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Osmotic Dehydration Kinetics of Catfish (*Clarias Garipinus*) Muscles in Sodium Chloride Solution

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I. Introduction

Osmotic dehydration, as a preservation technique, is one of the most underutilized unit operations in post-harvest processing of biomaterials. It is a moisture removal process in which the sample is immersed in a hypertonic solution. During this process, two counter current flows dominate because of the semi-permeable nature of the plant cell structure. Thus water and other water soluble constituents flow from the tissues of the sample into the solution and a simultaneous transfer of solute from solution into the sample (Singhi et al, 2008; Taiwo et al, 2002; Park et al, 2002). Of course, the driving force for the diffusion of water from the tissue into the solution is provided by the higher osmotic pressure of the hypertonic solution. The most common hypertonic solutions applied for this complementary drying process are salts, alcohols, sorbitol and sugar solutions and the attendant beneficial effects of the osmotic dehydration are low energy cost, retention of nutritional value, eco-friendliness and stability of quality of product. However, the rate of water removal from any biomaterial, to a large extent, depends on several factors which include solute concentration, duration of dehydration, temperature, size and geometry of the material (Rastogi and Raghavarao, 2004).

These attendant advantages of osmotic dehydration over other conventional drying methods has led several scientists to investigate the osmotic dehydration of various biomaterials (Corzo and Gomez, 2004; Azoubel & Murr, 2003; Moazzam, 2012; Erle and Shubert, 2001).

However, information on the osmotic dehydration of Catfish is still lacking. Therefore, to optimize the important complementary drying process in the fishing industry, the objectives of this study are tailored to investigate the influence of solute concentration and immersion duration on weight reduction, water loss, solid gains, mass shrinkage ratio and dehydration rate, in sodium chloride solution.

II. Materials and Methods

a) Sample Preparation

Two matured market-size catfish (*Clarias garipinus*) weighing 1.8kg each were purchased from the Tombia Junction Market in Bayelsa State, Nigeria on July, 2014. The samples were immediately taken in plastic basins to the Food Processing Laboratory of the Niger Delta University, Bayelsa State and eviscerated. 32 samples weighing 5g each were cut out and five samples used to determine the initial moisture content using the oven method at 105^{0}C and the remainder for the experimentation proper.

b) Apparatus Used

The basic apparatus used for the experimentation were: a convective oven (Venticell, MMM, Medcener, Germany) which was used to determine the initial moisture content at 105^{0}C; a Camry digital balance for weight determination, 250ml beakers, conical flasks, 200ml measuring cylinder, chopping board and a kitchen knife were used.

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Nine (9) different concentration levels of sodium chloride (NaCl) solution were obtained in the following ratios:

Sample Code	Solution	
F_1	90% water	10% NaCl
F_2	80% water	20% NaCl
F_3	70% water	30% NaCl
F_4	60% water	40% NaCl
F_5	50% water	50% NaCl
F_6	40% water	60% NaCl
F_7	30% water	70% NaCl
F_8	20% water	80% NaCl
F_9	10% water	90% NaCl

The 5g samples were then immersed in the different osmotic solutions (%NaCl + % water) at a room temperature of 25^{0}C for a period of 5 hrs. A sample to solution ratio of 1:10 was used to avoid significant dilution of solute and the beaker occasionally agitated to ensure uniform mixture of absorbed water from sample. After 5 hrs, samples were withdrawn from the solution and the dehydrated samples bottled with absorbent paper to remove excess solution. Of course, at different time intervals within the 5 hrs, samples were withdrawn and weighed until the expiration of the 5 hrs. This procedure was replicated thrice and the average weights of samples recorded in accordance with AOAC (2000).

The desired response variables which included weight reduction (WR), water loss (WL), Solid gain (SG), mass shrinkage ratio (SR) and dehydration efficiency index (EI) were then calculated with the following equations.

$$WR\ (\%) = \frac{(w_i - w_f)}{w_i} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \qquad (1)$$

$$WL\ (\%) = \frac{(w_i x_i - w_f x_f)}{w_i} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \qquad (2)$$

$$SG\ (\%) = \left(wf\ \left(1 - \frac{x_f}{100}\right) - w_i\left(1 - \frac{x_i}{100}\right)\right) \times 100 \ldots\ldots\ldots\ldots\ldots. \qquad (3)$$

Where w_i and w_f are the initial and final sample weights, in grams respectively: x_i and x_f are the initial and final sample moisture contents, respectively in percentage. Similarly, mass shrinkage ratio was determined as

$$SR = \frac{W_t}{W_o} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \qquad (4)$$

Where W_t is weight at any time (t) (g) and W_o weight at time = 0 (g).

