases over the storage period of trout, Caspian kutum, and zander that is slow in +10 to +14 °C and very slow in +0 °C. On the other hand, this products causes bitterness in the texture (Kiesvaara, Heiniö, Mustranta, Hattula, & Hallikainen, 1992).

About IMP and HxR, temperature was more effective in IMP and HxR production and fillets under vacuum showed higher IMP and HxR in a short-term run. According to hypoxanthine production process from ATP production time, at high temperatures and long-term runs, ATP values of fillets increased and converted into inosine monophosphate, inosine, and hypoxanthine rapidly and inosine monophosphate and inosine values decreased. According to the explanations, fillets packaged under vacuum at 0 °C and days 5 showed the best consumption properties. Fillets under vacuum showed higher scores in terms of sensory analysis at low temperature and shorted time. Kumar, Dora, Sreekanta, Supratim, & Subha (2015) reported low sensory quality with increased storage time that is consistent with the findings of the present study, Yildiz (2017) investigated salty fillet changes using response surfaces and this modeling could predict changes in fillet. One of the reasons for reduced sensory properties is fat oxidation that

caused degradation and drop of sensory quality and reduced nutritional materials such as essential polyunsaturated fatty acids or PUFA and production of toxic oxidation products.

This result was observable both in model and empirical results. In sum, the fitted models as well as the predicted values for independent variables and dependent responses pointed to the consistency between the results and the empirical response and a temperature of 0 °C and time of 5 days constituted the best treatment for the storage of the silver carp fillet packaged under vacuum.

Conclusions

The current study showed that the silver carp fillets under vacuum and a temperature of 0 °C showed acceptable and desirable conditions for 5 days. According to the findings of this study, the real values of total microbial load and total nitrogen were similar. In investigating the freshness index and sensory analysis, it was observed that the amount of purine nucleotides and products of their decomposition, the silver carp fillet showed a desirable quality under vacuum and a temperature of 0 °C for 5 days.

References

- Ayoola, G., Johnson, O., Adelowotan, T., Aibinu, I., Adenipekun, E., Adepoju-Bello, A., . . . Odugbemi, T. (2008). Evaluation of the chemical constituents and the antimicrobial activity of the volatile oil of Citrus reticulata fruit (Tangerine fruit peel) from South West Nigeria. *African Journal of Biotechnology*, 7(13).
- Azeredo, H. M. C., Brito, E. S., Moreira, G. E. G., Farias, V. L., & Bruno, L. M. (2006). Effect of drying and storage time on the physico-chemical properties of mango leathers. *International Journal of Food Science and Technology*, 635–638.
- Burt, S. (2004). Essential oils: their antibacterial properties and potential applications in foods—a review. *International journal of food microbiology*, 94(3), 223-253.
- Caccioni, D. R., Guizzardi, M., Biondi, D. M., Renda, A., & Ruberto, G. (1998). Relationship between volatile components of citrus fruit essential oils and antimicrobial action on *Penicillium digitatum* and *Penicillium italicum*. *International journal of food microbiology*, 73-79.
- Chanthaphon, S., Chanthachum, S., & Hongpattarakere, T. (2008). Antimicrobial activities of essential oils and crude extracts from tropical Citrus spp. against food-related microorganisms. *Songklanakarin Journal of Science & Technology*, 30.
- Farajian, P., Katsagani, M., & Zampelas, A. (2010). Short-term effects of a snack including dried prunes on energy intake and satiety in normal-weight individuals. *Eating Behaviors*, 201–203.
- Farhat, A., Fabiano-Tixier, A.-S., El Maataoui, M., Maingonnat, J.-F., Romdhane, M., & Chemat, F. (2011). Microwave steam diffusion for extraction of essential oil from orange peel: kinetic data, extract's global yield and mechanism. *Food chemistry*, 125(1), 255-261.
- Fisher, K., & Phillips, C. A. (2006). The effect of lemon, orange and bergamot essential oils and their components on the survival of *Campylobacter jejuni*, *Escherichia coli* O157, *Listeria monocytogenes*, *Bacillus cereus* and *Staphylococcus aureus* in vitro and in food systems. *Journal of Applied Microbiology*, 101(6), 1232-1240. doi:<https://doi.org/10.1111/j.1365-2672.2006.03035.x>
- Fisher, K., Rowe, C., & Phillips, C. A. (2007). The survival of three strains of *Arcobacter butzleri* in the presence of lemon, orange and bergamot essential oils and their components in vitro and on food. *Letters in Applied Microbiology*, 44(5), 495-499. doi:<https://doi.org/10.1111/j.1472-765X.2006.02106.x>
- Harbone, J. (1998). A guide to modern techniques of plant analysis. *Pytochemical methods*, 3rd edition. Published by Chapman and Hall, London.

