

Original Research Article

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Nutritional and Organoleptic Changes of Grass Carp (*Ctenopharyngodon idella*, Valenciennes, 1844) Meat upon Smoking and Thermal Processing

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ABSTRACT

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Presence of intramuscular bones, muddy flavour and soft texture of meat are the major constraints which reduces consumer acceptability of carps. A study was under taken in order to find out the effects of smoking and thermal processing on nutritional and organoleptic quality of grass carp meat. Mildly smoked (2.5 h) at 700C grass carp packed in retort pouches and cans was processed to various F₀ values (2, 4, 6, 8 and 10 min) at a temperature of 121.1°C. Nutritional quality parameters, thiamine content and pepsin digestibility has decreased with the increase in extent of thermal processing. Influence of type of container (cans and retortable pouches) on nutritional quality were also compared and found that retort pouch processed product as superior. Muddy flavour was not perceived in any of the products and texture of meat found improving with extent of thermal process. The products processed at 121.1°C for F₀ value of 6 and 8 min were found commercially sterile. Therefore, considering nutritional quality, sensory quality and extent of sterilization, thermal process for an F₀ value of 6 min could be recommended.

Highlights

Smoking of fillets before thermal processing was found advantageous for reducing muddy flavour and improving the sensory quality of retort pouch processed product.

The products processed at 121.1°C for F₀ value of 6 were found to be better in terms of nutritional, textural and organoleptic quality. Retort pouch processed products are superior

in nutritional quality as compared to canned product.

Introduction

Aquaculture is one of the fastest growing industries in India. According to the latest available statistics by FAO, India stands second in aquaculture production. The bony fishes including Indian major carps, viz., catla, rohu and mrigal, together with the three

exotic carps, viz., silver carp, grass carp and common carp, form a major component of Indian aquaculture due to their low cost of production and good marketing potential. Even though there is great potential for processing of carps for internal market as well as for export, the growth of the industry is not very appreciable. According to Gopal *et al.*, (2012) the presence of inter muscular bones and consumer perception of muddy flavour are the major reasons for the lower acceptability of the fish. Muddy flavour in freshwater fishes is mainly due to the presence of geosmin compound synthesised by blue green algae and actinomycetes. Fish absorbs it from water through gills, and after passing digestive tract, it is finally deposited in fat tissues. This consequently affects the flavour of fish flesh (Lovell, 1979). Studies have shown that combination of smoking and thermal processing can be advantageous; smoking masks muddy flavour and thermal processing considerably softens the bones (Vijayan *et al.*, 1998). One of the most common methods for processing freshwater fishes to a marketable end product is smoking. Smoke curing is a traditional fish preservation method of considerable economic importance worldwide. Nearly 2% of world's fish catch is used for preparing smoked products. Nowadays smoking process is mainly used in food processing sector with an intension of imparting typical flavour and other desirable organoleptic qualities to the smoked foods. However, till now little attention has been given in India to develop smoke curing of fish.

Thermal processing technique emphasizes the achievement of commercial sterility while minimising the changes in nutritional value and eating quality (Holdsworth and Simpson, 2007). Conventional canning operations have the tendency to induce adverse changes to the nutritional and sensory attributes of foods. It has been established that for the same extent

of microbial sterilization given, heating for a longer period at a lower temperature is more detrimental to the sensory and nutritional qualities of food than heating at a higher temperature but for a shorter period.

Various processing steps can have negative impact on the nutritional quality of the proteins. One means of assessing it is by determining the protein digestibility (Hryniewiecki, 2000). During smoking and thermal processing breakage of secondary, tertiary and quaternary structures occurs which unfolds the proteins and improves their bioavailability since peptide bonds become readily accessible to digestive enzymes. Modifications of primary protein structures on the other hand may lower digestibility and produce proteins that are not biologically available.

According to Awuah *et al.*, (2007), vitamins are one among the most sensitive food components to be affected by heating. Heat labile vitamins like thiamine, ascorbic acid, riboflavin, niacin, pyridoxine and panthothenic acid, are the vitamins most damaged by thermal processing. The rate of destruction of thiamine has been found to increase more or less steadily with increase in temperature or time. Thus thiamine content is commonly used as an index of nutritional quality of thermal processed low acid foods. Even though novel heating alternatives could replace conventional thermal processing methods, their adoption would require prior justification in terms of significant quality improvements and economic viability to the food processor.