The dehydration efficiency index,EI was also obtained as follows

$$EI = \frac{WL}{SG} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \qquad (5)$$

c) *Statistical Analysis*

A descriptive statistical analysis was performed to compare the means and evaluate significant differences using one-way analysis of variance (Anova) at 95% confidence level.

III. Results and Discussions

a) *Weight Reduction, WR (%)*

Figure 1 provides an overview of the average values of percent weight reduction of catfish muscles as influenced by concentration of solute and dehydration time. Generally, WR (%) increased from 5 minutes to 5 hrs of immersion time for all concentration levels. At F9, 8.0% of weight reduction was noticed after 5 minutes of dehydration. This value increased to 32.0% after 5 hrs. For F1, no weight reduction was observed in the first 25 minutes of dehydration, but a weight reduction of 4.0% was recorded after 5 hrs. Beneficially, F7 showed the best results as it had the highest values for WR. These results show that both solute concentration and immersion time had significant effects on percentage weight reduction of catfish muscle during osmotic dehydration. To prove this observation, a statistical analysis (Anova) was performed at 95% confidence level and the results presented in Table 1 indicated that the effect of solute concentration and immersion was very significant .Similar results had been reported by

Collignan et al (2001) on the osmotic treatment of fish and meat

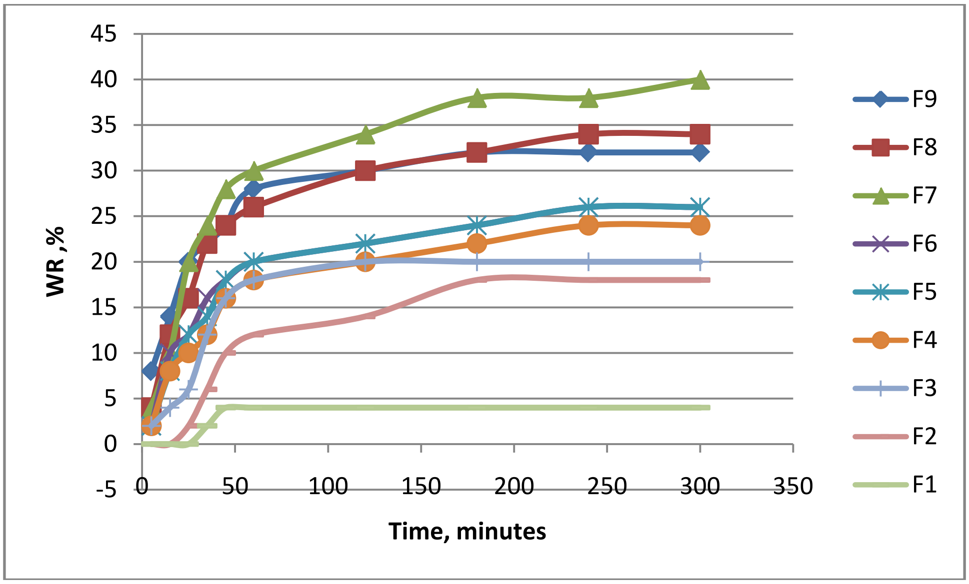

Figure 1 : Response of weight reduction WR (%) to solute concentration and immersion time

Table 1 : One-Way Anova on effect of NaCl concentration and immersion time on WR

Source	SS	DF	MS	Prob	F- ratio	F-critical
Between group	1980.250	1	1980.250	0.0001	32.867	4.6001
Within group	843.5000	14	60.25			
Total	2823.75	15				

b) Water Loss, (WL) (%)

Graphical judgment of average percent water loss values are shown in Figure 2. It is clear, that in all cases, water loss increased with increase in both solute concentration and immersion time. Evidentially, at F9, WL value of 13.7% was recorded within 5 minutes of immersion, but increased to 47.36% after 5 hrs.

