Food Chemistry **27** (1988) 95–106

Processing of Smoked Common Carp Fish and its Relation to Some Chemical, Physical and Organoleptic Properties

Ibrahim M. Hassan

Food Science Department, Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Cairo, Egypt

(Received 6 February 1987; revised version received 2 April 1987; accepted 11 May 1987)

ABSTRACT

A successful process was developed for smoking of common carp fish (Cyprinus carpio) *through different trials of brining and smoking conditions. Brining in 15% NaCl for 2 days at 4°C, followed by surface desalting in water for only 30 min and partial natural drying at room temperature before cold smoking at 39 to 41°C for 6 h, proved to be the best conditions for the production of an acceptable common carp fish product. Raising the salt concentration in the brining operation to 24% resulted in a similarly acceptable smoked product with less preferable taste. Changes in moisture, total lipid, crude protein and salt contents, as well as pH values, water-holding capacities, plasticities and protein solubilities were followed during different stages of various processing operations.*

INTRODUCTION

Common carp fish (*Cyprinus carpio*) was introduced to Egypt by the Ministry of Agriculture in 1978. Some trials have also been made by the National Institute of Oceanography since 1974. The commercial production of common carp fish (CCF) in Egypt has developed rapidly during the last few years. Local marketing, however, faced some difficulties, probably due to its unsuitability for Egyptian popular dishes. The smoking process for CCF could be a good approach to upgrade this species maximally for

domestic marketing. Smoking of fish imparts a mild flavour and colour popular in developed countries but in some developing countries high levels of salting and a heavy smoking process are used. Different types of smoked fish products are presently produced. The differences in processes employed depend primarily upon the type of fish and regional preferences for a particular product. In 1980 about 0·91% of the total world fish catch was smoked. This quantity is substantially higher than the 0·80% in 1977 (FAO, 1983).

Smoke vapour constituents responsible for imparting biological stability to the product are phenolic compounds, acids and carbonyls (Foster & Simpson, 1961; Porter *et al.*, 1965). However, smoked products are shelf-stable only if they are sufficiently smoked and/or if the salt content is sufficient to lower the water activity to a level which would not support microbiological activity. Shelf-stable products are either hard or dry or semi-moist and salty (Chan *et al.*, 1975).

Brine strengths of 70% to 80% seemed to yield the most attractive smoked products. A 90% to 100% saturated brine resulted in a 2–3% loss of fish weight corresponding to 2–3% of salt absorbed (Cutting, 1965). Murno & Morrison (1965) found that the pre-smoking salting caused a decrease in protein content according to the type of salting. The losses in nitrogenous compounds during salting of different types of fish were discussed by many researchers (Zaitsev *et al.*, 1969; Dessoki, 1971; Aminullah Bhuiyan *et al.*, 1986).

Developing a suitable smoking process for common carp fish to achieve more efficient utilization of this newly introduced fishery resource in Egypt is the main objective of the present study. Changes in the proximate composition, salt content and nitrogenous compounds, as well as water-holding capacity (WHC) and plasticity of fish tissues during processing to smoked products were investigated. Sensory evaluation of the smoked products is also discussed.

MATERIALS AND METHODS

Raw material

Fresh fish of the species *Cyprinus carpio* were obtained from the governmental fish farm at Barseek, Behira Governorate. The common carp fish (CCF) were approximately 400 to 500 g weight each. Just after harvesting, the fish were thoroughly iced and transferred to the laboratory within 5 h. Upon arrival, commercial style cleaning with removal of gills, viscera and washing several times with tap water was applied.

Brining

Commercial salt was used in the preparation of brine. The fish were divided into two groups. The first group was brined in 15% NaCl solution (B_{15}) for 48 h at $4 \pm 1°C$, while the second group was brined in 24% NaCl solution (B_{24}) for the same period and the same temperature. The weight of fish and brine were equal for both methods of brining.

Desalting and drying

The desalting process was carried out by immersing the brined fish in water for 30 min. The desalted fish were then subjected to partial sun-drying at recorded temperatures of a maximum of 28°C and minimum of 21°C. The sun-drying process was carried out for 20 h.

