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Combined Effects of Light Salting and Microwave Pre-Drying on the Quality of Rainbow Trout (*Oncorhynchus mykiss*) Fish Nuggets

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Abstract: In this research, the combined effects of 8 and 10 percent light salting (by weight) and microwave pre-drying procedure at temperature of 180°C in 30, 60 and 90 seconds on the quality of rainbow trout nuggets were examined. Overall 7 treatments were consists of control treatment (battered and breaded fillets- without light salting and pre-dryin), A8 (8% light salted fillets, pre-dried 30 minutes, battered and breaded), A10 (10% light salted fillets, pre-dried 30 minutes, battered and breaded), B8 (8% light salted fillets, pre-dried 60 minutes, battered and breaded), B10 (10% light salted fillets, pre-dried 60 minutes, battered and breaded), C8 (8% light salted fillets, pre-dried 90 minutes, battered and breaded), C10 (10% light salted fillets, pre-dried 90 minutes, battered and breaded). Different treatments showed significant differences in moisture and fat contents. Consequently, the highest moisture content was observed in the control treatment, while the highest and the lowest amount of fat detected in the control treatment (8.07±0.24) and A10 treatment (6.28±0.04) respectively ($p < 0.05$). The amount of product yield, water holding capacity and sensory evaluation did not reveal significant differences among the treatments ($p< 0.05$). However, the amount of pH, color indexes and reduce of oil uptake in other treatments were significantly lower than the control treatment ($p < 0.05$). Treatment A10, with moisture value of 51.93 and fat content of 6.28 showed the highest moisture content (after control treatment) and the least amount of fat among all treatments. According to the results of this study, the combined effects of light salting and pre-drying processes did not reveal any significant influence on the quality of produced rainbow trout fish nuggets, but caused reduction of oil absorption during the deep frying process.

Key words: Fish Nuggets % Light Salting % Pre-Drying % Deep Frying % Rainbow Trout

INTRODUCTION

In this study, rainbow trout (*Oncorhynchus mykiss*), one of the most popular fish, which is reproduced in large areas of the country was used to produce fish nuggets. Pre-frying battered and breaded products such as fish nugget, fish finger, breaded fish and shrimp can be absorbed amount of oil up to 15 to 30 percent of the product's weight. The presence of large amounts of oil in these products can cause some sorts of concerns for their consumers in terms of health, obesity, or cardiovascular diseases. These concerns could adversely affect the marketing of the final products [1, 2].

Some ways to reduce the amount of oil uptake in the battered and breaded products are improving batter compound, eliminating pre-frying steps, cooking with microwaves and, decreasing the initial moisture content of the food product [2, 3]. Since the main effective factor in oil uptake is batter formula, several attempts has been done to improve the batter formula in battered and breaded products qualities so that their oil uptake would be reduced. The most significant attempt was the application of small amounts of hydrocolloids (usually one percent by dry weight of batter formula) in the batter formula [4].

The gel-forming ability of hydrocolloids, with their natural hydrophilic properties, enables them to prevent oil absorption in the battered and breaded products. In these processes, methylcellulose (MC) and hydroxypropyl methyl cellulose (HPMC) have most applications [5-8]. Two of the best recommendations to reduce the oil content are to lower the initial moisture content as well as

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to keep the remaining moisture content during the deep fat frying process [3]. According to previous studies, reducing water availability through immersion of potato slices in salt solution could reduce oil absorption in fried potatoes [9]. Moreover, pre-drying of potatoes before frying using microwave, hot air current and cooking can also lead to a significant reduction of oil content in different products of potatoes [10, 11].