It was however different at F1, where no water loss was noticed within the first 25 minutes of immersion but increased later to 7.04% after 5hrs. This initial delay in WL at F1 is, perhaps, due to the low osmotic pressure exhibited in the 10% NaCl and 90% water concentration. Here also, F7 displayed the best NaCl concentration level with the highest water loss value. These results point to the fact that both solute concentration level and immersion time had important roles to play in the osmotic dehydration of catfish muscles. These findings agree with those of Milica et al (2013) on *carassius carassius* and Azoubel and Murr (2003) on cashew. An Anova shows that these variables are significant to water loss (p= 0.0000) as indicated in Table 2.

Figure 2 : Effect of NaCl conc and immersion time on water loss

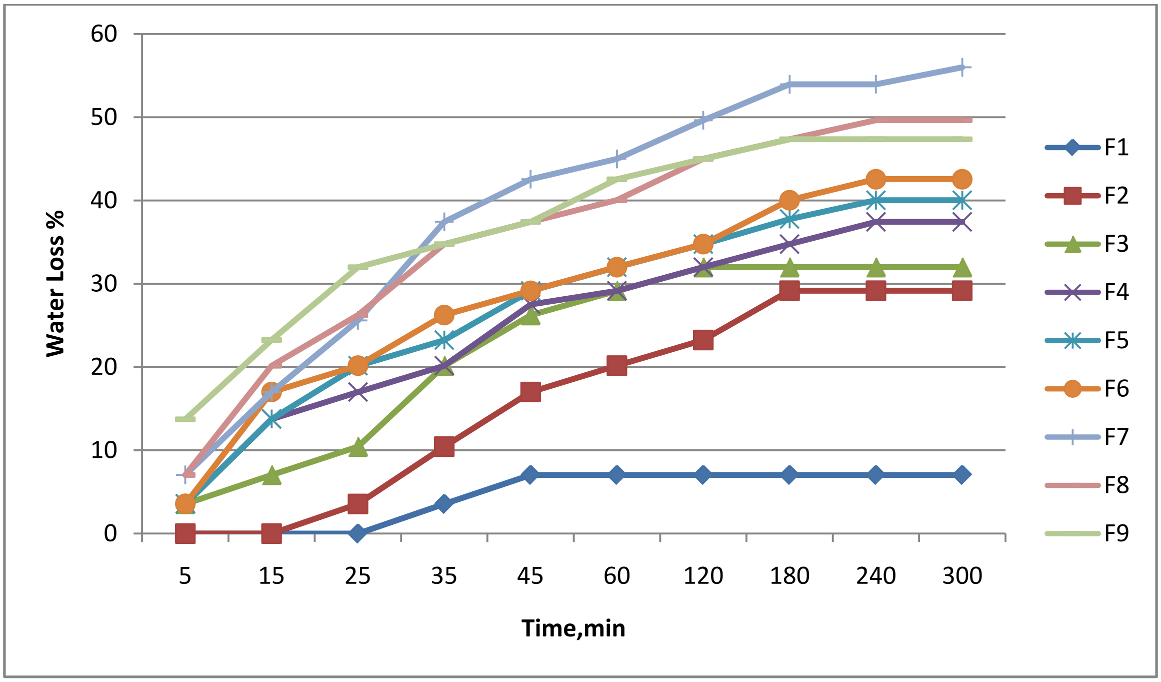

Table 2 : One-Way Anova on effect of NaCl concentration and immersion time on WL

Source	SS	DF	MS	Prob	F-ratio	F-critical
Between group	4407.6321	1	4407.6321	0.0000	38.707	4.6001
Within group	1594.1886	14	113.8706			
Total	6001.8207	15				

c) *Solid Gain, SG (%)*

Solid gain which is the transfer of solute molecules from the solution into the catfish muscles was investigated as a function of solute concentration and immersion duration. Figure 3, therefore shows the graphical view of the effect NaCl concentration and immersion time on solid gain. Results show that, generally, solid gain increases positively with increase in solute concentration and immersion duration. At F9, 11.03% of solid gain was recorded in 5minutes of immersion, but increased to 25.83% in 3 hrs and then remained constant for the rest 2 hrs. This trend was noticeable in virtually all solute concentration levels, implying that osmotic pressure attained equilibrium state after 3 hrs of dehydration.