- Inouye, S., Uchida, K., Maruyama, N., Yamaguchi, H., & Abe, S. (2006). A novel method to estimate the contribution of the vapor activity of essential oils in agar diffusion assay. *Nippon Ishinkin Gakkai Zasshi*, 47(2), 91-98. doi:<https://doi.org/10.3314/jjmm.47.91>
- Jafari, S., Esfahani, S., Fazeli, M., Jamalifar, H., Samadi, M., Samadi, N., . . . Khanavi, M. (2011). Antimicrobial activity of lime essential oil against food-borne pathogens isolated from cream-filled cakes and pastries. *Int. J. Biol. Chem*, 5(4), 258-265. doi:<https://doi.org/10.3923/ijbc.2011.258.265>
- Kim, J., Marshall, M. R., & Wei, C.-i. (1995). Antibacterial activity of some essential oil components against five foodborne pathogens. *Journal of Agricultural and Food Chemistry*, 43(11), 2839-2845. doi:<https://doi.org/10.1021/jf00059a013>
- Kim, Y.-S., & Shin, D.-H. (2004). Volatile constituents from the leaves of *Callicarpa japonica* Thunb. and their antibacterial activities. *Journal of Agricultural and Food Chemistry*, 52(4), 781-787. doi:<https://doi.org/10.1021/jf034936d>
- Lin, C.-M., Sheu, S.-R., Hsu, S.-C., & Tsai, Y.-H. (2010). Determination of bactericidal efficacy of essential oil extracted from orange peel on the food contact surfaces. *Food control*, 21(12), 1710-1715. doi:<https://doi.org/10.1016/j.foodcont.2010.06.008>
- López, P., Sánchez, C., Batlle, R., & Nerín, C. (2007). Vapor-phase activities of cinnamon, thyme, and oregano essential oils and key constituents against foodborne microorganisms. *Journal of Agricultural and Food Chemistry*, 55(11), 4348-4356. doi:<https://doi.org/10.1021/jf063295u>
- Nazer, A., Kobilinsky, A., Tholozan, J.-L., & Dubois-Brissonnet, F. (2005). Combinations of food antimicrobials at low levels to inhibit the growth of *Salmonella* sv. Typhimurium: a synergistic effect? *Food Microbiology*, 22(5), 391-398. doi:<https://doi.org/10.1016/j.fm.2004.10.003>
- Nedorostova, L., Kloucek, P., Kokoska, L., Stolcova, M., & Pulkrabek, J. (2009). Antimicrobial properties of selected essential oils in vapour phase against foodborne bacteria. *Food control*, 20(2), 157-160. doi:<https://doi.org/10.1016/j.foodcont.2008.03.007>
- Nielsen, P. V., & Rios, R. (2000). Inhibition of fungal growth on bread by volatile components from spices and herbs, and the possible application in active packaging, with special emphasis on mustard essential oil. *International Journal of Food Microbiology*, 60(2-3), 219-229. doi:[https://doi.org/10.1016/S0168-1605\(00\)00343-3](https://doi.org/10.1016/S0168-1605(00)00343-3)
- Nychas, G., Drosinos, E., & Board, R. (1998). Chemical changes in stored meat. *The microbiology of meat and poultry*, 288-326.
- Papadima, S., & Bloukas, J. (1999). Effect of fat level and storage conditions on quality characteristics of traditional Greek sausages. *Meat Science*, 51(2), 103-113. doi:[https://doi.org/10.1016/S0309-1740\(98\)00103-X](https://doi.org/10.1016/S0309-1740(98)00103-X)
- Stacewicz-Sapuntzakis, M., Bowen, P. E., Hussain, E. A., Damayanti-Wood, B. I., & Farnsworth, N. R. (2001). Chemical composition and potential health effects of prunes: a functional food? *Critical reviews in food science and nutrition*, 41(4), 251-286. doi:<https://doi.org/10.1080/20014091091814>
- Stephen, A. M. (1983). 3 - Other Plant Polysaccharides. In G. O. Aspinall (Ed.), *The Polysaccharides* (pp. 97-193): Academic Press.
- Subba, M., Soumithri, T., & Rao, R. S. (1967). Antimicrobial action of citrus oils. *Journal of Food Science*, 32(2), 225-227. doi:<https://doi.org/10.1111/j.1365-2621.1967.tb01299.x>
- Suppakul, P., Miltz, J., Sonneveld, K., & Bigger, S. W. (2003). Antimicrobial properties of basil and its possible application in food packaging. *Journal of Agricultural and Food Chemistry*, 51(11), 3197-3207. doi:<https://doi.org/10.1021/jf021038t>
- Tinker, L. F., Davis, P. A., & Schneeman, B. O. (1994). Prune fiber or pectin compared with cellulose lowers plasma and liver lipids in rats with diet-induced hyperlipidemia. *The Journal of nutrition*, 124(1), 31-40. doi:<https://doi.org/10.1093/jn/124.1.31>