Smoked fish curry is a ready-to-eat convenience form of product which can have great scope in internal as well as export markets. Grass carp (*Ctenopharyngodon idella*) was used for the study as a representative of carps. The local fish farmers

reported that the meat of grass carp is inferior to other cultured fishes and so, the market demand is less and is even lower as compared to other carps. There is a great potential for the processing of freshwater fishes including carps, but the Indian fish processing industry is presently concentrating on marine fishes. The study involved packing smoked fish fillets in retort pouches as well as cans with curry as the packing medium followed by thermal processing. The consumer acceptability and quality of the products were assessed by conducting various tests. The outcome of the study is expected to make retort pouch processed smoked grass carp curry that can achieve greater market demand. In practice improvements have to be done in thermal processing in order to minimise overcooking of the product during sterilization. The studies regarding the nutritional quality are expected to give suggestions to the processor for producing products with minimum nutritional loss.

Materials and Methods

Materials

Live grass carp (*Ctenopharygodon idella*) weighing average of 350 g was purchased from a fish farm that was then iced and transported in an insulated box to the laboratory within four hours.

Smoking

The raw material was thoroughly washed with potable water until the surface become clean and totally free of slime. Scales and viscera were removed, washed thoroughly and filleted to pieces of approximately 17.5 x 7 x 1.1 cm. The skinned fillets were immersed in brine of concentration 5% for a period of 15 min followed by draining for a period of 30 min under refrigerated condition. Smoking was carried out in a mechanical smoke kiln

(Kerres make, Germany) at a temperature of 700C for 2.5 h using beech wood chips (3-5 mm size) as fuel.

Preparation of curry

Ingredients, as given in Table 1, were weighed out. Malabar tamarind was soaked in warm water for 10 min and the pulp was squeezed out. Refined oil was heated to frying temperature of 1800C in a frying pan, to which fenugreek seed and ground onion were added and fried until the onion attained a light brown colour. To this, ground green chilli, ginger, and garlic were added and frying continued for 2-3 min. Turmeric powder, chilli powder and coriander powder were added and frying continued for another few minutes and then removed from flame. Tamarind juice and salt were added to the mixture and boiled for a period of 5 min. The pH of the curry was then adjusted to 3.5 by addition of tamarind juice.

Thermal process studies

Retort pouches made of polystyrene-aluminium foil-polypropylene laminate of size 15.5 X 17 cm and cans made of tin free steel (TFS) of 307 X 109 size were used for packing the products. Smoked grass carp pieces of size of about 3 X 2.5 X 0.9 cm, were packed in the pouches and cans. A thermocouple probe inserted into a fish piece in each pack with its tip reaching its centre and was placed in such a manner that the tip of the probe lied at the pre-determined cold spot. To this hot curry was added in the proportion, fish: curry = 50:50 (weight by weight). Immediately upon adding hot curry the pouches were sealed using a pneumatic sealer and cans by a double seamer. The packs were loaded into a still overhead pressure retort operated using steam and compressed air. The thermocouple lead wires were taken out of the retort through a gland

and were connected to thermocouple data recorder (Ellab make, Denmark). The process temperature adopted was 121.1°C. The extent of sterilization achieved in the product by thermal processing was calculated as F_0 value. The reference organism assumed was *Clostridium botulinum* (type A) spores. Its z -value of 10°C and reference temperature of 121.1°C were adopted for calculation. These were programmed in the F-value computer for the various trials. Each lot was processed for the required period in order to obtain F_0 values of 2, 4, 6, 8 and 10 min.

Chemical analysis

The moisture content was determined by the oven drying method of AOAC (1975). The method of AOAC (1984) was followed for ash content estimation. Total nitrogen and crude protein contents were estimated by the micro kjeldahl method of AOAC (1984). The method of AOAC (2000) was followed for determining crude fat content. A sample of 5 g meat was homogenised with 10 ml of distilled water and pH was measured using digital pH meter (Metler Toledo) as per the method of IS: 2168-1971. Pepsin digestibility was determined according to the method of Miller *et al.*, (2000). The colorimetric procedure of Hochberg *et al.*, (1944) was followed for determining thiamine content in the samples.

