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Chemical and sensory quality changes of fish fingers, made from mirror carp (*Cyprinus carpio* L., 1758), during frozen storage (−18 °C)

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Abstract

The effects of frozen storage at −18 °C on the chemical and sensory qualities of fish fingers produced from unwashed and washed mirror carp (*Cyprinus carpio*) mince were investigated. The amounts of moisture, crude protein, lipid, crude ash, ω3 polyunsaturated fatty acids (PUFA ω3), and ω6 polyunsaturated fatty acids (PUFA ω6) in fish fingers produced from unwashed mince (UWF) were found to be 68.50%, 15.5%, 6.00%, 2.20% 2.31%, and 55.2%, respectively, while they were found to be 70.23%, 10.8%, 2.14%, 1.80%, 2.28%, and 54.6%, respectively, in carp fingers produced from washed mince (WF). The thiobarbituric acid value (TBA, mg malonaldehyde/kg) was found to be significantly higher in mince of WF than in mince of UWF and increased significantly during frozen storage in both the mince of UWF and WF ($p < 0.05$). A significant decrease in pH was obtained throughout the washing treatment ($p < 0.05$). There were no significant differences of pH in either the mince of UWF or WF between the beginning and end of the storage periods ($p > 0.05$), whereas a sharp increase was observed in the fourth month in both groups. The protein solubilities of the mince of both UWF and WF decreased significantly throughout the storage periods ($p < 0.05$). Sensory parameters of colour, odour, flavour, and general acceptability for both groups decreased during the frozen storage period ($p < 0.05$) but were still within acceptable limits. It was also concluded that mirror carp was a good source for fish fingers and that product could be stored for five months in a frozen state without undesirable changes of sensory and chemical qualities.

Keywords: Carp; Fish fingers; Fatty acids; Washing; Frozen storage; Quality

1. Introduction

Carp, as a freshwater fish species, has been one of the most widely cultured species all over the world due to its fast growth rate, easy cultivation and high feed efficiency ratio. In Turkey, two *Cyprinus carpio* species, named "common" and "mirror" carp, are extensively cultured. Total carp production in Turkey through aquaculture increased from 288 tons to 687 tons between 1994 and 2001 (Celiker, 2003). So, demand has come, from the carp producer, to develop alternative products to increase the carp consumption, The intramuscular bones can be separated from flesh with a variety of devices (Gelman & Benjamin, 1988) and the mincing of fish flesh and washing of mince can improve taste, thanks to different kinds of additives that enable the elimination of unwanted flavours, and odours (Hoke, Jahncke, Silva, & Hearnsberger, 1994; Hoke, Jahncke, Silva, Hearnsberger, & Suriyaphan, 2000; Hultin, 1992; Lin, Meyers, & Godber, 1996; Negbenebor, Godiya, & Igene, 1999).

Fish fingers, or sticks, produced from minced fish flesh as a battered and breaded product, are commonly stored and marketed in the frozen state. However, fish and fishery products can undergo undesirable changes

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during frozen storage and deterioration may limit the storage time. These undesirable changes result from protein denaturation (Benjakul, Visessanguan, Thongkaew, & Tanaka, 2005; Fijuwara, Oosawa, & Saeki, 1998; Hsieh & Regenstein, 1989) and lipid oxidation (Kurade & Baranowski, 1987; Richards, 2002; Sarma, Reddy, & Srikar, 2000). Many reports have focussed on alternative products from carp mince such as fish burgers, fish balls, frankfurters and other sausages (Gelman and Benjamin, 1989; Siddaiah, Reddy, Raju, & Chandrasekhar, 2001; Yanar & Fenercioglu, 1998). However, there are almost no studies on fish fingers produced from carp mince. The aim of this study was to produce fish fingers from carp flesh and to investigate the chemical (pH, TBA and protein solubility) and sensory quality changes during frozen (−18 °C) storage.