However, average values of solid gain in F1 were found to be 0.0% for the first 25 minutes of dehydration but increased to 5.92% after 45 minutes and remained constant for the rest of the experimentation. At 95% confidence interval, Anova reveals a significant difference between means of SG values (Table 3). It therefore shows that solute concentration and immersion duration play significant roles in the solid gain of catfish muscle during osmotic dehydration. Comparatively, results presented here concur both in immersion time and solute concentrations with that of Milica et al (2013) on Carassius muscles.

Figure 3 : Effect of NaCl concentration and immersion time on Solid Gain

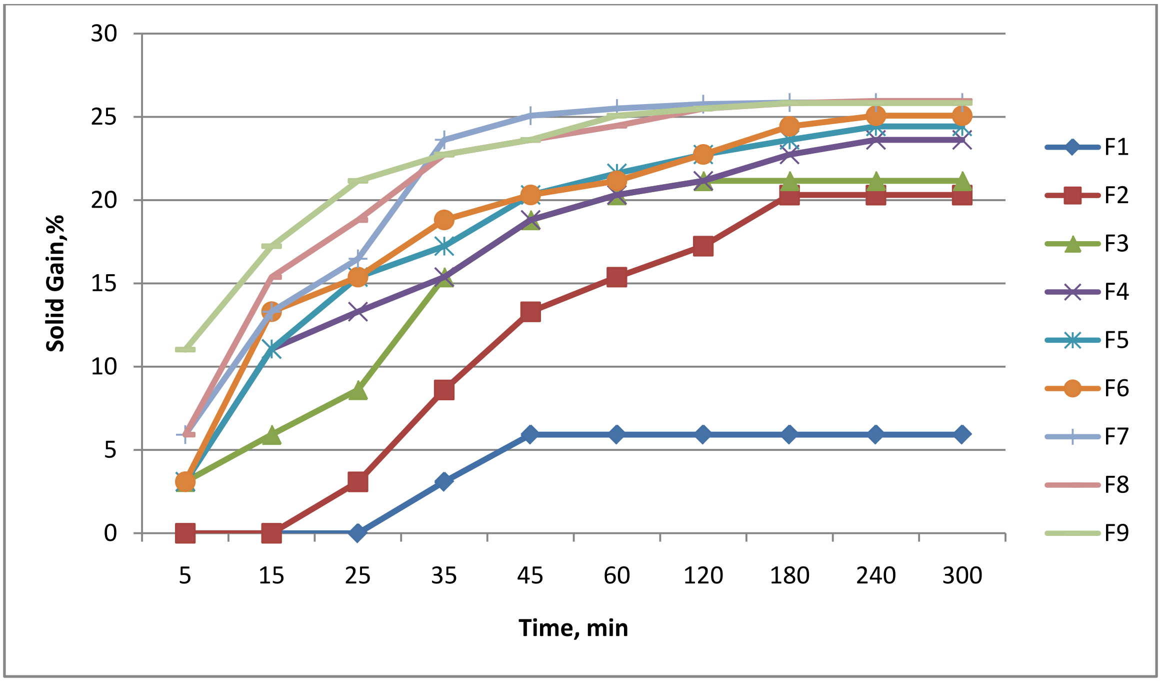

Table 3 : One-Way Anova on effect of NaCl concentration and immersion time on SG

Source	SS	DF	MS	Prob	F-ratio	F-critical
Between group	1352.9523	1	1352.9523	0.0000	54.7916	4.6001
Within group	345.6976	14	24.6927			
Total	1698.6499	15				

d) Mass Shrinkage Ratio (SR)