Commercial sterility

Commercial sterility of thermal processed samples in retort pouches and cans were estimated according to IS: 2168-1971. The samples were incubated, one lot at 37°C for 15 days and another lot at 55°C for 5 days and were observed for any bulging during the incubation period. The incubated samples were aseptically opened; one gram of the contents was aseptically weighed out and inoculated into sterilized thioglycollate broth

in test tubes. Liquid paraffin was pipetted out into the tube to form a layer on top of the broth in the test tube. The contents of the pouch were examined for any spoilage. Two tubes each from aerobic and anaerobic conditions, along with blanks were incubated at 37°C and 55°C for 48 h. The tubes were examined for development of any turbidity in the media.

Sensory analysis

The sensory quality of the processed samples was presented to a panel of judges in a coded form. They were assigned to evaluate the appearance and colour, texture, taste, overall acceptability, smoke flavour and muddy flavour of each sample and record their judgements in the score sheets provided. They were also assigned to check the texture of fish bones. Sensory scores are calculated according to Meilgaard *et al.*, (2006).

Statistical analysis

The experiments were carried out using Completely Randomized Design (CRD). Data obtained were analysed using Analysis of Variance (ANOVA) technique (Snedecor and Cochran, 1968). Pair wise comparison of treatment means was done wherever necessary using least significance ($p \leq 0.05$). Organoleptic scores were compared using Kruskal-Wallis and related tests (Sprent, 1989).

Results and Discussion

Effect of smoking on nutritional characteristics of grass carp

The proximate composition of raw grass carp meat was found to be 78.1±0.85% moisture, 18.4±0.25% protein, 2.3±0.05% fat and 0.9±0.01% ash which reveals there are no remarkable variations as compared to

proximate composition of meats of other carps. Gopal *et al.*, (2012) reported that on an average meat of Indian major carps contains 70-80% moisture, 15-19% protein, 3-9% fat and 1-1.4% ash.

The changes occurred in chemical parameters of raw grass carp meat upon smoking are shown in Table 2. Smoking for a period of 2.5 h at 70°C resulted in reduction of moisture content from 78% to 51.2% on account of evaporation of water. Significant differences ($p \leq 0.05$) were observed between smoking periods for both pH and moisture content. The drop in pH is probably due to the deposition of carbonyl compounds from wood smoke in meat and compounds aroused from lipid oxidation. Thiamine content of raw grass carp meat was about 86.32 $\mu\text{g}/100 \text{ g}$. Variations are possible because thiamine is not synthesised in fishes and they attain it through the food chain. A decrease in thiamine content was observed upon smoking. Temperature of smoke could be responsible for the thiamine destruction during smoking. Lamden (1972) has also reported that thiamine loss increases with increase in temperature and time.

The nutritive qualities of any food protein are determined by the content of essential amino acids and protein digestibility (Hryniewiecki, 2000). In the present study, pepsin digestibility was used in order to determine the extent of protein digestibility of the product. Pepsin digestibility was found to decrease slightly with smoking (Table 2). Similar observations were reported by Lilabati *et al.*, (1993) during the traditional smoking of silurid fishes. The decrease in protein digestibility is mainly attributed to protein denaturation as result of heat induced rupture of secondary and higher structures of protein (Ledward, 1979 and Unlusayin *et al.*, 2001). The decrease in pepsin digestibility can also be due to the interactions of proteins

with the smoke constituents (Lokesh *et al.*, 1989).

Effect of thermal processing on physico-chemical properties of smoked fish

In the present study fish pieces smoked for a period of 2.5 h were packed in retort pouches as well as cans and processed to various F_0 values. The come up time required for the retort to attain a temperature of 121.1°C was 8 min. According to Anon, (1968) the come up time should be kept as short as possible in order to achieve faster heat penetration rate. The minimal process lethality (F_0) required for reducing population of *C. botulinum* through 12 decimal reductions is 2.52 min (Stumbo, 1973). Even though a minimum F_0 value of 3 min can render the product commercially sterile, a much higher F_0 value is often adopted in order to guarantee a microbiologically safe product. The F_0 value recommended by Frott and Lewis (1994) for fish and fish products ranges from 5 to 20 min. Operator's process time required for retort pouch packed products processed at 121.1°C to achieve F_0 value of 2 min was 7 min whereas it increased to 8 min, 9 min, 11 min and 13 min for achieving F_0 values of 4, 6, 8 and 10 respectively. Whereas in case of cans it took 13, 15, 17, 19, and 21 min for achieving F_0 values of 2, 4, 6, 8 and 10 min respectively. The shorter process time required for the pouch could be attributed to (i) lower thickness of product and hence, cold spot lying closer to surface and (ii) higher surface area to volume ratio for pouch aiding heat penetration (Mohan *et al.*, 2008).