Smoking

The sun-dried fish were cold-smoked in a laboratory smoke house similar to that used by Anon. (1958) and Dessoki (1971). The fish were suspended in the smoke house vertically from their heads by the hooking method. Smoke was produced from the hard sawdust of beech wood (*Fagus silvatica*). The smoking process was continued for either 6(S_6) or 12(S_{12}) h at a temperature of about 40°C as recommended by Zaitsev *et al.* (1969). The air properties during the smoking process are recorded in Fig. 1. The four smoked products observed are those subjected to the following treatments:

(1) Brined in 15% NaCl for 48 h at $4 \pm 1°C$, desalted for 30 min, sun-dried for 20 h and smoked for 6 h ($B_{15}S_6$).

(2) Brined in 24% NaCl for 48 h at $4 \pm 1°C$, desalted for 30 min, sun-dried for 20 h and smoked for 6 h ($B_{24}S_6$).

(3) Brined in 15% NaCl for 48 h at $4 \pm 1°C$, desalted for 30 min, sun-dried for 20 h and smoked for 12 h ($B_{15}S_{12}$).

(4) Brined in 24% NaCl for 48 h at $4 \pm 1°C$, desalted for 30 min, sun-dried for 20 h and smoked for 12 h ($B_{24}S_{12}$).

Analytical methods

The heads, tails, fins and back bones were removed and the remaining flesh was minced twice with an electric meat mincer. All determinations were done in at least four replicates and the mean values, as well as the standard error, are reported in the 'Results and Discussion' section.

Moisture, ash, salt (NaCl%), total nitrogen and pH (using an E.I.L. 7010 pH meter with glass electrode) were determined according to the AOAC methods (1980). Nitrogenous compounds were extracted by 5%

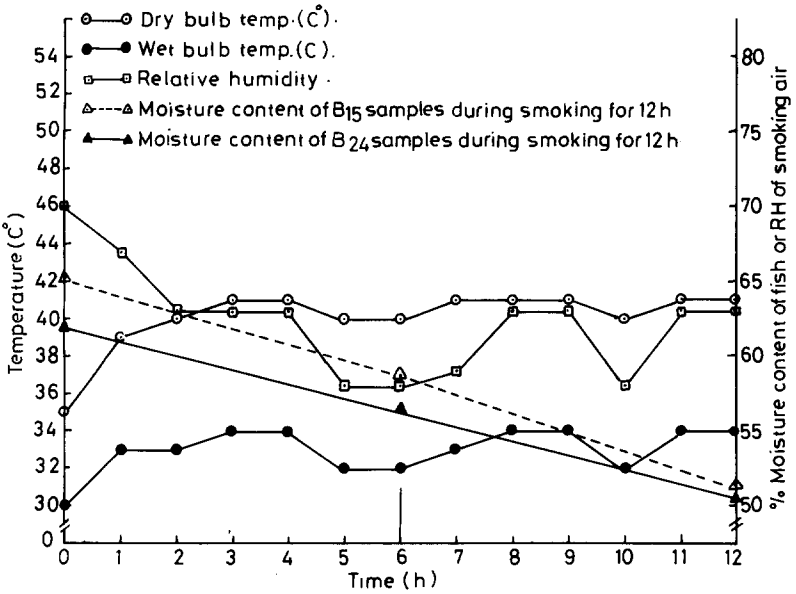

Fig. 1. Moisture contents of common carp fish and smoking air properties during smoking processes.

NaCl cold solution and total soluble nitrogen and soluble protein nitrogen were also determined as reported by the AOAC (1980). Lipids were determined by means of the method of Bligh & Dyer (1959). WHC and plasticity were determined using the Grau and Hamm (1957) method as modified by Volovinskaia & Kelman (1962) with moisture contents in all treated samples adjusted to be almost equal to that of raw fish.

