Quality of "Taffi" (Siganus sutor) smoked with 6 different tree species

A TECHNICAL REPORT

Funded by the Lighthouse Foundation, Germany

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11/20/2009

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1.0Summary

Siganus sutor (common name *Taffi*) in the Kenyan coast were obtained at Gazi in the south coast of Kenya and smoked using sawdust, *Acacia raddiana*, *Prosopis juliophora*, coconut husks from *Cocos nucifera* tree, *Azadirachta indica* (Neem tree) and mangrove stumps in Moa, Tana delta area. Organoleptic assessment was determined upon completion of smoking. Insect and mould infestation, moisture, humidity, temperature were determined during storage.

The organoleptic parameters determined on a hedonic scale of 1 (not acceptable) to 5 (highly acceptable) were taste, texture, appearance and provision for overall acceptability. There was no significant difference ($p<0.05$) in taste, texture, appearance and overall acceptability in the fish smoked using the 6 different trees species except for difference in taste observed between fish smoked using Neem tree and the ones smoked with sawdust and coconut husks.

The organoleptic scores for taste in all cases were between 3.0 to 4.5, texture 3.0 to 4.0, appearance 3.1 to 3.9 and overall acceptability 3.1 to 3.6. The quality score for taste was highest in the fish smoked with sawdust and coconut husks and significantly different ($p<0.05$) from the rest. The taste score the fish smoked with Neem tree had the lowest score of 3. The fish smoked with sawdust and coconut husks also had the highest mean scores of 4.3 for overall acceptability though not significant and the *Taffi* smoked Neem had the lowest score of 3.1.

A score of 2 and below was not acceptable. The scores were however above the level of rejection meaning that all the products were acceptable.

The high scores showed that all the fuel materials used had a significant positive impact on the quality of *Taffi*,. There was no insect attack on the fish during the 39 day storage period. The first fish to be rejected due to mould attack were smoked by Neem, *Prosopis* and coconut husks after 32 days of storage. The remainder smoked with sawdust, *Acacia* and mangrove stumps were rejected by the 39th day when mould appeared. The moisture content was lowest in *Acacia* smoked *Taffi* and highest in sawdust, mangrove and Neem smoked *Taffi.* Coconut husks and *Prosopis* occupied the positions in between. *Acacia*, coconut husks and *Prosopis* had the highest oven temperatures and lowest humidity during smoking and also smoked the fish to lower moisture content. Moisture increased in all the fish smoked with the different trees during storage. The mean humidity during the storage period was 86.6% ±5.58 while temperature was 24.8^{0}C ±0.97.

2.0 Introduction

Landed fish deteriorates rapidly under tropical conditions like Kenya. More often than not the, because of the distance between the landing sites and the urban markets, the fish has to be traditionally processed, preserved and stored. Refrigeration facilities are not available hence sun or smoke drying is the preferred traditional method of preservation. Smoking is one of the oldest food preservation methods. It consists of the application of wood smoke on food. However nowadays in developed countries, the process is predominantly used to give food organoleptic characteristics as opposed to preservation in developing countries (Varlet *et al*, 2007). Fish is very rich in the essential amino acids, has high quality vitamins and its fatty acid fraction has well established health benefits (Huss, 1995). Fish is also very important in terms of employment/income generation, poverty alleviation, foreign exchange earnings and provision of raw materials for the animal feed industry (FAO, 2007). Fish however spoils rapidly once out of water unless preserved (Huss, 1995) and is still highly susceptible to damage by insects and other microorganisms when smoked or dried then stored (Akinwumi *et al,* 2007). In Kenya, the preservation methods of fish commonly used are open air sun drying for both marine and freshwater fish, smoking for freshwater fish and frying for some marine fish. Fish landings at the coast of Kenya are seasonal and can occur when the weather is dump and open air sun drying is not possible. This calls for introduction of preservation methods traditionally not used for preserving marine fish. Recent attempts with success have been made to introduce marine fish smoking at the coast (Oduor-Odote and Obiero, 2009). This has been done using improved fish smoking ovens that consume less wood fuel and are less labour intensive thus easier to adopt and produce quality products that can enter the market as new products.