2. Materials and methods

2.1. Sample preparation

Mirror carp (*C. carpio*), between 700 and 800 g in weight, were captured from Seyhan Dam Lake. Having been transferred to the laboratory, the fish were beheaded, gutted and washed. Then, they were filleted. The yield of flesh achieved by hand-filleting was 38.14%. The fillets were minced with a kitchen meat mincer, using a 3 mm diameter holes plate. Conventional standards were utilized for preparation of carp fingers according to the US Department of Agriculture (USDA, 2001) and Long, Komarik, and Tressler (1983). The carp finger mince included 93.5% carp mince, 1.5% salt, 1% sugar, 3% wheat flour, 0.243% cumin, 0.243% onion, 0.243% garlic powder, 0.243% pepper and 0.020% thyme. The ingredients were homogenized with a kitchen blender. The batter and breading materials were purchased from Pinar Company (Yasar Holding A.Ş., İzmir, Turkey). The batter was put into a kitchen blender with a cold water/batter flour ratio of 2.2:1 (w/w) for 2 min and it was prepared according to the guidelines of the Pinar Company. After the batter application, it was also covered with conventional breading crumbs and then pre-fried at 180 °C for 30 s. In addition to this, minced fish was washed in ice cold water (2 °C) with a ratio of 1.5:2 (mince meat to water), to eliminate a mossy odour, and strained using a cheese cloth in a refrigerator at 2 °C for 8 h. Afterwards, the samples were dewatered by squeezing manually. Then, the same procedure was conducted for the production of carp fingers from washed mince. The total weights of carp fingers produced from unwashed mince (UWF) and washed mince (WF) were 22.60 ± 1.9 g and 17.12 ± 1.2 g, respectively. Eight carp fingers were packaged in a foam plate and wrapped with cling film. After that, they were quick-frozen at −40 °C for 4 h and then stored at −18 °C for five months.

2.2. Analyses

Analyses for the determination of the proximate composition and the initial chemical quality parameters of carp fingers were performed on the production day. Crude protein, lipid, moisture and crude ash were analyzed in quadruplet but fatty acids were analyzed in duplicate. Chemical quality analyses were performed in triplicate. Whole fish fingers were used to determine proximate and fatty acid composition, microbiological quality, and for sensory assessment. For the analyses, 15 fish fingers were taken out randomly from frozen storage, 4 °C overnight, and batter and breading were removed from the fish fingers for chemical quality analyses.

2.3. Microbiological analysis

Aerobic plate count, *Escherichia coli* and total *coliforms*, and *staphylococcus* were done according to Unlütürk and Turantas (1996), Anonymous (1998) and Ozcelik (1992), respectively.

2.4. Proximate composition

The crude protein was determined by the Kjeldahl method (AOAC, 1984). Lipids were extracted by the method of Bligh and Dyer (1959). The water content and crude ash content were determined in an oven at 103 °C and 550 °C, respectively, until the weight became constant.

2.5. Fatty acid methyl esters (FAMEs)

The fatty acid methyl esters (FAMEs) of carp finger were determined as by Paquot (1979). Thermoquest trace gas chromatography was equipped with a SP-2330 fused silica capillary column (30 m × 0.25 mm, ID-0.20 μl) and a flame ionization detector (FID). Fatty acids of the lipid in the Bligh–Dyer extract were transesterified to methyl esters by base-catalyzed, followed by a boron trifluoride-catalyzed, esterification. The methyl esters were dissolved in *n*-heptane. The helium carrier gas flow was 0.5 ml/min. The initial oven temperature programme was kept constant for 2 min at 120 °C, and then raised by 5 °C min^{-1} to 220 °C for 8 min. The injection split ratio was 1:150. The injection and detector temperatures were 250 and 240 °C, respectively. Split flow ratio was 75 ml/min. The fatty acids were expressed as percentages of the total fatty acid content.