The solid: liquid proportion of fish curry was 50:50 by weight at the time of packing. This was changed to 60:40 upon processing in pouch. The lower moisture content of smoked fish pieces may have a tendency to absorb water from the curry which could be the reason for the weight gain. Therefore, a

separate precooking step could be avoided if smoked fish of sufficiently lower moisture content is used for packing. However, the extent of smoking should be optimised in order to obtain a stable solid weight without affecting the product flavour.

Curry with a pH of 3.5 was used as the packing medium for all the trials. pH of the unprocessed product was 5.13 and increased to 5.75 when processed for an F_0 of 2 min; thereafter a decreasing trend was observed with increase in F_0 value (Fig. 1). According to Hamm (1966) increase in pH during heating could be attributed to charge changes, hydrogen bonding or a combination of both which take place within myofibrillar proteins. Similarly, with the increase in heating, the splitting of hydrogen bonds and release of H^+ into the product might have occurred and that could be the reason for drop in pH (Correia and Mittal, 1991). They also proposed that the loss of basic amino groups due to maillard reaction will also cause drop in pH. Bindu (2009) also observed a decrease in pH value by 0.02 unit during the processing of smoked tuna pieces packed in retort pouches for an F_0 value of 10 min.

Thiamine destruction can be used as an indicator of nutritional loss in thermal processed food. In the case of products packed in retort pouches and processed at a temperature of 121.1°C, thiamine content showed a decreasing trend with increase in the extent of sterilization (Fig. 2). Products that were not thermal processed contained 63.26 $\mu\text{g}/100\text{g}$ thiamine, whereas the content dropped to 44.94 $\mu\text{g}/100\text{g}$ in retortable pouches and 38.91 $\mu\text{g}/100\text{g}$ in cans when processed to an F_0 value of 10 min. According to Tannenbaum (1976) thiamine destruction rate is a function of temperature, time of heating and the pH of the packing medium. Kong *et al.*, (2007) have reported considerable variations in thiamine content

during the thermal processing of salmon meat. They observed that thiamine content was 2.03 $\mu\text{g}/\text{g}$ in raw salmon meat and was reduced to 0.4 $\mu\text{g}/\text{g}$ when subjected to a thermal process of 30 min at a temperature 121.1°C. Stability of thiamine can also decrease with increase in pH (Lamden, 1972). Briozzo *et al.*, (1987) found that with reduction in pH from 6.9 to 5.0 the thiamine loss of canned pea, corn, and beef liver purees has dramatically decreased. They recommended that a mild reduction in pH of food could minimise thiamine loss in canned low acid food.

Heat denaturation of proteins does not necessarily cause nutritional loss (Aubourg, 2001) but may reduce digestibility of protein (Opstvedt *et al.*, 1984). Modifications of primary protein structures due to heat denaturation may lower digestibility and produce proteins that are not biologically available (Swaisgood, 1985). In the present study, protein quality of thermal processed smoked grass carp meat was evaluated by estimating pepsin digestibility. Pepsin digestibility of retort pouched grass carp was found decreasing significantly with increase in the F_0 value ($p \leq 0.05$) (Fig. 3). Unprocessed products were observed to have 93.78% pepsin digestibility and was found to decrease with increase in the extent of sterilization given. Canning reduced pepsin digestibility from 93.78% in unprocessed fish pieces to 83.50% whereas by retort pouch processing it was reduced only to 87.15%. This is probably due to the greater period of heating required for canned product (21 min) compared to that for retort pouch processed product (13 min). A similar observation was made by Tanaka and Kimura (1988) who reported a reduction in pepsin digestibility by 6% when big eye tuna packed in flexible containers was processed at temperature of 1150C and 1240C to different F_0 values.

Table.1 Ingredients of fish curry

Ingredient	Weight (g)
Smoked fish	1000
Onion	60
Ginger	13
Green chillies	25
Fenugreek	0.8
Turmeric powder	2.5
Chilli powder	60
Coriander powder	20
Oil	50
Salt	16
Water	500
Malabar tamarind	50

Table.2 Variations in chemical parameters in raw grass carp meat on smoking for 2h at 70°C

Parameter	Raw	Smoked (2h)
Moisture (%)	78.1±0.85	51.2±0.71
pH	6.6±0.02	6.36±0.05
Thiamine content (µg/100 g)	86.32±1.02	63.89±0.68
Pepsin digestibility (%)	96.11±1.15	93.38±0.92

All the means are significantly different.