With an increased fish consumption expected due to awareness of its health benefits (Ruidavets *et al*, 2007 Monten *et al*, 2009) coupled with the government's efforts to increase fish production by introducing fish farming through an economic stimulus package (GoK Budget 2009-2010), selling fish as just standard products may not fetch high income and newer processing methods need to be introduced to help in preservation while introducing newer products in the market. The rabbit fish –*Siganus sutor* commonly known as *Taffi* is one of the most popular marine fishes landed at the coast. It is either sold fresh, fried and only dried when there is glut and when its quality has started to deteriorate. Introducing smoking of *Taffi* as a new product will reduce post harvest losses during periods of glut and avail a newer product in the market. This strategy is informed by earlier positive responses received by other smoked marine fish on trial (Oduor-Odote and Obiero, 2009). The use of wood as source of energy for fish smoking is widely practiced in Africa (Nerquaye-Tetteh, *et al,* 2002). Smoking improves flavor and appearance of fish (Cardinal *et al,* 2006, Simko 2005).

An alien tree species considered a nuisance that has encroached some parts of the coast especially the Tana delta area is *Prosopis juliofora* ("Mathenge") (Oduor and Githiomi, 2003; Pasiecznik *et al* 2006**)**. *P. juliofora* has potential as a wood fuel (Puri *et al*, 1994) though it has not been tried to smoke fish. It can ease pressure off *Acacia raddiana*, the current tree of choice for fish smoking in the area (Oduor-Odote *et al*, 2008). Coconut plantations provide numerous products such as coconut meat, milk and husks. Coconut husks can be used for cooking, heating and as the heating base for smoking meat and fish. The use of coconut husks for fish smoking was tried by (Benjakul and Aroonrueng**,** 1999). The current revival of the coconut industry by the government of Kenya will see the availability of coconut husks ideal for use in fish smoking as they are virtually collected for free thus lowering the wood fuel costs and ultimately product price.

If found to be suitable for fish smoking, its further use can ease pressure off pressure on local trees like mangroves. The use of mangrove trees in fish smoking is discouraged due to their ecological importance. Dead mangrove stumps are used in the study as a control for coconut husks. The processing of fish inevitably entails a storage period for the finished product prior to marketing and consumption. Since fish are composed of perishable nutrients, storage period should be kept to a minimum with adequate storage conditions provided so as to prevent deteriorative changes occurring through oxidative damage and or microbial, insect or rodent infestation. (Adebote *et al*, 2006; Davies *et al*, 2009; Daramola *et al*, 2007; Oduor-Odote and Obiero, 2009). Exact statistics of storage losses of smoked fish products during storage are not available but observations indicate that insect infestation especially by beetles is common. Evaluation of insect and mould attack will help improve storage conditions in future. The main interest in using Neem (*Azadirachtica*) in fish smoking is because of activity of its components as a deterrent for both insect activity and mould. It has multiple pesticidal and medicinal properties, smoke from its leaves are used as insect repellant, about 135 different compounds are found in every part of the tree and it has antimicrobial effects (Battacharyya, (2007); Coventry and Allan (2001); Mordue and **Nisbet** (2000); Biswas et *al,* (2002). In Kenya, interest started being shown in the Neem tree for commercial and industrial potential in 1980's and it continues till now (Nderitu *et al,* 2008). No work is reported for the use of Neem tree in Kenya in fish smoking and for control of insect infestation during storage of smoked fish products.

There is a current rush in the construction industry in Kenya and use and demand for timber has grown. This is even evidenced from furniture shops making and displaying their items by the roadside currently. This high consumption of timber is yielding a lot of sawdust as a by-product. Use of sawdust in fish smoking has been tried by Oyewole *et al*, (2006). The use of sawdust in fish smoking if successful shall avail another free source of fuel for fish smoking just like coconut husks. This shall help reduce costs of final product as well as limit completely cutting of trees for fish smoking as much as the smoking method used here itself uses less fuel.

This study intended to produce at community level, smoked marine fish smoked with 6 different tree species or products.

The objective of this study was therefore to evaluate the relative effects of 6 tree species or products- *Acacia raddiana, Prosopis juliofora*, Neem (*Azadirachta indica*), coconut husks from *Cocos nicifera*, mangrove stumps and sawdust on quality of smoked *Taffi* (*Siganus sutor*) and to monitor insect and mould infestation in the fish products smoked with Neem tree during storage.

3.0Study area

The fish were from Gazi in the South coast of Kenya though they were smoked in Moa in the North coast of Kenya. Moa which is in the Tana delta has fish smoking infrastructure capable of holding such a study all at the same time. Moa lies 4 km off the Garsen-Witu road on your way to Lamu.