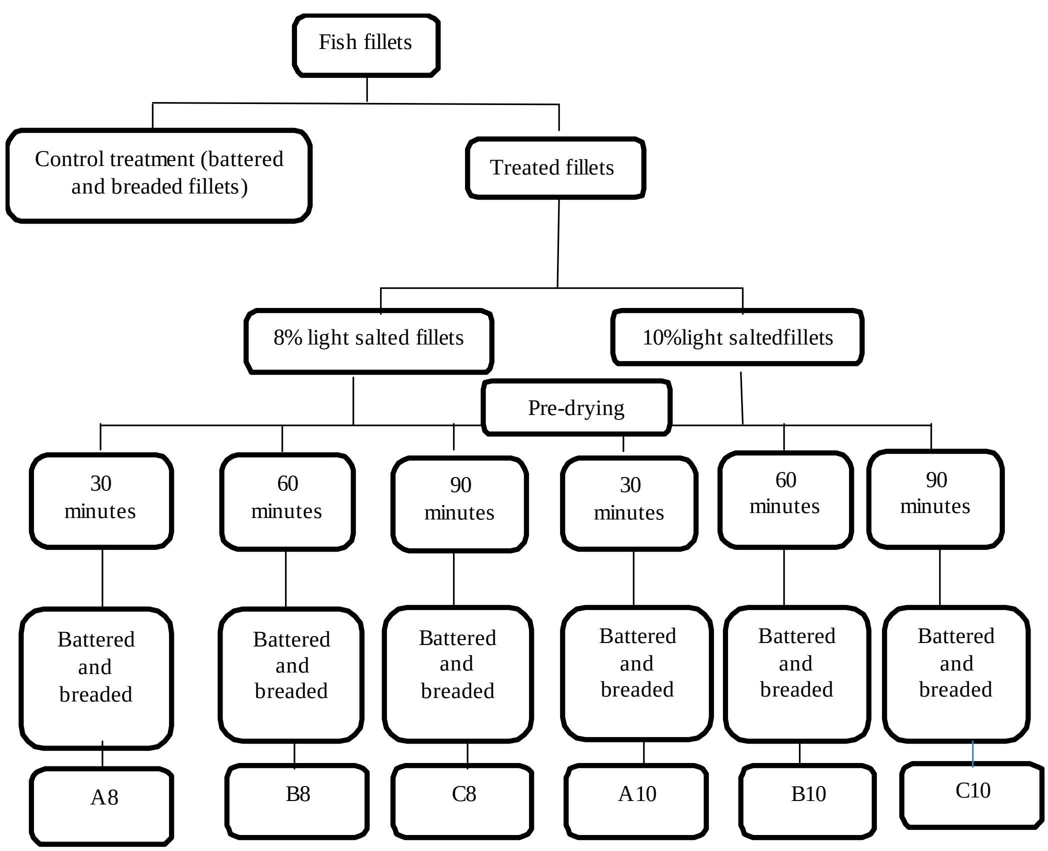
In addition through osmosis process, salt can enhance the meat flavor that causes exit of some moisture and reduces water activities. This water exit also will result in limited bacterial growth and less enzymes activities. In the process of light salting, the added salt amount is 8 to10 % of the product weight which makes the salt concentration of the product 4 to 6 %. Light salting as no effect on protein denaturation and can reduce16 to18 % of the product initial [12].

Amount of salt intake depends on several factors such as fish species, fish size, weight, thickness, meat properties, composition, physiological status, method of salting, salt concentration, duration of salting and ratio of salt to fish. Due to the existing differences between the concentration and osmotic pressure of the meat cells and the salt factors, usually two parallel streams occur in fish salting processes: exit of water and absorption of salt. These processes themselves lead to changing meat characteristics [13, 14].

The aim of this study was to investigate the combined effects of light salting and microwave pre-drying at 180°C on quality and amount of oil absorption in rainbow trout nuggets.

MATERIALS AND METHODS

Fish Nugget Production: Fresh rainbow trout (*Oncorhynchus mykiss*) weighing around 350±10 g and taken from local markets of the Gorgancity after appropriate ice storage it were transferred to the fish-processing laboratory of Gorgan University of Agricultural Sciences and Natural Resources. After washing, the fishes were beheaded, gutted, washed and filleted by hand. The back parts of the rainbow trout, that had equal diameters, were used for the production of fish nuggets. The fillets were cut with a sharp knife into rectangular-shaped portions (fish nuggets) in measures of 5×3×2 and weights of 27±3g.



Flowchart 1: Light salting and pre-drying rainbow trout fish nugget samples

After separating the fillets for the control trearment, remaining fillets were divided into two groups and exposed to 8 and 10 percent of salting respectively. Light salting time was 15 minutes. Each 8 and 10 light salted groups divided into three groups and each group pre-dried in 180°C at three different times of 30, 60 and 90 minutes. Overall 7 treatments were consists of control treatment (battered and breaded fillets- without light salting and pre-dryin), A8 (8% light salted fillets, pre-dried 30 minutes, battered and breaded), A10 (10% light salted fillets, pre-dried 30 minutes, battered and breaded), B8 (8% light salted fillets, pre-dried 60 minutes, battered and breaded), B10 (10% light salted fillets, pre-dried 60 minutes, battered and breaded), C8 (8% light salted fillets, pre-dried 90 minutes, battered and breaded), C10 (10% light salted fillets, pre-dried 90 minutes, battered and breaded) (Flowchart. 1). The microwave oven was heated for 45 minutes to achieve 180°C prior to drying [3].