2.6. Chemical quality

Thiobarbituric acid value (TBA, mg malonaldehyde/kg) was determined using a spectrophotometric method (Tarladgis, Watts, & Yonathan, 1960). pH was

determined for the homogeneous mixtures of fish and distilled water (1:10, w:v), using a digital Mettler Toledo pH meter (Santos, James, & Teutscher, 1981). The extraction of mince was performed with 0.02 M $NaHCO_3$ and 5% NaCl, according to Dyer, Fench, and Snow (1950). The protein content of the extract was determined by the biuret method (Snow, 1950). Bovine serum albumin was used as a standard. The protein solubility in samples was expressed as a percentage of the total muscle protein.

2.7. Sensory quality

Sensory quality of fish fingers produced from unwashed and washed mince was assessed by eight trained persons. The fish fingers were deep-fried with sunflower oil until they were cooked before being presented to the panellists. Sensory evaluation was carried out according to the Paulus, Zacharias, Robinson, and Geidel (1979) sensory assessment scheme. Panellists scored for colour, odour, flavour, general acceptability and texture, using a nine-point hedonic scale (1, dislike extremely to 9, like extremely).

2.8. Statistical analyses

Data were analyzed by one-way analysis of variance (ANOVA), using the SPSS 10.0 for Windows. An independent sample *t*-test was used to determine differences between UWF, WF, UWF and WF. Duncans multiple range test for chemical quality and the Kruskal–Wallis H for sensory quality were used to find significant differences between storage periods.

3. Results and discussion

3.1. Proximate analyses and fatty acid composition of fish fingers

The moisture, crude protein, lipid and crude ash contents of fish fingers produced from unwashed mince (UWF) were found to be 68.50%, 15.5%, 6.00% and 2.20%, respectively. The proximate composition of the fish fingers showed similarities to the findings of Cakli, Taskaya, Celik, Ataman, and Cadun (in press) who studied the production of fish fingers produced from *Tinca tinca*. Similar results have also been reported by Sayar (2001) for fish fingers produced from hake fillet (*Merlangus merlangus*) and by Celik, Cakli, and Taskaya (2002) for fish fingers produced from imported Alaska Pollack sold in supermarkets. In fish fingers produced from washed mince (WF), the moisture, crude protein, lipid and crude ash contents were found to be 70.23%, 10.8%, 2.14% and 1.80%, respectively. The crude protein, lipid, and crude ash contents of fish fingers decreased significantly as a result of the washing treatment ($p < 0.05$). Similarly, a decreasing effect of washing treatment on proximate analysis parameters was established by Biscalchin-gryschek, Oetterer, Gallo, Filho, and Neiva (2001), Lin et al. (1996) and Adu, Babbitt, and Crawford (1983). In this study, the sum of the moisture, crude protein, lipid and crude ash content has been determined to be 92.24% in UWF and 84.95% in WF. The remaining percentages of the total proximate analyses are thought to be due to carbohydrate. In general, fish are known to have low amounts of carbohydrate in their muscle. However, the higher amount of carbohydrate in UWF and WF might be derived from coating materials which contain carbohydrate-rich ingredients, such as flour, starch and bread crumbs. This result has been confirmed by Sayar (2001) who found 15.2% carbohydrate levels in fish fingers.

Total saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), ω3 polyunsaturated fatty acids (PUFA ω3), and ω6 polyunsaturated fatty acids (PUFA ω6) were found to be 14.8%, 27.0%, 2.31%, and 55.2% in UWF, while they were found to be 14.7%, 28.0%, 2.28%, and 54.6% in WF, respectively. The dominant fatty acids in UWF and WF were found to be linoleic acid (54.7% in UWF and 54.2% in WF) and oleic acid (25.0% in UWF and 26.1% in WF). Compared to marine fish, freshwater fish species contain and are characterized by higher amounts of ω6 PUFA, such as linoleic and arachidonic acids, than ω3 PUFA (Steffens, 1997). However, the higher amount of linoleic acid (18:2 ω6) for UWF and WF was thought to arise from pre-frying treatment of carp fingers that led to absorption of the frying oil. These suggestions were confirmed by Hoffman, Prinsloo, Casey, and Theron (1994) in African catfish (*Clarias gariepinus*), Ågren and Hänninen (1993) in rainbow trout (*Oncorhynchus mykiss*), vendace (*Coregonus albula*) and pike (*Esox lucius*), and Mai, Shimp, Weihrauch, and Kinsella (1978) in white sucker (*Catastomus commersoni*) and bluegill (*Lepomis macrochirus*). Similar to our findings, oleic acid (18:1ω9) was reported to be a common dominant fatty acid in common carp (Csengeri & Farkas, 1993; Kim & Lee, 1986; Paavar, Kuusik, Groos, Mõttus, & Tohvert, 2002).