4.0Materials and Methods

4.1Construction of Smoking Ovens

Six block-walled improved double door fish smoking ovens were constructed according to (Oduor-Odote *et a*l, 2008; Brownell and Lopez, 1985)

Collection and preparation of samples for processing

The fish were purchased in Gazi and Shimoni in the south coast of Kenya. They were gutted immediately, and washed in fresh water with ice. They were placed in 100 litre Coleman ice boxes) with ice, sealed then transported by road to Moa, 450km away on a 5hr journey. The fish were transferred to the smoking trays whose mesh was oiled prior to the distribution of fish using liquid food vegetable oil so that fish muscle did not stick during smoking. About 120 pieces of fish were randomly placed on each side of the 6 fish smoking trays. Each tray therefore contained 240 pieces of fish. The trays with the fish were transferred under shade and inclined at an angle to let the fish drip dry for 1 hour. Small logs of wood from *Acacia raddiana, Prosopis julifora,* mangrove stumps, and *Azadirachtin indica* were cut into chunks using a power saw (HUSQVARNA 61-268 272XP). The chunks were reduced further using a handsaw into smaller pieces with lengths of about 50 cm and a fairly uniform thickness of 4.0 to 7.0 cm. The coconut husks and sawdust collected in Gazi and Mombasa respectively then transported to Moa were utilized without any further reduction in size. The fire was lit 30 minutes before start of smoking using grass and left to burn till the flames died off and only smouldering wood remained.

The pieces of wood and wood products were weighed each time before being put in the fire pits of the smoking ovens. 6 pieces of fish from each treatment were weighed in a SALT PETER electronic field balance to give a representative sample of weights at the beginning of the experiment in each of the trays. They were returned to the trays. The starting weights of wood fuel were weighed before the start of the experiment. The fish were transferred to the smoking chambers already pre-prepared to specification (Oduor-Odote and Obiero 2009). Each set of trays with the fish were smoked using the 6 tree types all at the same time in each of the 6 double door ovens. The fish on each of the trays were labeled as follows- TA – (*Taffi Acacia*); TP – (*Taffi Prosopis*); TN- (*Taffi* Neem); TM-(*Taff*i Mangrove); (TC- (*Taffi* coconut) and TS-(*Taffi*-Sawdust)). To control the excessive temperature in the ovens, the intensity of the fire was reduced by intermittent withdrawal of some of the logs from the fire point. The stokehole was often closed for coconut husks to prevent them burning rapidly and kept open for sawdust to catch fire them smoulder. At intervals, the positioning of the fish was interchanged to effect uniform penetration.

Temperature and humidity in the smoking ovens as well as drying rate was measured every 2 hours with the latter using 3 randomly chosen fish from each of the trays. At the end of smoking, the fish were removed from the kilns and exposed to air to cool for 2 to 3 hours (Akande *et al* 1996a). The fillets were packed in labeled plastic open sided milk crates and transported for storage in the open on benches in KMFRI lab Mombasa (350 km away) and for organoleptic analysis as well as storage evaluation.

4.2 Moisture analysis

Moisture was determined according to AOAC (1990).

4.3Sensory evaluation

This involved locally semi-trained panelists drawn from KMFRI staff. The organoleptic parameters that were evaluated included appearance, texture, taste. A provision for a score on overall acceptability was given (Oduor-Odote and Obiero, 2009). A 5 point hedonic scale was used.

A score of 2 and below was considered not acceptable. The fish fillets were coded with numbers of 2 digits indicating no information about the samples to avoid bias in preferred treatments. Samples for taste (cooked flavour) were heated in a microwave oven (LG INTELLOWAVE) without any additives like salt before tasting. Normal consumption temperature for food was used.

8 panelists who were neither hungry nor satiated were used at each sampling time. The panelists were advised not to smoke or eat 1 hour before the sensory evaluation, to avoid perfumes or aftershave and avoid being in the panel if sick or suffering from cold. Each panelist was served as similar a part of the fish as possible i.e. a sample from the tail parts

or loin parts. The quantities of samples were at least 2-3 bites for each panelist. The panelists received each sample separately. Rinsing the mouth between samples was done using plain unsalted crackers then water.

4.4 Storage Trials

Insect and or mould attack was monitored during the storage period. Attacks by insects or moulds were determined according to (Khan and Khan, 2001). Any sign of mould attack was the limit of acceptability while a score equal to or above 3 for insects was the limit of acceptability beyond which the fish were rejected. Insect and mould attacks were monitored daily till the first sign of mould attack.

5.0 Data analysis

Analysis of variance (ANOVA) carried out on the results were performed in the statistical program NCSS 2000 (NCSS, Utah, USA). The program (ANOVA) calculates multiple comparisons using Duncan's test to determine if sample groups are different. Significance level was defined at 0.05 (α=0.05).