After salting and pre-drying operations, pieces of fish were pre-dusted with wheat flour then immersed in batter formula. That batter formula was developed according to the Chen *et al*. [7] formula, which consisted of 55 % wheat flour, 30 % cornstarch, 10 % gluten, 2 % leavening and 3 % salt that were mixed with water at 10°C in ratios of 1:1/5 (water to solid ratio). After the distillation of the extra batter for 30 seconds, nuggets were breaded with conventional breading crumbs. The battered and breaded fish nuggets were pre-deep-fried in sunflower oil at 190°C for 30 seconds (Moulinex Toucan Automatic fryer, Portugal) and after being allowed to cool down at room temperature, the nuggets were packed in Ziploc bags and stored at -20°C. After one week of maintenance, the produced nuggets were removed from the freezer. They got thawing in room temperature; the final frying procedure was performed at 180°C for 2.30 minutes. Finally, after their cooling, the required analyses were implemented.

Moisture and Fat Analysis: Moisture and fat content of samples were analyzed by the method of AOAC [15]. The 10g of each sample were dried in an oven at 105°C until constant weights were achieved and moisture content was calculated. Samples were then extracted using a Soxhlet extraction (416 SE, Gerhardt, Germany) with petroleum ether for 2.30 hour to determine fat content.

Amount of Reducing Oil Uptake: The percentage of oil uptake reduction was calculated by using Daraiigarmkhane *et al*. [16] as:

$$A\ (\%) = (S_{AF} - S_{BC}) / (S_{BC}) \times 100$$

A = The amount of oil uptake reduction (%)
S_{AF} = The amount of oil uptake in samples after coating
S_{BC} = The amount of oil uptake in samples before coating

Product Yield: The weight of each coated fish fillets was recorded before and after deep fat frying. The product yield was calculated and expressed as percentage by weight of frying fish fillets/weight of raw fish fillets×100 [17].

Water Holding Capacity: The expressible water is inversely related to the water holding capacity (WHC) and lowest percent of water extracted means the highest WHC. For measuring expressible water of the fish fillets According to Das *et al*. [17], about 5 g cooked sample weighted onto two layers of Whatman No. 1 filter paper. The samples were placed at the 50 ml centrifuge tubes and centrifuged at 1500 rpm for 5 min. Then the meat samples were re-weighted and the amount of expressible water was calculated as:

$$EW\ (\%) = (W1 - W2) / W1 \times 100$$

EW = Expressible water
W1 = Initial weight
W2 = Final weight

The pH Measurement: The pH measurement was carried out using a pH Lat Stirrer Metrohm model 728 pH meter. Fish nugget (5 g) was homogenized thoroughly with 45 ml of distilled water and the homogenate was subjected to pH determination in a room temperature according to the method of Das *et al*. [17].

Color Measurements: Samples color with three replicates was measured with a Lovibond (Lovibond CAM-system, England 500). The parameters determined were L* is an approximate of lightness between black and white within the range 0-100, redness (+a*) or greenness (-a*) and yellowness (+b*) or blueness (-b*) [18].

Sensory Evaluation: The sensory evaluation of rainbow trout fillets was carried out according Das *et al*. [17] by seven trained panelists. The fish fillets were deep-fried in sunflower oil at 180°C for 2 minutes. The panelists were scored for color, odor, flavor, texture and general acceptability on an 8-point hedonic scale sensory evaluation (1: dislike extremely to 8: like extremely).

Statistical Analysis: The statistical analysis of the data was performed through using one-way analysis of variance (ANOVA).The results were processed by SPSS 18.0 analysis. Test of significant differences between groups was determined by Duncan's multiple range test calculated at $p < 0.05$. Non-parametric Kruskal-Wallis tests for analysis of sensory data (for multiple group comparisons) and Mann-Whitney (for comparison with other groups) were used. The graphs were plotted in Excel software.

RESULTS

The results of moisture and fat studies on fried nuggets showed significant differences among different treatments ($p < 0.05$) (Fig. 1). Control treatment showed the highest and A8 and B10 treatments showed the lowest moisture content ($p < 0.05$), while the highest and lowest amount of fat were observed in control treatment with 8.07±0.24 and A10 treatment with 6.28±0.04 ($p < 0.05$).