It is known that EPA and DHA have an essential role in human diet to prevent diseases. Since these fatty acids occur in high amounts only in seafood, it is necessary to study them. In our study, the amounts of EPA+DHA in UWF and WF were determined to be 1.44% and 1.51%, respectively. The information concerning the nutrient values of UWF and WF is of importance, both to consumers and to researchers working on nutrient tables. It was determined that the ratio of ω3/ω6 was lower than in other fish fillets, as a consequence of the high amounts of 18:2 ω6. Similarly, Ågren and Hänninen (1993) reported that the ratio of ω3/ω6 in flesh of three freshwater fish species was drastically decreased from 3.68 to 0.15 when vendace was fried with sunflower oil.

3.2. Frozen storage

3.2.1. Microbiological quality

For the determination of the initial freshness quality of carp fingers before frozen storage, aerobic plate count (APC), *E. coli*, total *coliforms*, and *staphylococcus aureus* were analyzed. Total bacterial count was found to be 2×105 CFU/g for UWF and 8×104 CFU/g for WF, while *E. coli*, total *coliforms* and *staphylococcus* could not be found. The International Commission on Microbiological Specifications for Food (ICMSF) recommend that the flesh APC should not exceed 10^6/g wet weight. This recommendation was met by our results. These data indicate that the processing of carp finger until frozen storage has been done under good sanitary conditions.

3.2.2. Chemical quality parameters

The changes in TBA (mg malonaldehyde/kg), pH values and protein solubility (%) of the mince of UWF and WF during frozen storage are shown in Table 1.

The TBA value is widely used as an indicator of the degree of lipid oxidation. In the present study, the TBA value in the minces of both UWF and WF significantly increased from 0.17 to 0.27 and from 0.20 to 0.25 during frozen storage, respectively ($p < 0.05$) (Table 1). The increasing of the TBA value during frozen storage has been demonstrated by Chuapoehuk and Raksakulthai (1982) for fish fingers (made from lizard fish, threadfin bream and barracuda), by Cakli et al. (in press) for fish fingers (made from *T. tinca*), by Yanar and Fenercioglu (1998) for fish balls made from carp, by Gelman and Benjamin (1988), for minced pond-bred flesh of silver carp, and by Tokur, Polat, Beklevik, and Ozkütük (2004) for fish burgers made from tilapia. The development of the TBA value was very slow in fish fingers during the five month frozen storage (Table 1). Although similar observations were made by the researchers mentioned above, our data have revealed much lower TBA values than the other authors. The washing treatment significantly affected the TBA values of fish fingers initially, in the first and third months of frozen storage period ($p < 0.05$), but not in the other months. Undeland, Hultin, and Richard (2003) found that the development of lipid oxidation products was faster in washed cod muscle than in unwashed cod mince within ~4 days. Similar results have also been found for minced herring, during frozen storage, by Undeland, Ekstrand, and Lingnert (1998). They suggested that some antioxidants could be removed by washing. This suggestion could explain why our TBA values were higher in washed mince than unwashed mince.