6.0 Results and Discussion

6.1 Sensory evaluation

The sensory scores after smoking are given in Table 1. The results showed no significant difference ($p<0.05$) in taste, texture, appearance and overall acceptability in the fish smoked using the 6 different trees species except for difference in taste observed between fish smoked using Neem tree and the ones smoked with sawdust and coconut husks.

The organoleptic scores for taste in all cases were between 3.0 to 4.5, texture 3.0 to 4.0, appearance 3.1 to 3.9 and overall acceptability 3.1 to 3.6. The highest score for taste was from fish smoked with coconut husks and sawdust with a quality score 4.5 and was significantly different $p<0.05$) from the rest. The taste for the fish smoked with Neem tree had the lowest score of 3. The fish smoked with sawdust and coconut husks also had the highest mean scores of 4.3 for overall acceptability though not significant and the *Taffi* smoked Neem had the lowest score of 3.1.

Table 1 Mean sensory scores of appearance, taste, texture and overall acceptability attributes of *Tafi* smoked using different tree types (N = 8).

	Mean attribute score			
Tree type	Appearance	Taste	Texture	Overall acceptability
Acacia	3.1	3.5	3.1	3.6
Prosopis	3.3	4.3	3.9	3.5
Mangrove	3.6	3.6	3.6	3.4
Coconut	3.9	4.5^{a}	4.0	4.3
Sawdust	3.6	4.5^{a}	3.3	4.3
Neem	3.3	3.0^{b}	3.0	3.1
p-value	*0.667*	***0.012***	*0.171*	*0.058*

Data within the same column for each pair with different letters (superscript) are significantly ($p<0.05$) different.

A score of 2 and below was not acceptable. The scores were however above the level of rejection meaning that all the products were acceptable.

Acacia is usually the tree of choice in areas active in fish smoking at the coast. These results suggested that *Prosopis,* Neem, mangroves, sawdust, mangrove stumps and coconut husks can also be used to smoke *Taffi* without significant differences in taste, texture, appearance and overall acceptability except in a few cases of taste where the Neem tree had the lowest score. The differences in taste observed in *Taffi* smoked with coconut husks, sawdust and Neem from the rest of the tree types could be due to the different compounds in sawdust, coconut husks and Neem tree interacting differently with body components of the fish. It can be postulated that since the sawdust is from previously sawed wood of many varieties of different species whose origin could not be easily determined in the sawdust, composition of smoke, phenolic and carbonyl compounds in the cocktail of sawdust all contributed to the superior organoleptic qualities of the sawdust. High organoleptic scores for coconut husks used in smoking catfish fillet have been reported by Benjakul and Aroonrueng (1999). They argued that the initial moisture content in the wood products could possibly alter the type and amount of volatile compounds in smoke and would influence overall sensory properties. Lower-moisture wood tended to produce a higher amount of phenols, acids, carbonyls than middle-moisture samples. The superior performance of coconut husks could be due to but not limited to the above facts. For Neem, the reason for the lower taste scores could be due to the components which are usually bitter that probably interacted with the fish muscle and produced the undesirable aftertaste in the mouth of panelists. More detailed studies need to be done to determine which smoke component is responsible for the differences. The scores for texture were lower in Neem, *Acacia* and sawdust smoked *Taffi*. Texture is an important quality in fish products that is both a sensory characteristic for the consumer and an important attribute for the mechanical processing of fillet. Textural characteristics include hardness (firmness) which is one of the most important traits in fish (Bourne, 1978; Lin *et al*, 2009). Textural changes observed in smoked products are also due to protein denaturation during smoking process (Benjakul and Aroonrueng, 1999).

Firmness is influenced by intrinsic structure and properties of the components of the flesh, such as myofibrillar, sarcoplasmic protein and connective tissue. Firmness is however also influenced by cooking. The myofibrillar and sarcoplasmic proteins of fish bond and contract differently in fish. They bond and contract together, are denatured, coagulate together and increase the mechanical strength of the muscle. Differences in texture of muscle were observed by Lin, *et al* (2009) after heating criss grass carp and grass carp. The factors that were identified to be responsible for changes in texture were short muscle fibre diameter, dense fiber density, large collagen amounts, narrow inter-myofibrillar spaces and gaps. Whereas more specific studies are required to explain the differences in texture in the different tree species the differences in texture scores could be due to any of the above reasons.