Organoleptic evaluation

Fifteen panelists from the staff members of the Food Science Department, Ain Shams University, were asked to evaluate the smoked products for odour, taste, texture and colour attributes using a 7-point hedonic scale with 1 designating 'dislike very much' and 7 being 'like very much' (Peryam & Pilgrim, 1957). The average of the mean values of the aforementioned attributes were considered as the overall quality. Statistical analysis of the results was done by the analysis of variance (Larmond, 1974).

RESULTS AND DISCUSSION

Proximate composition

The moisture content (78·23%) accompanied with a low level of lipids (3·44%), as shown in Table 1, indicates that CCF can be considered as lean

TABLE 1
Proximate Composition (w/w %)[a] and Salt Content (% NaCl) during the Processing of Smoked Common Carp Fish

Treatment	*Sample component*				
	Water	*Lipid*	*Crude protein*	*Ash*	*Salt (% NaCl)*
Raw	78·23 ± 0·55	3·44 ± 0·48 (15·8)[d]	17·5 ± 0·83 (80·3)	0·96 ± 0·09 (4·41)	0·14 ± 0·04 (0·64)
Brining					
B_{15}[b]	74·02 ± 0·79	3·50 ± 0·67 (13·8)	15·8 ± 0·42 (61·0)	7·03 ± 0·49 (27·1)	5·66 ± 0·52 (21·8)
B_{24}[b]	71·18 ± 0·49	3·98 ± 0·27 (13·8)	16·5 ± 0·62 (57·3)	8·67 ± 0·29 (30·1)	7·89 ± 0·80 (27·4)
Desalting[c]					
B_{15}	75·16 ± 0·35	3·48 ± 0·61 (14·0)	14·8 ± 0·45 (59·5)	6·70 ± 0·21 (27·0)	4·88 ± 0·39 (19·7)
B_{24}	72·28 ± 0·37	4·07 ± 0·25 (14·7)	15·6 ± 0·46 (56·1)	8·18 ± 0·13 (29·5)	6·64 ± 0·76 (24·0)
Partial drying[c]					
B_{15}	65·07 ± 0·45	4·44 ± 0·20 (12·7)	20·8 ± 0·55 (59·6)	8·70 ± 0·23 (27·8)	6·78 ± 0·59 (19·4)
B_{24}	61·98 ± 0·43	4·66 ± 0·69 (12·3)	21·9 ± 0·14 (57·5)	11·1 ± 0·23 (29·3)	9·02 ± 0·61 (23·7)
Smoking for 6 h:					
$B_{15}S_6$	58·84 ± 0·31	4·34 ± 0·39 (10·5)	25·0 ± 0·15 (60·8)	11·0 ± 0·16 (26·8)	8·83 ± 0·62 (21·5)
$B_{24}S_6$	56·45 ± 0·30	3·75 ± 0·54 (8·61)	26·2 ± 0·38 (60·1)	12·5 ± 0·13 (28·7)	10·1 ± 0·49 (23·2)
Smoking for 12 h:					
$B_{15}S_{12}$	51·32 ± 0·70	4·09 ± 0·18 (8·40)	29·4 ± 0·23 (60·4)	13·8 ± 0·23 (28·4)	10·6 ± 0·42 (21·8)
$B_{24}S_{12}$	50·45 ± 0·15	4·29 ± 0·39 (8·66)	28·9 ± 0·69 (58·3)	14·9 ± 0·12 (30·1)	12·3 ± 0·38 (24·8)

[a] Results are the averages of 8 fish.
[b] Brined in 15% (B_{15}) and 24% (B_{24}) NaCl solution for 48 h at 4°C ± 1.
[c] After brining, samples B_{15} and B_{24} were subjected to the same treatments of desalting for 30 min and sun-drying for 20 h as well as smoking for 6 (S_6) and 12 (S_{12}) h.
[d] Values in parentheses represent percentage on dry weight basis.