Table.3 Survival of microorganisms in retort pouch packed grass carp curry subjected to various extents of thermal processing

F ₀ value	Aerobic		Anaerobic	
	37°C	55°C	37°C	55°C
2	-	-	+	+
4	-	-	-	+
6	-	-	-	-
8	-	-	-	-
10	-	-	-	-

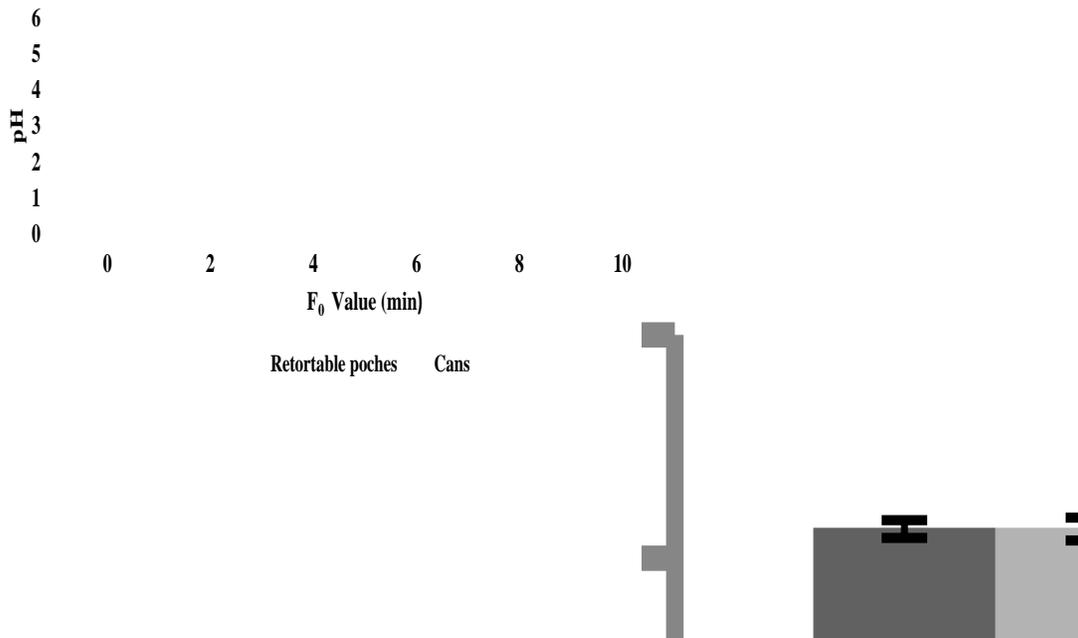


Fig.1 Variations in pH of grass carp curry packed in retort pouch and cans subjected to various extents of thermal processing at 121.1°C