There were no significant differences between the initial values and those at the end of the storage period for pH in the mince of UWF and WF, while there was a sharp increase ($p < 0.05$) at the fourth month. It is interesting that, when the pH increased, the TBA values in the mince of both UWF and WF decreased at the fourth month and that the TBA values increased while pH decreased at the fifth month. It has been observed that hemoglobin (Hb) can show strong pro-oxidant activity for some species between pH 6 and pH 7 and it can retard oxidation at pH values above 7 (Richards & Hultin, 2002; Tokur et al., 2004; Undeland, Richards, & Hultin, 2002). This may explain why the TBA value decreased when the pH increased and vice versa. These results show that the washing treatment led to a low pH value ($p < 0.05$).

Protein solubility (extracted in 5% NaCl), in the mince of both UWF and WF, did significantly decrease from 60.7% to 27.9% and from 18.1% to 11.8%, respectively, throughout frozen storage ($p < 0.05$). Similarly, numerous researchers have reported that protein solubility decreased during frozen storage as a result of denaturation and aggregation of myofibrillar proteins in fish mince (Benjakul et al., 2005; Careche, Mazo, Torrejon, & Tejada, 1998; Huidobro, Alvarez, & Tejada, 1998; Leelapongwattana, Benjakul, Visessanguan, & Howell, 2005; Mackie, 1993; Suvanich, Jahncke, & Marshall, 2000). A sharp decrease (18.1%) was observed in the protein solubility of the mince of WF, while a

Table 1
Chemical quality parameters of the mince of UWF and WF during frozen storage at 18 °C[1,2,3]

Months	TBA		pH		Protein solubility (%)	
	UWF	WF	UWF	FW	UWF 100[4]	WF 100[4]
0	$0.16 \pm 0.01^{a*}$	0.20 ± 0.02^{a}	$6.80 \pm 0.00^{a*}$	6.68 ± 0.01^{a}	$60.7 \pm 1.31^{a*}$	18.1 ± 0.45^{a}
1	$0.17 \pm 0.01^{a*}$	0.16 ± 0.00^{b}	$6.70 \pm 0.00^{a*}$	6.61 ± 0.01^{a}	$59.6 \pm 0.88^{a*}$	27.2 ± 1.12^{b}
2	0.19 ± 0.01^{b}	0.19 ± 0.02^{a}	$6.83 \pm 0.02^{a*}$	6.81 ± 0.01^{b}	$49.0 \pm 1.25^{b*}$	26.9 ± 1.83^{b}
3	$0.16 \pm 0.02^{a*}$	0.23 ± 0.02^{c}	6.72 ± 0.19^{a}	6.65 ± 0.08^{a}	$32.7 \pm 0.63^{c*}$	21.5 ± 0.57^{c}
4	0.14 ± 0.02^{c}	0.14 ± 0.01^{d}	7.26 ± 0.04^{b}	7.20 ± 0.01^{c}	$25.1 \pm 0.15^{d*}$	11.8 ± 0.23^{d}
5	0.27 ± 0.03^{d}	0.25 ± 0.02^{e}	6.74 ± 0.00^{a}	6.67 ± 0.06^{a}	27.9 ± 0.22^{e}	–

[1] Data are expressed as means ± standard deviation ($n = 3$).
[2] Means within the same row shown in * are statistically different at $p < 0.05$.
[3] Means within the same column having different superscripts are significantly different at $p < 0.05$.
[4] Data obtained from mince before pre-frying treatment.