fish (Borgstrom, 1961). During the brining operation water migrates from the CCF and a considerable increase in ash content occurs (Table 1). On the other hand, crude protein decreased by 19·3% and 23% (on a dry weight basis) when the CCF was brined in 15% and 24% NaCl solutions, respectively. Such results coincide with those obtained by Dessoki (1971) for scombry fish. The desalting process was proposed to avoid the accumulation

of salt at the periphery of outer fish tissues during the subsequent partial dehydration processes. By desalting for 30 min, reabsorption of water occurred by about 1·14% and 1·10% in both brined samples (B_{15} and B_{24}). The loss of nitrogenous compounds during the brining processes may be due to the enhancement of protein solubility by increasing salt content in tissues (Hamm, 1960) and the destruction of proteins followed by leaching of these components into the brine solution.

As a result of several trials in the present work, it was found that 20 h of sun-drying at temperatures ranging between 21 and 28°C were suitable for reducing the moisture content to the range 62–65% (Table 1). Lipids showed a slight loss being 1·30% and 2·40% (dry weight) in B_{15} and B_{24} samples. The higher loss in moisture and lipids in B_{24} samples may be due to more protein denaturation as a result of high contents of salt in tissues to an extent that may cause a decrease in WHC and emulsifying properties of proteins.

During the cold smoking processes, either for 6 or 12 h, a progressive loss in moisture (Fig. 1) and a slight loss in the lipid content (Table 1) accompanied by a slight increase in ash and protein levels, were observed. This means that the cause of moisture loss during the smoking process was mainly due to evaporation and not to drip separation. The spongy texture of semi-dried muscles can no longer hold the molten fats and they drip away (Prater & Coote, 1962). Some lipid, soluble protein, ash and nitrogen component losses during the smoking process were reported by Shiau & Chai (1985).

Temperature and heating time during the smoking were the two main factors affecting the quality of smoked fish. Figure 1 shows the smoking air properties during smoking where the dry-bulb temperature was adjusted after 1 h to be between 39°C and 41°C whereas the wet-bulb temperature was from 32°C to 34°C. The RH was maintained near 60% during the smoking process. Chan *et al.* (1975) found that maximum smoke deposition was achieved at 60% RH.

Salt content

The salt content (NaCl%) during the different processes used for producing smoked CCF is also shown in Table 1. The NaCl content in raw CCF was 0·64% (dry weight).

Brining at low temperature was preferred because of good sanitary quality and convenience (Shiau & Chai, 1985). After brining of the CCF for 2 days at 15% and 24% NaCl solution, it contained 5·66 and 7·89% NaCl, respectively (Table 1). Desalting for 30 min reduced the NaCl contents in CCF to 4·88% and 6·64% which occurred by diffusion. The NaCl content seemed to be slightly reduced by sun-drying (dry weight) which may be due to

drip separation, changes in protein as a result of new cross linkages and decrease of free chemical groups which are able to bind water (Dessoki, 1971). The water phase salt content (WPS) ($NaCl \times 100/NaCl + H_2O$) defined by the FDA (1970) regulations recommended a minimum of 5% WPS for cold smoked fish. Egyptian regulations issued by the Egyptian Organization for Standardization and Quality Control (EQS) require at least 8% salt in cold smoked sardine and 14% in cold smoked mullet (wet weight). No local data about the smoking process of CCF are available. In the present investigation the WPS contents were 13·1, 15·2, 17·1 and 19·6 for $B_{15}S_6$, $B_{24}S_6$, $B_{15}S_{12}$ and $B_{24}S_{12}$, respectively. These concentrations are high enough to inhibit the growth of any food poisoning organisms present. Bannerman (1980) stated that a minimum concentration of 3% has been found to be effective for hot smoked fish, particularly mackerel and trout. Aminullah Bhuiyan *et al.* (1986) reported that the final concentrations of salt of smoked Atlantic mackerel were 3·78% to 4·23% (NaCl) and these were enough to inhibit the growth of any food poisoning organism, particularly *Clostridium botulinum.*