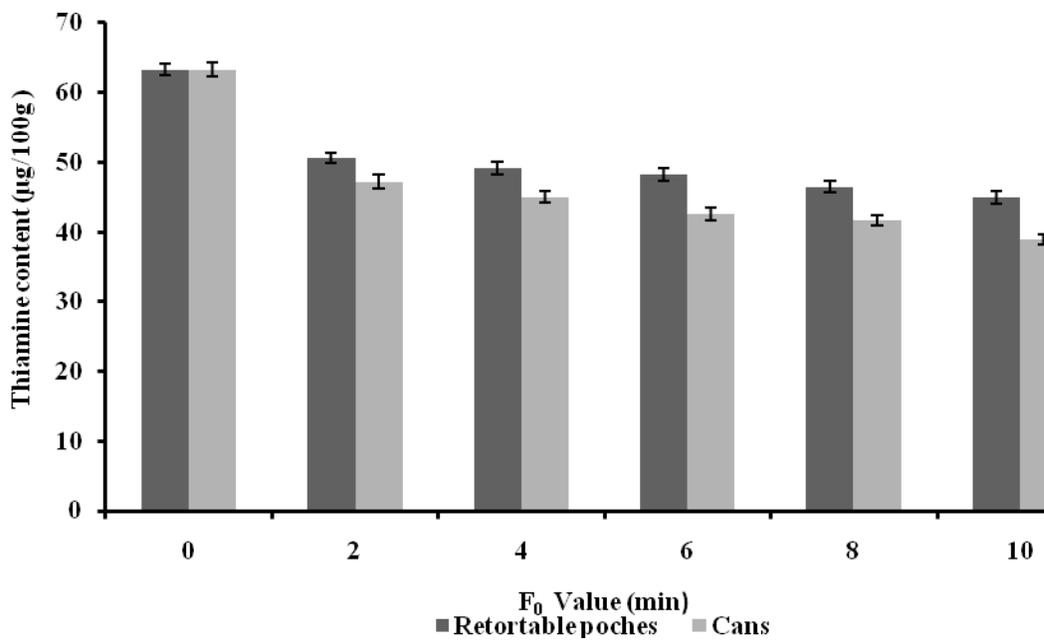


Fig.2 Variations in thiamine content of grass carp curry packed in retort pouch and cans subjected to various extents of thermal processing at 121.1°C

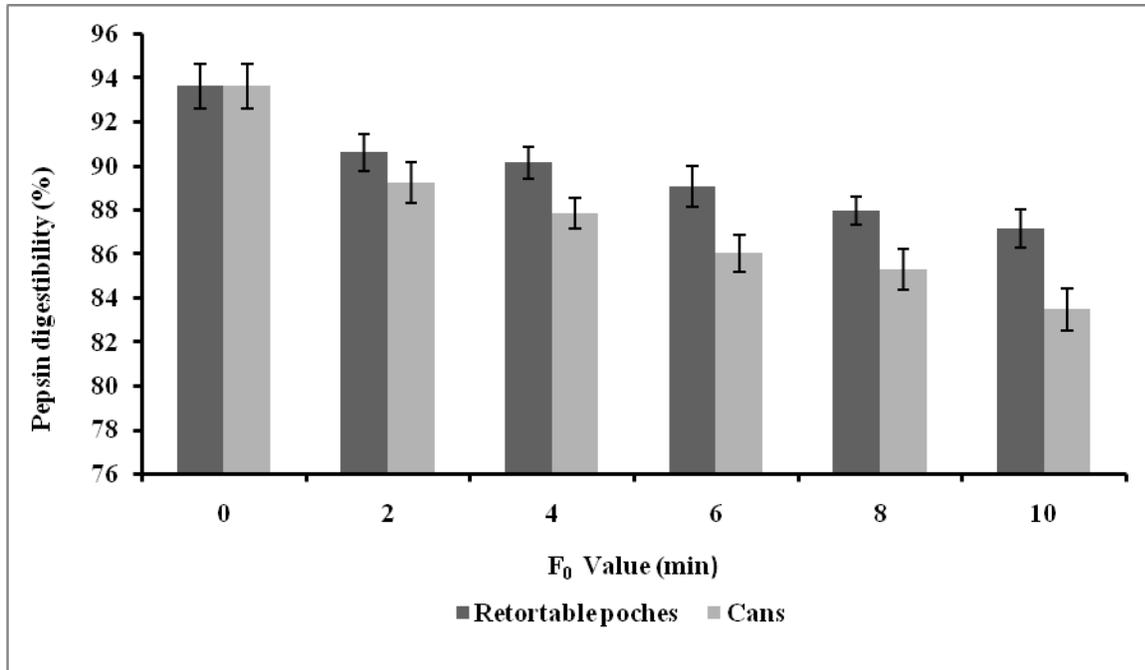


Fig.3 Variations in pepsin digestibility of grass carp curry packed in retort pouch and cans subjected to various extents of thermal processing at 121.1°C