Table 2
Sensory quality changes of UWF and WF during frozen storage (−18 °C)[1,2,3]

Months	Colour		Odour		Flavour		General Acceptability	
	UWF	WF	UWF	WF	UWF	WF	UWF	WF
0	8.63 ± 0.52^{a}	8.75 ± 0.46^{a}	8.38 ± 0.52^{ab}	8.75 ± 0.46^{a}	$8.13 \pm 0.35^{a*}$	8.75 ± 0.46^{a}	8.25 ± 0.46^{a}	8.75 ± 0.46^{a}
1	8.13 ± 0.64^{ab}	8.44 ± 0.50^{ab}	8.50 ± 0.50^{b}	8.75 ± 0.46^{a}	$8.19 \pm 0.53^{a*}$	8.94 ± 0.18^{a}	$8.38 \pm 0.52^{a*}$	9.00 ± 0.00^{a}
2	$8.13 \pm 0.35^{ab*}$	8.75 ± 0.46^{a}	8.75 ± 0.46^{b}	8.88 ± 0.35^{a}	$7.75 \pm 0.89^{ab*}$	8.75 ± 0.71^{a}	$7.75 \pm 0.46^{ab*}$	8.75 ± 0.71^{a}
3	7.75 ± 0.71^{bc}	8.00 ± 0.93^{bc}	7.38 ± 0.52^{ac}	7.88 ± 0.64^{b}	7.13 ± 0.99^{b}	7.88 ± 0.64^{b}	7.25 ± 0.71^{bc}	7.88 ± 0.64^{bc}
4	7.50 ± 0.53^{c}	7.63 ± 0.52^{c}	7.75 ± 0.46^{ac}	7.75 ± 0.46^{b}	$7.00 \pm 0.53^{b*}$	7.63 ± 0.52^{b}	$6.88 \pm 0.83^{c*}$	8.00 ± 0.53^{b}
5	7.75 ± 0.46^{bc}	7.88 ± 0.35^{c}	$7.88 \pm 0.64_{cd}$	8.00 ± 0.53^{b}	7.38 ± 0.74^{b}	7.88 ± 0.64^{b}	7.13 ± 0.83^{bc}	7.38 ± 0.74^{c}

[1] Data are expressed as means ± standard deviation ($n = 8$).
[2] Means within the same row shown in * are statistically different at $p < 0.05$.
[3] Means within the same column having different superscripts are significantly different at $p < 0.05$.

moderate decrease (60.7%) was observed in the protein solubility of the mince of UWF after a pre-frying treatment at the beginning of storage. The reason for the differences in protein solubility could be an effect of washing treatment which causes a loss of myofibrillar protein (Lin & Park, 1996; Lin, Park, & Morrissey, 1995). The data indicated that the protein in mirror carp mince was much less stable (against washing and high temperature cooking, i.e., 180 °C pre-frying). There seem to be no findings in the literature about the effect of high temperature cooking, after washing of mince fish, on protein solubility. The protein solubility increased when the TBA value increased in the mince of both UWF and WF. This can be explained by interaction between protein and lipid oxidation products, causing a decline of protein solubility (Alzagtat & Alli, 2002; Careche & Tejeda, 1994; Siddaiah et al., 2001).

3.2.3. Sensory quality

The sensory qualities of fish fingers produced from mirror carp were evaluated in terms of colour, odour, flavour, and general acceptability (Table 2). The sensory scores, in both UWF and WF declined significantly throughout the five months of frozen storage ($p < 0.05$). However, both groups remained quite fresh after the storage periods. The flavour and general acceptability seem to be significantly effected by the washing treatment at the zeroth, first, second and fourth months ($p < 0.05$). Although unwashed fish fingers had more nutritional value, panellists highly preferred washed fish fingers because of their desirable flavour. The acceptability of fish and fishery products during frozen storage depends on the changes in their sensory attributes. The data also indicated that carp finger produced from unwashed and washed carp mince could be stored at −18 °C for five months while retaining their good quality characteristics in terms of sensory assessment ($p > 0.05$). These conclusions were supported by the results for chemical quality analyses.

Thanks to the present study, the fish fingers produced from mirror carp, as an alternative product, can be stored for five months in a frozen state without undesirable changes of sensory and chemical quality. However, it is suggested that fish fingers (as an alternative product) and the effects of frozen storage on chemical and sensory qualities should be further investigated, in a larger scale study, preferably as a socio-economic evaluation, a production feasibility report, and an evaluation of long term frozen storage on quality changes.

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