The lowest scores for appearance were observed in *Acacia, Prosopis* and Neem tree and higher scores in mangrove, sawdust and coconut husk smoked fish. The appearance of the final product is important as it has to be consistent with market demand and it gives the first impression of the product. Appearance of smoked *Taffi* using the different trees or tree products encompasses many items. The appearance is usually judged based on among other things, the black golden luster which the smoke of the different tree products would confer on the fish muscles differently. Better performances for sawdust and coconut husks when used in fish smoking over other fuel woods have been reported by Akande *et al*, (1996b) and Benjakul and Aroonrueng,(1999). They attributed better scores for sawdust to be due to the heavier smoke and the low fire characteristic of sawdust and polymerization of extractable proteins. Since components in the 6 tree smokes and how they interact with *Taffi* muscle surface are not known, exact factors that led to differences in appearance may not be clear and can be studied further.

The fact that there were organoleptic scores much higher than 2, the limit of rejection and majorly no significant difference in sensory attributes except for a few cases especially in taste for Neem during smoking in this study indicates that smoked *Taffi* is an acceptable new product waiting to enter the market. Neem tree, mangrove stumps, *Prosopis* and coconut husks and saw dust have potential for use in fish smoking and can be analyzed further for intrinsic properties in smoking marine fish.

Sawdust and coconut husks are waste products normally available for free and their performance in fish smoking could lower costs considerably in fish smoking while conserving the environment. The *Prosopis* tree which is alien and a nuisance could find good use in fish smoking.

Inspite of *Acacia, Prosopis,* Neem, mangroves, sawdust and coconut husks being used for smoking fish, the components of their smokes have not been studied in relation to fish smoking. Different fuel sources give smoke that has distinctly different sensory properties. Many factors influence the quality of smoked fish products including the properties of fish flesh, maturity, age, sex, seasonal variations and factors involved in the smoking procedure such as wood type, composition of smoke, temperature, humidity, velocity and density of the smoke (Simko, 2005). Phenolic and carbonyl compounds contribute towards taste in smoked fish (Maga and Fopajuwo, 1986; Martinez *et al*, 2007). Organoleptic properties of smoked foods are decisively influenced by composition of the smoke and nature of wood involved. There is no agreement about which wood or mixture of woods imparts the preferred sensorial properties to smoked fish (Guillén and Manzanos, 2002). Further studies for characterization of the individual wood components is still recommended

6.3 Moisture, Insect and mould during storage

The moisture content is as shown Table 2. Moisture was 5.83% in the *Acacia* smoked *Taffi*, 9.59% in coconut husk smoked *Taffi*, 9.80 in *Prosopis,* 12.28% in sawdust, 13.48% in Neem and 13.54% in mangrove smoked *Taffi*.

Table 2 Moisture content of *Taffi* after smoking

Tree	%Moisture	sd
Sawdust	12.28	0.22
Acacia	5.83	0.04
Coconut	9.59	0.13
Mangrove	13.54	0.09
Neem	13.48	0.13
Prosopis	9.80	0.02

The moisture content was therefore lowest in *Acacia* smoked *Taffi* and highest in sawdust, mangrove and Neem smoked *Taffi.* Coconut husks and *Prosopis* occupied the positions in between. *Acacia*, coconut husks and *Prosopis* had the highest oven temperatures and lowest humidity during smoking and also smoked the fish to the lower moisture content (Table 3, Figure 1 and 2).