As dehydration progresses, structural changes occur in the sample due to weight loss. This can be accounted for by the mass shrinkage ratio as recommended by Midilli, 2011 and Shanmugama and Natarajan, 2006. Results of mass shrinkage ratio of catfish muscle as affected by sodium chloride concentration and immersion time are graphically presented in Figure 4. Generally, shrinkage ratio decreases with increase in immersion time. For F9 and at 5 min of immersion, a shrinkage ratio of 0.92 was recorded. This SR value decreased to 0.68 in 5 hrs. Also, for F1 and at 5 min of immersion, no shrinkage was noted but became 0.96 after 5 hrs. Similarly, shrinkage ratio decreased with increase in sodium chloride concentration levels. After 5 hrs of dehydration, mass shrinkage ratio values of 0.96 and 0.68 were recorded for F1 and F9 respectively. This is attributed to the fact that, as sodium chloride concentration and immersion time increases more water loss and weight reduction was observed. F7 again showed the lowest and best shrinkage ration of 0.60 after 5hrs of dehydration. Table 4 shows the result of the ANOVA on the effect of sodium chloride and immersion time on mass shrinkage ratio. These results agree positively with the findings of Saeed et al (2008) and Midilli (2001) for Roselle and Pistachio fruits respectively.

Figure 4 : Effect of NaCl concentration and immersion time on shrinkage ratio (SR)

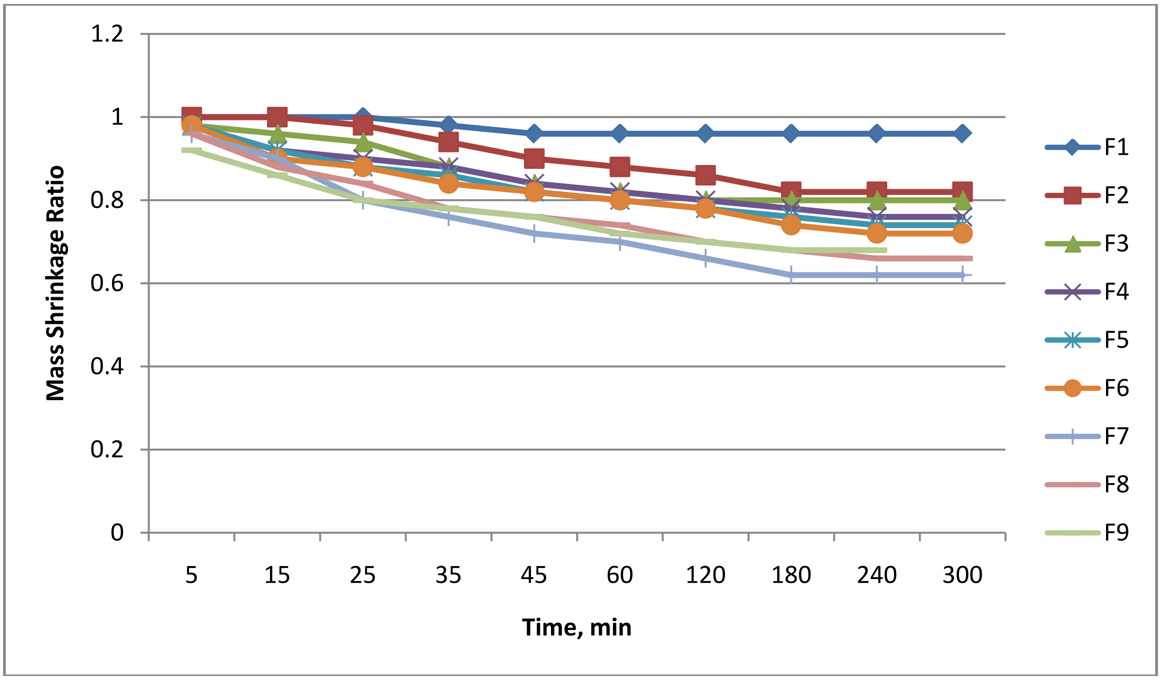

Table 4 : One-Way Anova on effect of NaCl concentration and immersion time on SR

Source	SS	DF	MS	Prob	F-ratio	F-critical
Between group	0.1980	1	0.1980	0.0001	32.867	4.6001
Within group	0.0844	14	0.0060			
Total	0.2824	15				

e) Dehydration Efficiency Index (EI)