In Table 1, the amounts of pH, water holding capacity (WHC), product yield and percentage of oil uptake reduction are shown for different treatments of rainbow trout nuggets. The product yield and WHC did not show any significant differences among the treatments ($p < 0.05$), while pH value and percentage of oil uptake reduction decreased significantly in all treatments except the control one ($p < 0.05$). The lowest amount of pH was observed in C8 treatments and the highest amount of oil uptake reduction was observed in A10 treatment.

Changes in color characteristics of pre- and final fried fish nuggets are presented in Table 2 showing that there were different results in terms of lightness, redness and yellowness among the treatments ($p < 0.05$). In pre-fried nuggets the highest amount of lightness and yellowness were observed in control treatment, the lowest amount of lightness in C8 treatment and the lowest amount of yellowness were observed in A8 and A10 treatments ($p < 0.05$). A8, A10 and C8 treatments showed the lowest value of redness index. In the final fried nuggets,

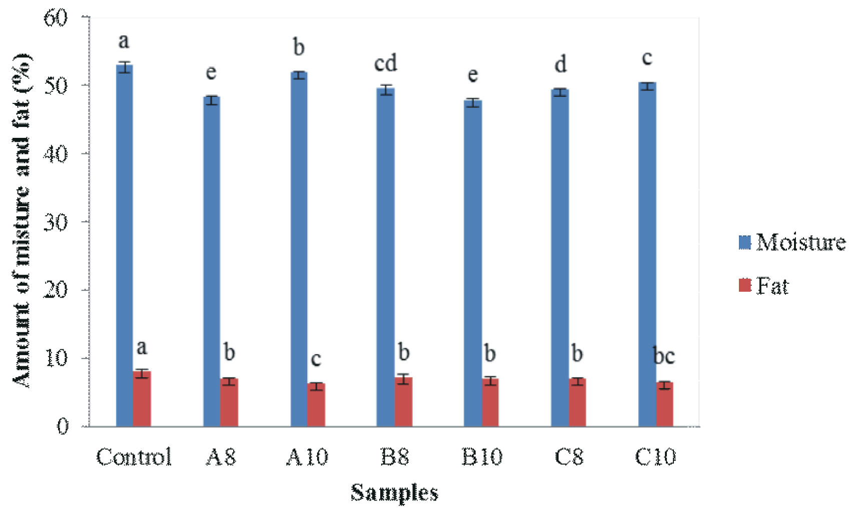


Fig. 1: Moisture and fat content in light salted and pre-dried rainbow trout fish nuggets Bars represent standard deviation from triplicate determinations

Table 1: Amount of oil uptake, pH, WHC and product yield in light salted and pre-dried rainbow trout fish nuggets

Treatments	Amount of oil uptake (%)	pH	WHC	Product yield (%)
Control	-	$6.15±0.3^{a}$	$8.2±0.15^{ab}$	$86.78±0.76^{ab}$
A8	$12.27±1.02^{c}$	$5.93±0.01^{b}$	$8.66±0.39^{a}$	$87.4±0.54^{ab}$
A10	$22.18±0.51^{a}$	$5.89±0.01^{bc}$	$8.99±0.73^{a}$	$85.07±2.07^{b}$
B8	$11.03±0.94^{c}$	$5.88±0.01^{c}$	$7.92±0.79^{ab}$	$89.34±0.77^{a}$
B10	$12.64±0.88^{c}$	$5.91±0b^{c}$	$6.36±0.57^{a}$	$87.5±0.9^{ab}$
C8	$12.64±1.13^{c}$	$5.83±0.01^{d}$	$7.17±0.72^{ab}$	$86.11±0.55^{ab}$
C10	$18.46±0.68^{b}$	$5.93±0.01^{b}$	$8.93±0.67^{a}$	$87.98±0.13^{ab}$

Mean values with different superscripts letters at the same column are significantly different among samples (P<0.05)

Table 2: Changes in color characteristics in light salted and pre-dried rainbow trout fish nuggets