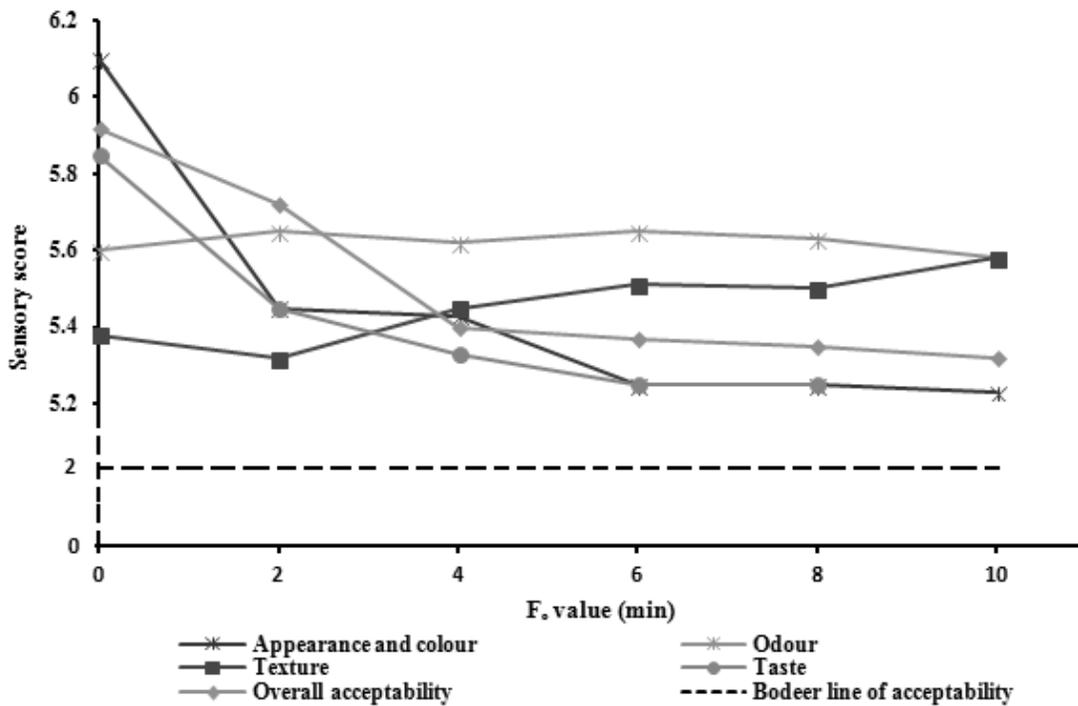


Fig.4 Sensory evaluation scores of retort pouch processed grass carp curry subjected to various extents of thermal processing

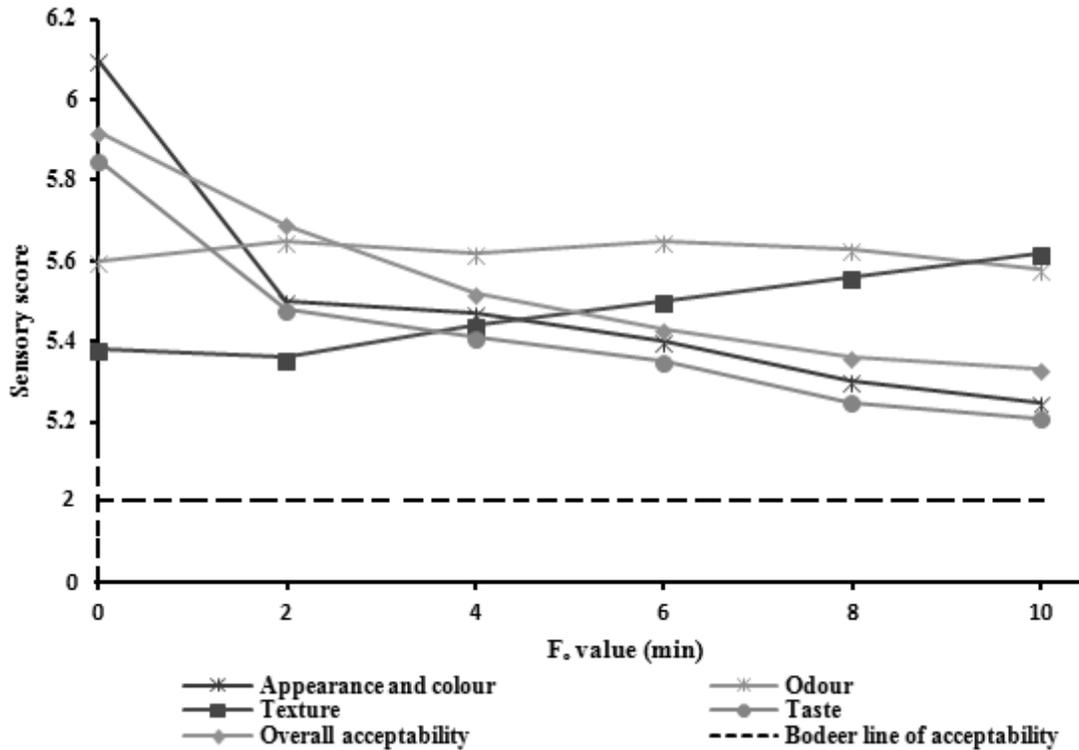


Fig.5 Sensory evaluation scores of canned grass carp curry subjected to various extents of thermal processing

Denaturation of proteins that occurred during heating may be the reason for reduction in pepsin digestibility (Unusyayin *et al.*, 2001). However, Baga *et al.*, (1992) found that canning of tuna at a temperature of 1250C and F₀ values less than 12 min had only slight effect on protein digestibility. Zygmunt *et al.*, (2009) observed that canned fish were characterized by lower protein digestibility (between 90.6% and 95.4%) than smoked, marinated or salted products and they inferred that it could be of drastic thermal process given during canning.