- Tyagi, A. K., & Malik, A. (2011). Antimicrobial potential and chemical composition of *Mentha piperita* oil in liquid and vapour phase against food spoiling microorganisms. *Food control*, 22(11), 1707-1714. doi:<https://doi.org/10.1016/j.foodcont.2011.04.002>
- Verma, S., & Sahoo, J. (2000). Improvement in the quality of ground chevon during refrigerated storage by tocopherol acetate preblending. *Meat Science*, 56(4), 403-413. doi:[https://doi.org/10.1016/S0309-1740\(00\)00072-3](https://doi.org/10.1016/S0309-1740(00)00072-3)

پیش‌بینی تغییرات کیفی کپور نقره‌ای بسته‌بندی‌شده در شرایط خلأ با کمک روش سطح پاسخ

فروغ ظریف^۱، لاله رومیانی^{۲*}، سروش زرین‌آبادی^۳

۱- دانشجوی کارشناسی ارشد، گروه مهندسی شیمی، واحد اهواز، دانشگاه آزاد اسلامی، اهواز، ایران

۲- دانشیار، گروه شیلات، واحد اهواز، دانشگاه آزاد اسلامی، اهواز، ایران

* نویسندهٔ مسئول (l.roomiani@iauhvaz.ac.ir)

۳- استادیار، گروه مهندسی شیمی، واحد اهواز، دانشگاه آزاد اسلامی، اهواز، ایران

چکیده

هدف از مطالعه حاضر استفاده از مدل‌سازی مرکب برای پیش‌بینی تغییرات میکروبی، میزان بازهای نیتروژنی فرار (TVB-N)، آنالیز حسی و نیز فاکتور تازگی فیلهٔ کپور نقره‌ای (*Hypophthalmichthys molitrix*) بسته‌بندی‌شده در شرایط خلأ بود. ماهیان بسته‌بندی‌شده در خلأ در دماهای صفر، ۶ و ۱۲ درجهٔ سانتی‌گراد که براساس خروجی نرم‌افزار State-Ease Design Expert بهینه‌شده بودند، به مدت ۵، ۱۰ و ۱۵ روز نگهداری شدند. درخصوص پارامترهای کیفی فیلهٔ کپور نقره‌ای بسته‌بندی‌شده، بین تمامی تیمارها در زمان و در درجه‌حرارت‌های موردبررسی اختلاف معنی‌داری مشاهده شد ($P < 0.05$). دو پارامتر اینوزین‌مونوفسفات (IMP) و اینوزین (HxR) با افزایش زمان و دما روند کاهشی را نشان دادند ($P < 0.05$). شاخص تازگی و آنالیز حسی در مدت زمان کوتاه (۵ روز) در حالت مجاز و بهینه قرار داشتند. در این آزمون مقادیر پیش‌بینی‌شده با درصد مقبولیت ۷۸ درصد با مقادیر برآورده‌شده همخوانی داشتند. مشاهدات بیانگر همبستگی خوب بین نتایج به‌دست‌آمده با روش تجربی و مقادیر پیش‌بینی‌شده با روش آماری بود. مدل‌های موردبررسی از ضریب تبیین (R^2) و ضریب تبیین اصلاح‌شده ($R^2\text{-adj}$) نزدیک به ۱ برخوردار بودند، که نشان می‌دهد مدل آزمایشی به‌کارگرفته‌شده، قادر به بررسی پیش‌بینی تغییرات کیفی فیله با درصد خطای پایین بود. موفقیت این کار می‌تواند سبب بهبود مدل‌های جنبشی در صنعت غذا شود، لذا کاربرد آن به ماندگاری محصولات غذایی کمک شایانی می‌کند.

واژه‌های کلیدی: بسته‌بندی خلأ، تغییرات کیفی، روش سطح پاسخ، کپور نقره‌ای