pH changes and solubility of nitrogenous compounds

Table 2 shows that the average pH value of CCF was 6·39. After brining in 15% and 24% NaCl, the pH decreased by 0·14 and 0·18 units, respectively. Such a decline in the pH of fish muscles upon brining may be due to the post-mortem changes accompanied by lactic acid formation and increasing the concentration of the acids as a result of water migration outside the muscles. Also, in the basic range of iso-electric point (IP) of muscle proteins (pH > 5) the binding of cations (Cl^-) with proteins increases and the binding of anions (Na^+) decreases (Hamm, 1960). Cleavage of amino groups by Cl^- enhances the acidic properties of carboxylic groups with a corresponding reduction in the pH values. The slight increase by desalting and the slight decrease by sun-drying may be mainly due to the reabsorption or loss of water during both processes, respectively.

Smoking leads to a remarkable reduction in the pH values by 0·24, 0·16, 0·42 and 0·50 units when compared to sun-dried samples. The more the smoking time, the lower was the pH value. pH changes during smoking may be mainly due to smoke acids absorption and loss of moisture as well as the reaction of phenols or polyphenols and carbonyls with protein SH and amino groups, respectively. (Krylova *et al.*, 1962). The high moisture content during smoking is an important factor for the absorption of smoke vapours, especially by surface and interstitial water (Lawrie, 1976).

Table 2 also presents the percentage of total soluble nitrogen (TSN), soluble protein nitrogen (SPN), and non-protein nitrogen (NPN). Both TSN

TABLE 2
Changes in the pH[a], Total Soluble Nitrogen, Soluble Protein Nitrogen and Non-Protein Nitrogen during the Production of Smoked Common Carp Fish

Treatment	*Property*			
	pH	*Total soluble nitrogen*	*Soluble protein nitrogen*	*Non-protein nitrogen*[e]
Raw	6·39 ± 0·01	1·57 ± 0·09 (7·21)	1·43 ± 0·08 (6·94)	0·14 (0·64)
Brining[b]				
B_{15}	6·25 ± 0·02	1·42 ± 0·06 (5·47)	1·23 ± 0·02 (4·73)	0·19 (0·74)
B_{24}	6·21 ± 0·03	1·50 ± 0·10 (5·20)	1·34 ± 0·04 (4·65)	0·16 (0·55)
Desalting				
B_{15}	6·28 ± 0·03	1·36 ± 0·04 (5·48)	1·18 ± 0·02 (4·75)	0·18 (0·73)
B_{24}	6·23 ± 0·01	1·34 ± 0·12 (4·83)	1·19 ± 0·02 (4·29)	0·15 (0·54)
Partial drying[c]				
B_{15}	6·24 ± 0·02	1·86 ± 0·06 (5·32)	1·54 ± 0·03 (4·41)	0·32 (0·91)
B_{24}	6·17 ± 0·02	1·80 ± 0·09 (4·73)	1·55 ± 0·03 (4·08)	0·25 (0·65)
Smoking for 6 h				
$B_{15}S_6$	6·00 ± 0·02	2·33 ± 0·15 (5·66)	1·87 ± 0·07 (4·54)	0·46 (1·12)
$B_{24}S_6$	6·01 ± 0·0·03	2·00 ± 0·04 (4·59)	1·65 ± 0·04 (3·79)	0·35 (0·80)
Smoking for 12 h				
$B_{15}S_{12}$	5·82 ± 0·02	2·35 ± 0·11 (4·83)	1·84 ± 0·13 (3·78)	0·51 (1·05)
$B_{24}S_{12}$	5·67 ± 0·04	1·93 ± 0·14 (3·90)	1·51 ± 0·11 (3·05)	0·42 (0·85)

[a,b,c,d] See Table 1.
[e] Non-protein nitrogen was calculated by subtracting SPN from TSN.

and SPN decreased during brining. The leaching of nitrogenous compounds into brining solution may occur from the ruptured fibres and destroyed membranes, as well as the destruction of proteins which might have taken place. The amount of NPN developed during sundrying may be due to protein destruction by the effect of proteolytic enzymes (Zaitsev *et al.*, 1969). After the first 6 h of smoking $B_{15}S_6$ samples showed a slight increase

in the SPN, whereas $B_{24}S_6$ samples showed a noticeable reduction as a result of higher salt levels. By 12 h of smoking, protein denaturation or aggregation was much more clearly observed, as can be seen in Table 2. Protein denaturation may occur either as a result of heating or development of salt concentration during the smoking process.