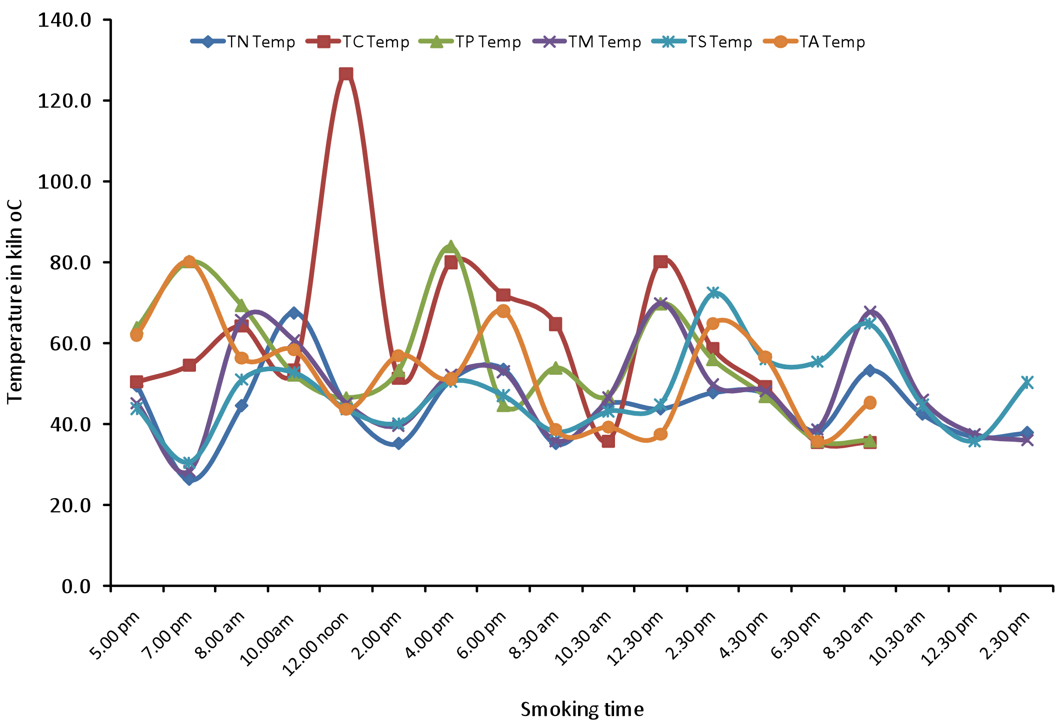

Figure 1 Temperature in smoking kilns during smoking of *Taffi*

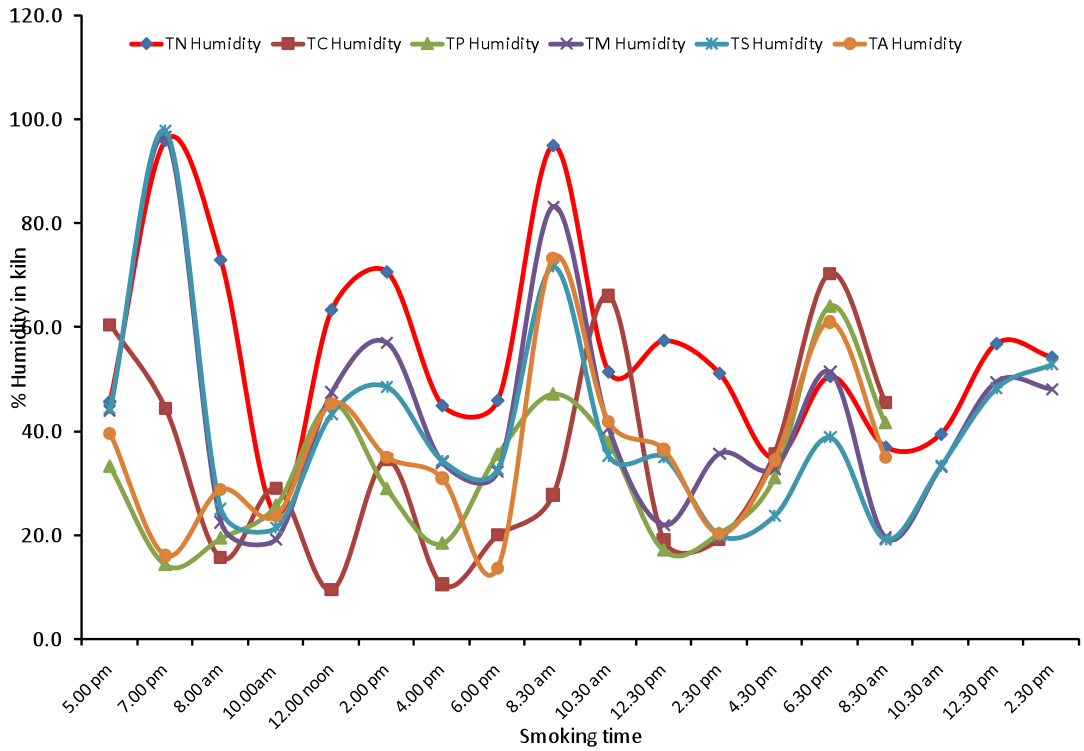

Figure 2 Humidity in smoking kilns during smoking of *Taffi*

Table 3 Mean temperature and humidity during smoking

	Temperature	Humidity
Sawdust	48.11	40.28
Acacia	52.96	35.7
Coconut husks	60.86	33.85
Mangrove	48.11	42.76
Neem	44.5	55.12
Prosopis	55.93	31.97

One of the reasons for the difference in the final moisture content is due to differences in burning properties of the trees (Oyewole *et al*, 2006). It can be postulated that *Acacia*, *Prosopis* and coconut husks burn hotter than sawdust, mangrove and Neem. The hot smoking involved the temperatures that were high enough to cook the fish over the long smoking time. The flame temperature which, determines the quality of heat available for combustion and establishes the maximum attainable thermal efficiency of converting the useful heat into work is lower in sawdust, Neem and mangrove. On the other hand, coconut husks, *Prosopis* and *Acacia* have a high heating value coupled with thermal efficiency thereby reducing the moisture content to much lower levels that may even prevent growth of microorganisms.