Sensory scores obtained for all the products (Cans and Retortable pouches) for each parameter were well above the borderline of acceptability score of 2 (Fig. 4 and 5) indicating that the products were of high sensory quality. Significant variations were not observed in the sensory quality between canned and retort pouch processed product. The unprocessed products obtained highest

sensory scores for all the parameters except for texture and odour. The sensory properties such as flavour, colour, and texture are very heat sensitive and therefore a reduction in the score for these parameters may have occurred in all the thermal processed products. However, significant differences were not observed between the extents of thermal process for any of the sensory evaluation parameters as per the statistical analysis ($p \leq 0.05$). This means that even in a well sterilized product (F₀ of 10 min), the sensory quality loss is minimal.

Some of the major constraints regarding thermal processing of carp meat are the soft texture of meat and excess precipitation of proteins which make the product unattractive (Vijayan *et al.*, 1998). In the present study protein precipitation was not observed in any of the products. The texture of the meat was firm in all cases which could be due to the effect of smoking. Textural quality was found

to increase with the extent of sterilization in both cans and retortable pouches. It could be an indication that hardened texture of meat after smoking may considerably get softened with an increase in thermal process. Ali *et al.*, (2005) observed a softening of retort pouch processed sardine meat upon thermal processing to higher F_0 values.

Smoked fish pieces which were not thermal processed were rated superior in taste. This may be because of mild cooking of meat imparted by smoking and the fresh flavour of spices in the curry medium. The taste scores were found decreasing slightly with an increase in F_0 value which could be due to the loss of heat labile taste components as a result thermal processing. Although slight changes in the sensory scores were seen in the scoring of the parameters, the overall acceptability scores were not affected by the extent of process given. Thus it may be concluded that the sensory quality of the product is stable over a wide range of thermal process conditions.

Persistence of smoke flavour was observed in all the products processed in cans and retortable pouches. Marked variations were not found between sensory score obtained for the products processed from F_0 value 2 to 10 min. However, none of the sensory panelists have perceived muddy flavour in any of the products. Vijayan *et al.*, (1998) reported that partial drying for a period of 2 h followed by smoking had masked the muddy flavour and improved the texture of meat in canned catla. Mild processing and curry ingredients could effectively mask or destroy the muddy flavour. One of the characteristics of well processed canned fish is that the small bones become easily crushable and chewable upon thermal processing. However, in the retort pouch processed products bones were not chewable even in well sterilized product (F_0 of 10 min). Slight softening of bones was

observed in canned product processed to an F_0 value of 10 min. This could be due to significantly shorter process time required to achieve the required F_0 value compared to canned products.

Technological improvements have to be done in thermal processing in order to minimise overcooking of the product during sterilization. Considering nutritional quality it is desirable to minimize the thermal process sufficient enough to achieve commercial sterility without sacrificing sensory attributes. The results of microbiological tests are given in the Table 3. During the incubation period at a temperature of 37°C and 55°C, all pouches appeared normal without any bulging. Presence of both mesophilic and thermophilic organisms was observed in products processed to an F_0 value of 2 min whereas products processed to an F_0 value of 4 min showed presence of only thermophilic organisms. Products processed at 121.1°C for F_0 values of 6, 8 and 10 min were found commercially sterile.

Considering the products achieved commercial sterility, the sensory scores were well above the borderline of acceptability. Smoking the fillets before thermal processing was found advantageous for reducing muddy flavour and improving the sensory quality of retort pouch processed product. The extent of loss of nutritional indicators, viz., thiamine content and pepsin digestibility were also not high and well within the acceptable limits. Therefore considering nutritional quality, sensory quality and extent of sterilization, thermal process for an F_0 value of 6 min could be recommended for retort pouch processed smoked grass carp curry. Application of higher temperature (generally not beyond 121.1°C) and use of retort pouches instead of cans are also suggested for better nutrient retention in thermal processed products. However, product development and

standardization of thermal process should be in such a way as to achieve commercial sterility and provide maximum retention of quality parameters.

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