Water-holding capacity and plasticity

Figures 2 and 3 show the WHC and plasticity during the processing of smoked CCF. According to the Grau & Hamm (1957) method applied in the present study, the higher the area (cm^2) the lower the WHC, and vice versa.

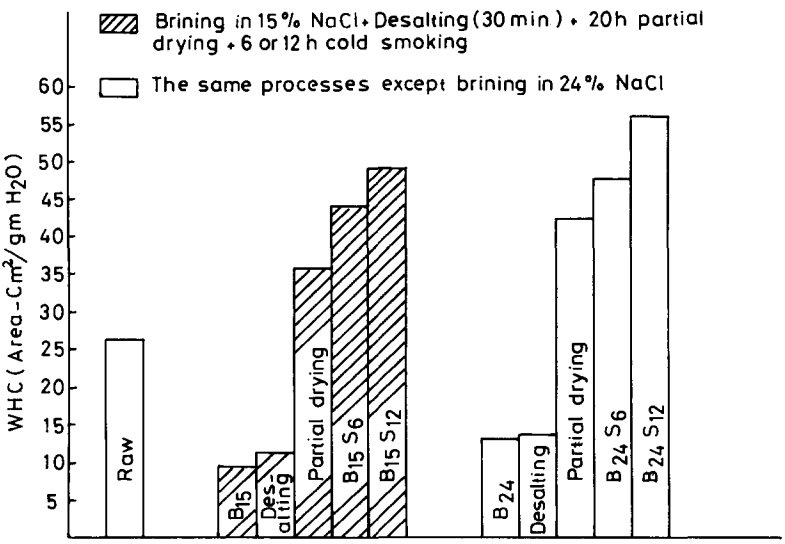

Fig. 2. Effect of brining, desalting, partial drying and smoking processes on the WHC of common carp fish.

As far as plasticity measurement is concerned, the bigger area indicates softness and the smaller area indicates toughness. Generally, it is clear in Fig. 2 that both brining and desalting greatly improved the WHC and plasticity of CCF. After sun-drying and smoking, high reduction in the WHC associated with hardness of fish tissues occurred. The hydration of muscles improved with increasing concentration of NaCl. It reached a maximum at 5% NaCl and then decreased with the advancement of NaCl concentration in tissues to such an extent that the hydration of muscles fell below the original (Hamm, 1960). The development of fish hardness (decrease of plasticity) upon sun-drying and smoking may be due to the protein denaturation as a result of the dehydrating effect of NaCl in this range of

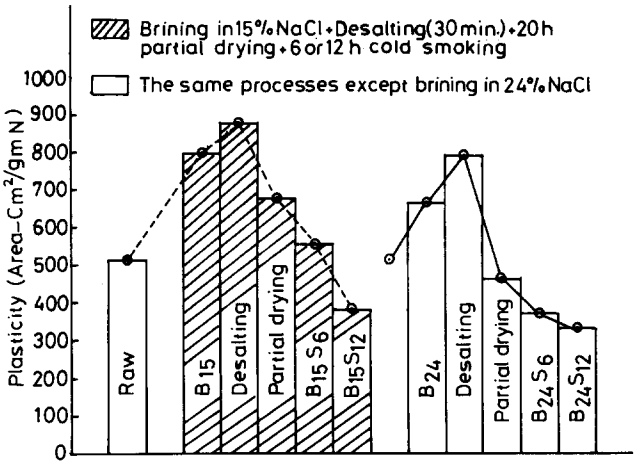

Fig. 3. Effect of brining, desalting, partial-drying and smoking processes on the plasticity of common carp fish.

concentration and heating (Table 1 and Fig. 1). According to the desalting theory, the shrinkage occurs because the ions of neutral salt attract the polar H_2O molecules and dehydrate protein in this manner. Locker (1956) reported that the increase of the rigidity of muscle by heating starts at about 35°C.