During storage, moisture content increased over time (Figure 3). Moisture in Neem, mangrove and coconut increased from 13.48% to 16.01%, 13.54 to 15.79% and 9.59 to 16.28% respectively by day 32. By day 39, moisture in sawdust, *Acacia* and *Prosopis* increased from 12.28 % to 16.86%, *Acacia* 5.83% to 14.58% and 9.80% to 15.56% respectively. Similar observations have been made by Daramola *et al*, (2007). He attributed the increase in moisture during storage to high humidity differences between ambient air and fish muscle moisture leading to muscle taking up moisture. When moisture is reduced to 25 % wet basis, contaminating agents cannot survive and autolytic activity is greatly reduced (Bala and Mondol, 2001). However to prevent mould growth during storage moisture must be reduced to below 15% (Bala and Mondol, 2001). Daramola *et al.,* (2007) indicates that for smoked fish to survive mould attack during storage after a few days, moisture should be below 12%. Other factors however like different arrangements of fish muscles vis-à-vis free/bound waters, and the fat content of fish species could be important factors to storage (Daramola *et al.,* 2007). In this study, after 30 days of storage, moisture was above 15% creating an environment for mould growth.

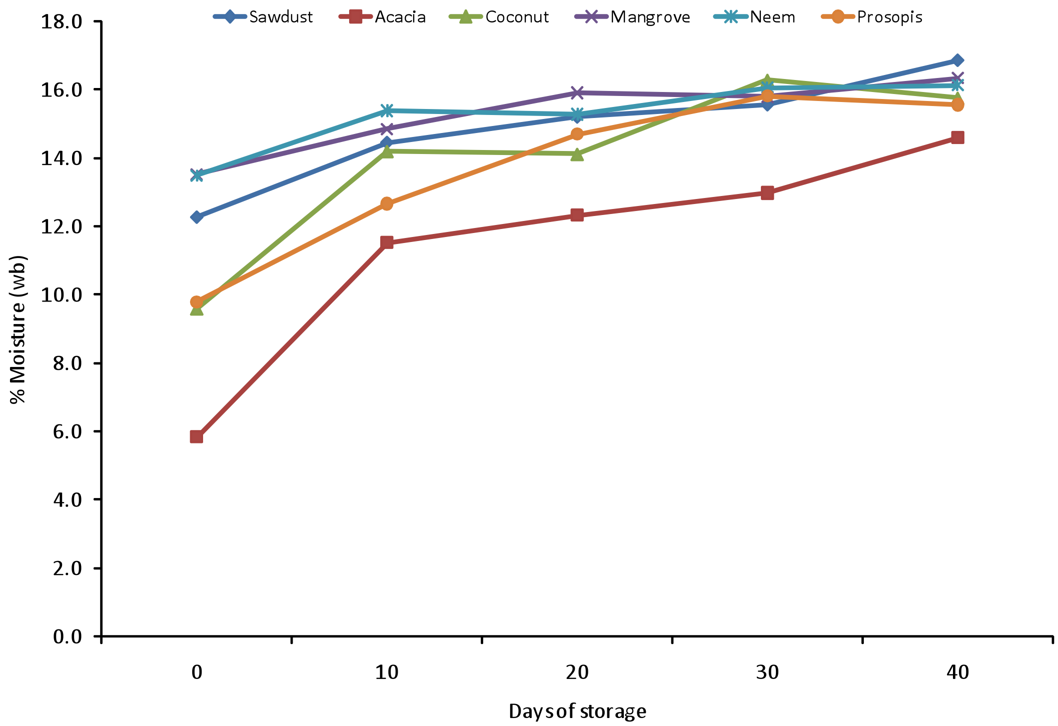

Figure 3 Moisture content during storage of *Taffi*

There was no sign of insect attack throughout the 39 day storage period. The first sign of mould attack was on day 32 for the fish smoked with Neem tree, *Prosopi*s and coconut husks. The particular fish were removed from the storage process. By day 39 however, all the samples were infested by mould and storage discontinued.