	Pre-Frying			Final Frying		
Treatments	L*	a*	b*	L*	a*	b*
Control	54.54±0.18^{a}	14.1±0^{ab}	22.97±0.13^{a}	47.45±0.67^{cd}	18.59±0.68^{ab}	55.81±0.57^{a}
A8	50.82±0.31^{c}	11.69±0.24^{c}	20.21±0.51^{d}	49.41±0.52^{ab}	17.19±0.23^{c}	23.69±0.36^{b}
A10	51.07±0.35^{c}	11.67±0.32^{c}	20.3±0.29^{d}	50.38±0.42^{a}	17.6±0.18^{bc}	24.03±0.13^{b}
B8	49.53±0.3^{d}	13.39±0.28^{b}	22.05±0.19^{b}	48.19±0.25^{bc}	18.1±0.23^{bc}	22.41±0.22^{c}
B10	47.24±0.53^{e}	14.41±0.56^{a}	21.11±0.16^{c}	46.68±0.35^{d}	19.55±0.04^{a}	21.53±0.34^{c}
C8	53±0.3^{b}	12.38±0.24^{c}	21.88±0.23^{bc}	49.22±0.41^{ab}	17.69±0.28^{bc}	23.77±0.27^{b}
C10	50.53±0.54^{cd}	13.39±0.21^{b}	21.17±0.25^{c}	50.01±0.43^{a}	16.99±0.45^{c}	24.3±0.19^{b}

Mean values with different superscripts letters at the same column are significantly different among samples at first time ($P<0.05$)

Table 3: Sensory evaluation in light salted and pre-dried rainbow trout fish nuggets

Treatment	Flavor	Color	Odor	Texture	Appearance	Overall acceptability
Control	5.71±0.78^{a}	6±0.53^{a}	7±0.58^{a}	6.28±0.42^{a}	5.86±0.55^{a}	5.86±0.67^{a}
A8	4.86±0.51^{a}	6.71±0.47^{a}	6.28±0.42^{a}	6.28±0.47^{a}	5.86±0.51^{a}	5±0.49^{a}
A10	4.57±0.43^{a}	6.86±0.67^{a}	6.14±0.4^{a}	6.43±0.68^{a}	6.28±0.47^{a}	5.57±0.57^{a}
B8	4.71±0.64^{a}	6.86±0.34^{a}	6.14±0.55^{a}	6.86±0.46^{a}	5.86±0.51^{a}	5.14±0.51^{a}
B10	4.71±0.86^{a}	6.86±0.26^{a}	6.14±0.7^{a}	6±0.62^{a}	6.57±0.43^{a}	5.28±0.61^{a}
C8	4.28±0.71^{a}	6.14±0.59^{a}	6.14±0.83^{a}	5.86±0.77^{a}	5.57±0.75^{a}	4.71±0.61^{a}
C10	4.43±0.65^{a}	6.14±0.59^{a}	6.28±0.6^{a}	6.14±0.7^{a}	5.86±0.55^{a}	5.28±0.75^{a}

Mean values with different superscripts letters at the same column are significantly different among samples at first time ($P<0.05$)

C10 and A10 treatments showed the highest lightness indices and B10 treatment showed the highest redness index. In addition C8 treatment demonstrated the lowest lightness index, whereas A8 and C10 treatments displayed the lowest redness index.

Statistical analysis of sensory evaluation did not show any significant differences in terms of factors such as of taste, color, smell, texture, appearance and overall acceptability among all treatments ($p < 0.05$) (Table 3).

DISCUSSION

Increased salt concentration caused increased moisture content and decreased fat amount and water holding capacity; in other hand, duration of the salting process was an important variable that affected the moisture content of the product. The moisture loss during salting was due to denaturation of fish meat proteins in the presence of salt. Previous studies demonstrated that during salting and drying processes the fat content could act as restrictive factor for diffusion of salt and moisture and it is formed a physical barrier against the transporting of salt and moisture [19, 20].

The amounts of moisture and fat in 10 percent (by weight) salting fish nuggets decreased by increase of pre-drying time. In concentration of 8 % salting the amount of moisture also decreased by increase of pre-drying time, whereas the fat content did not change significantly (Florchart 1). Increasing salt concentration caused increase the interaction of protein-protein and decreased the interactions of protein–moisture, which could itself lead to decrease of the ability of holding fat in cooked meat [19]. The control treatment showed the highest amount of moisture and fat content compared to other treatments. The protein denaturation and loss of water holding capacity resulted in reducing the moisture content during the salting process.