Sensory evaluation

Figure 4 shows the sensory evaluation of smoked CCF with different WPS contents. All products were organoleptically acceptable after cold smoking for either 6 or 12 h. The odour scores of the four smoked products ($B_{15}S_6$, $B_{24}S_6$, $B_{15}S_{12}$ and $B_{24}S_{12}$) did not differ significantly. However, significant differences were observed in taste, texture and colour and these were sufficient to give significant differences in the overall acceptability of the smoked products. Smoked CCF could be arranged descendingly, as far as the average scores of taste are concerned, as follows: $B_{15}S_6$, $B_{24}S_6$, $B_{15}S_{12}$ and $B_{24}S_{12}$. Samples brined in either 15% or 25% NaCl and subjected only to 6 h of cold smoking gave higher average scores in texture and colour as well as in overall quality which may be why most of the smoked fish products consumed in Egypt contain high levels of salt. But the levels of salt found in $B_{15}S_{12}$ and $B_{24}S_{12}$ samples were high enough to reduce, to some extent, the acceptability of the panelists for these products. Meanwhile, fine flavours and aromas (most of which are water soluble) could be accumulated in the tissues during the first 6 h of smoking when the surface tissues are still wet. Chan *et al.* (1975) reported that during smoking, the low dried fish surfaces

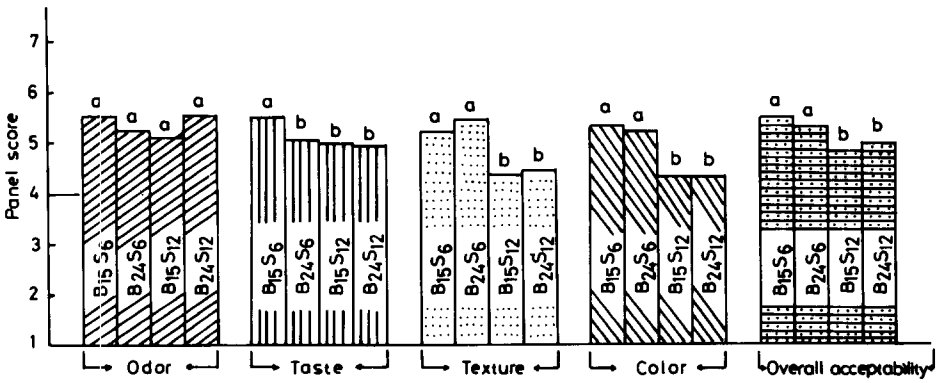

Fig. 4. Sensory evaluation of smoked common carp fish with different water phase salt contents. a–b Sensory score means with the same subscript leter in a row did not vary significantly ($P < 0{\cdot}05$) from each other, ($n = 15$ panelists). Hedonic scale: 7 'like very much' and 1 'dislike very much'. The water phase salt contents or $B_{15}S_6$, $B_{24}S_6$, $B_{15}S_{12}$ and $B_{24}S_{12}$ are 13·05, 15·16, 17·12 and 19·5%, respectively.

showed slower deposition of smoke when compared with wet surfaces. The better texture is assumed to be a result of less dehydration and denaturation as well as less salt. Moreover, smoking of fish for 12 h results in excessive darkening whereas fish samples smoked only for 6 h showed a more acceptable golden colour.

REFERENCES

Aminullah Bhuiyah, A. K. M., Ratnayake, W. M. N. & Ackman, R. G. (1986). Effect of smoking on the proximate composition of Atlantic Mackerel (*Scomber scombrus*). *J. Food Sci.*, **51**(2), 327–9.

Anon. (1958). Smoke barrel cooker. Domestic Hygiene and Engineering Co., *Institute Magazine*, **42**(6), 41.

AOAC (1980). *Official methods of analysis* (13th edn.) Association of Official Analytical Chemists, Washington, DC.