In every osmotic dehydration regime, the effectiveness of the process is been determined by the value of the dehydration efficiency index. Thus, high efficiency index ratios indicate high water removal from the sample with minimal solid gain. Conversely, low EI ratios indicate high solid gains and minimal water removal which is undesirable in any osmotic dehydration process. For this work, EI ratios increased with increase in immersion time. At F9, EI values of 1.24 and 1.83 were recorded for immersion times of 5 min and 5 hrs respectively. For F1, no efficiency index value was recorded for the first 25 min but increased to 1.18 in 45 min of dehydration and then remained constant for the rest 4 hours. This may be as a result of low osmotic pressure characterized by low NaCl concentration in the hypertonic solution. These results points to the fact that as immersion time increases, EI increases. Similarly, EI values increases linearly with increase in solute (NaCl) concentration. However, the highest EI value of 2.18 was recorded in F7 implying that hypertonic solution concentration levels of 30% NaCl and 70% water was the best. Overall, F7 still gave the best results and the statistical analyses on Table 5 shows that EI is significantly controlled by both sodium chloride concentration and immersion time.The results here are in concordance with the work of Milica et al (2013) on Carassius muscles.

Figure 5 : Effect of NaCl concentration and immersion time on EI

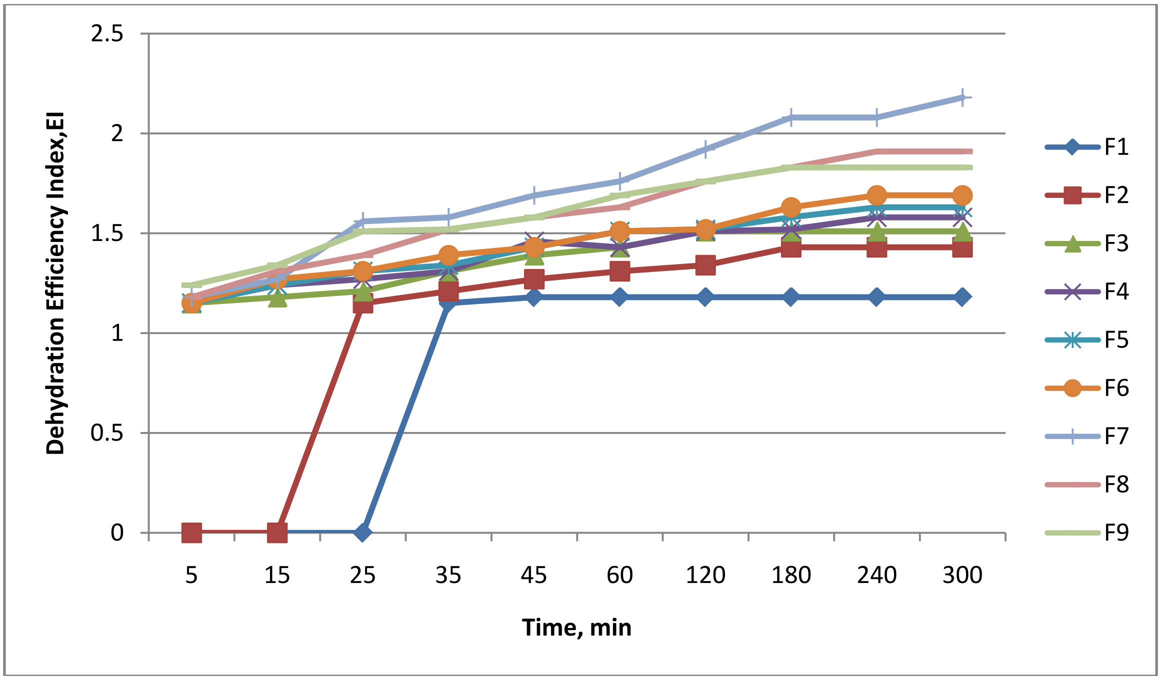

Table 5 : One-Way Anova on effect of NaCl concentration and immersion time on EI

Source	SS	DF	MS	Prob	F-ratio	F-critical
Between group	2.3639	1	2.3639	0.0034	32.867	4.6001
Within group	2.6629	14	0.1902			
Total	5.0268	15				

IV. Conclusions

Based on the findings of this experimentation, it can be concluded that solute (NaCl) concentration and immersion time both contributes significantly to osmotic dehydration of catfish muscle. The highest values of WR and WL were recorded in F7 after 5 hours of immersion in the hypertonic solution. F7 also recorded the highest dehydration efficiency index and lowest mass shrinkage ratio after 5 hours of dehydration. This makes F7 the best NaCl concentration level for dehydrating Catfish.

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