The combination of light salting and pre-drying processes resulted in reduced oil uptake in experimental treatments in comparison with the control treatment. A10 treatment with 22.28 showed the highest reduction of oil uptake. In addition, C10 treatment with18.46 % and A8, C8, B8 and B10 treatments were also graded in next stands. The high dry matter and low moisture content represented exit of more moisture from the tissues of fish and it possibly resulted in increase of the oil absorption [21]. In present study, due to exit of water during salting and pre-drying processes, the amount of moisture in fish tissues were reduced. Consequently, in the course of deep frying process the exchange and transportation of moisture and fat were minimized which resulted in decrease of fat uptake in the product.

During the salting process the amount of acidity (pH) altered and decreased in fish meat [22]. In the study done by Torarinsdottir *et al*. [13], the pH of cod fillets decreased from 6.9 to 6.6 using brine salting method and from 6.9 to 6.2 using dry salting method. In this study the amount of pH decreased from 6.15 (the highest amount) observed in control treatment, to 5.83 (the lowest amount) observed in C8 treatment.

By increasing the pre-drying time, the amount of pH in 10 % salting did not show significant differences, while in 8% salting the amount of pH increased by increasing pre-drying time. In previous studies, the decrease of pH to 5.98 value was observed in dry salting method of fish meat processing [23]. This amount of pH was near to pI point of myofibril proteins, which are the main fish proteins and resulted in reduction of water holding capacity of fish meat. One mechanisms that can reduce the water activity of fish meat is reduction of its water holding capacity.

Hamm [24] stated that, formed band between chloride ions and proteins were exerted by a network of proteins in low concentrations of salt. When protein concentration is relatively higher than 2 mol, the protein will denaturate. This resulted in cross-linkage of proteins as well as increased shrinkage and subsequent reduction of the moisture content and water holding capacity of meat. The changes of other compounds such as the amount of proteins or other soluble nitrogen compounds might justify the differences of product yield [25].

The amount of product yield and water holding capacity did not show significant differences in different treatments (Table 1). The obtained results were probably due to the low salting period (15 minutes) that did not cause any significant difference in meat moisture loss amount in different treatments. Accordingly, it did not influence protein denaturation and loss of water holding capacity as well.

Drying process by reducing the moisture content was responsible for changes in color of the product. Lauritzsen *et al*. [26] reported that reducing the moisture content could lead to decreased lightness (L*).In addition the changes in lightness and yellowness (b*) indexes were directly related to the amount of moisture. In pre-fried nuggets, control treatment showed lower redness and higher lightness and yellowness than other treatments. This results were justified due to existence of higher moisture content in control treatment comparing with other treatments.

Due to the lowest moisture, the C8 treatment revealed the lowest lightness and the highest redness indexes. Changes in color of the final fried nuggets had different fluctuations so that, A10 and C10 treatments showed high lightness and B10 treatment and control treatment showed the highest redness and the highest yellowness respectively ($p < 0.05$). The deep frying process affected the results of color in final fried nuggets. The frying process increased the amount of redness and yellowness and reduced the amount of lightness in fried fish nuggets. The golden color of fried crusts was due to Millard`s reaction and sugar Caramelization at higher temperature of frying process [27].

Amount of salt was the other factor that affected the color. The presence of calcium and magnesium ions in salts could cause increase of lightness, which was in contact with moisture [26]. The oxidation of fat and myoglobin at the end of the salting process could reduce the redness index, which could lead to discoloration of the fish meat. The low amount of pH might accelerate the oxidation of myoglobin in dry salting. Forming matt myoglobin in dry salt, might be more susceptible to oxidation and formation of other derivatives that resulted in discoloration [23].

According to the sensory evaluation the amount of sensory flavor, color, smell, texture, appearance and overall acceptability showed no significant differences among the treatments. Moghaddam *et al*. [28] did not observe significant differences in terms of quality of color and odor in the salted trout fillets at 4 and10°C temperatures. Similar results also were confirmed by Elyasi *et al*. [29] who showed that there was no difference among indexes of sensory evaluation of flavor, smell and texture and there was only significant difference in color and the overall acceptability indexes.

CONCLUSION

According to the results of present study, the combined effects of light salting and pre-drying processes not reveal any significant influence on the quality of produced rainbow trout nuggets. However, deep frying process caused reduction of the oil uptake. The combined effect of these processes did not show any significant differences on the product yield, water holding capacity and sensory evaluation. The A10 treatment had51.93moisture value and 6.28 fat content. These numbers indicated the highest amount of moisture (after the control treatment) and the least fat content among all treatments. In conclusion,10 percent light salting (by weight) and microwave pre-dried process at 180°C for 30 second, revealed the most influence on reduction of oil uptake in case of fried rainbow trout nuggets.

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