Bannerman, McK. A. (1980). *Hot smoking of fish.* Torry advisory note 82. Torry Research Station, Ministry of Agriculture, Fisheries and Food, Aberdeen, Scotland.

Bligh, E. G. & Dyer, W. J. (1959). A rapid method of total lipid extraction and purification. *Can. J. Biochem. Physiol.* **37**, 911.

Borgstrom, G. (1961). *Fish as food, Vol. 1, Production, biochemistry and microbiology*, Academic Press, New York and London, 146–51.

Chan, W. S., Toledo, R. T. & Deng, J. (1975). Effect of smoke house temperature, humidity and air flow on smoke penetration into fish muscle. *J. Food Sci.*, **40**, 240–3.

Cutting, C. L. (1965). *cf.* Borgstrom's *Fish as food*, Vol. 3, Part 1, Academic Press, New York and London, 55.

Dessoki, T. M. (1971). *Studies on smoking of fish.* Unpublished MSc. Thesis, Faculty of Agriculture, Ain Shams University, Cairo.

FAO (1983). *Year book of fishery statistics, 1981. Fishery commodities*, Vol. 53. Food and Agriculture Organisation of the UN Rome, 1983.

Food and Drug Administration (FDA) (1970). Good manufacturing practice, fish and seafood products, smoked and smoke flavoured fish. *Federal Register*, **35**, 221. (Part 128A.)

Foster, W. W. & Simpson, T. H. (1961). Studies of the smoking process for foods. 1. The importance of vapors, *J. Sci. Fd. Agric.*, **12**, 363.

Grau, R. & Hamm, R. (1957). Uber das Wasserbindungsvermogen des Saugetiermuskels. II. Mitt. Uber die Bestimung der Wasserbindung des Muskels. *Z. Lebensm. Untersuch. U. Forsch.*, **105**, 446.

Hamm, R. (1960). Biochemistry of meat hydration. *Advances in food research*, Vol. 10. (Chichester, C.O., Mark, E. M. & Stewart, G. F. (Eds)), Academic Press, New York and London, 356–436.

Krylova, N. N., Bazarova, K. I. & Kaznetsnova, V. V. (1962). Proc. 8th Meeting European Meat Res. Workers, Moscow. Paper No. 38. *cf. Meat Science.* (Lawrie, R. A. (Ed)), Pergamon Press, UK, 263.

Larmond, E. (1974). *Methods of sensory evaluation of food*, Canada Dept of Agric., Ottawa, KIAOC7, 19–24.

Lawrie, R. A. (1976). *Meat Science.* (2nd edn), Pergamon Press, UK.

Locker, R. H. (1956). The dissociation of myosin by heat coagulation. *Biochim. et Biophys. Acta*, **20**, 514.

Murno, I. C. & Morrison, A. B. (1965). Effect of salting and smoking on protein quality of cod, *J. Fish. Res. BG. of Canada*, **2**, 13.

Peryam, D. R. & Pilgrim, F. J. (1957). Hedonic scale method of measuring food preferences. *Food Technol.*, **11**,(9), 9.

Porter, R. W., Bratzler, L. J. & Pearson, A. M. (1965). Fractionation and study of compounds in wood smoke. *J. Food Sci.*, **30**, 615.

Prater, A. R. & Coote, G. G. (1962). C.S.I.R.O. Div. Food Press. Tech. Paper, No. 28. *cf.* Lawrie (1976).

Shiau, C. Y. & Chai, T. (1985). Smoked dogfish processing and its refrigerated storage stability. *J. Food Sci.*, **50**, 1348–50.

Volovinskaia, V. P. & Kelman, B. Y. (1962). Modification of the water holding capacity method of meat. *Proc. of Res. Meat Inst.*, Vol. 11, Moscow, 80.

Zaitsev, V. P., Kizivittev, E. V., Lagonov, L. L., Makarova, T. E., Minder, L. P. & Padsevalov, V. N. (1969). *Fish curing and processing*, Moscow.