Insects and mites are often found infesting cured fish during and after processing. Insect development during storage of cured fish in the open is influenced by temperature, relative humidity and moisture content (Haines and Rees, 1989; Ezenwaji *et al,* 2004; Daramola *et al,* 2007). At moisture contents below 14%, Ezenwaji *et al* (2004) found no insect egg deposition in fish muscle. The moisture content in the fish muscle during storage may be was not high enough to allow insects to deposit their eggs. The Natural products from the plants used in smoking if not thermo sensitive may offer protection (Adebote *et al*, (2006). It is not known whether the smoke of these entire 6 tree species also contain some bioactive compounds which when deposited on fish muscle during smoking prevents insect infestation. Prevention of mould attack in smoked fish is due to active microbial components in the respective smoke sources (Guillen and Manzanos, 2002).

Carboxylic acids and phenols have been reported to show the highest antimicrobial activity with carboxylic acids lowering the pH while phenols inhibit microorganisms (Benjakul and Aroonrueng, 1999; Guillen and Manzanos, 2002). It is also not clear whether bioactive compounds in *Neem tree* are inactivated by heat as it behaved just like the rest of the trees with no prior antimicrobial activity.

Moulds grow on smoked fish whenever there is enough moisture. Moulds also like humid and damp conditions (Bukola *et al*, (2008). The mean humidity during the storage period was 86.6% ±5.58 while temperature was 24.8^{0}C ±0.97 as shown in Figure 4.

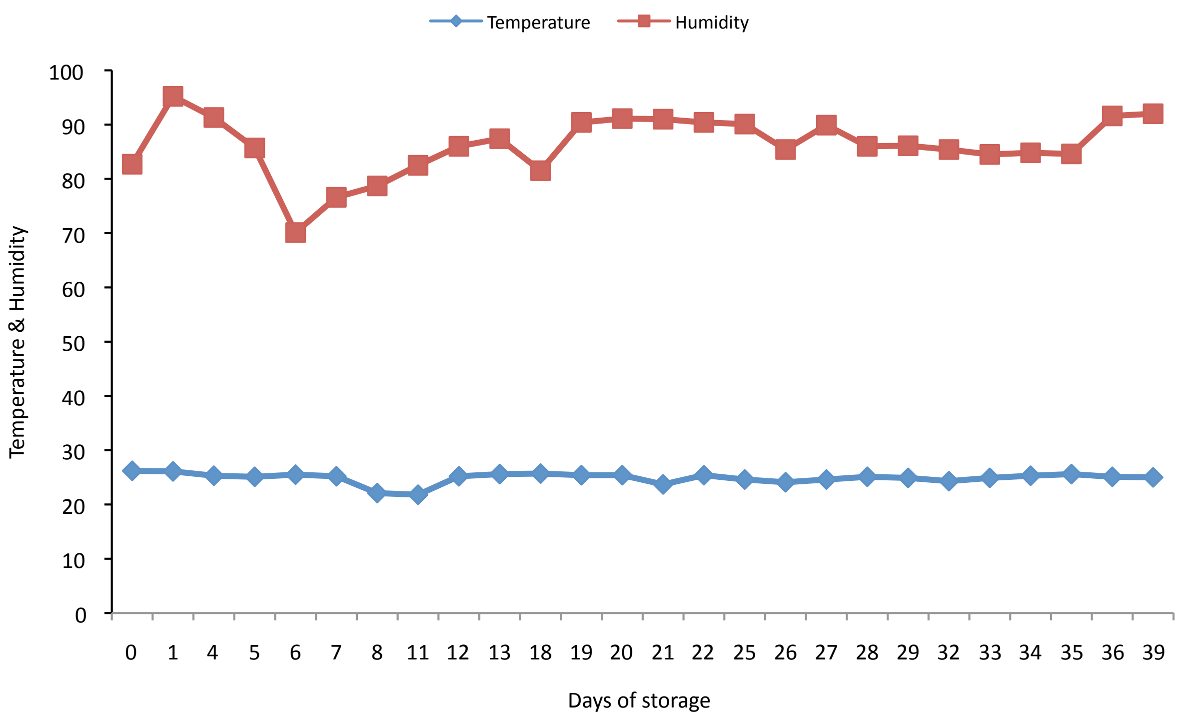

Figure 4 Variation of humidity and temperature during storage of *Taffi* in open air

In this study, the humidity was high and the absorption of moisture by the fish muscle also encouraged mould growth. It is well known that the environmental factors that govern storage or shelf life are ambient temperature and humidity as they dictate the rate at which chemical changes of spoilage take place (Daramola *et al,* 2007). It is because of high humidity and moisture in fish muscle that led to mould attack.

7.0 Conclusions

Smoked *Taffi* has organoleptic properties that are acceptable and can be availed in the market as a new product. Whereas the tree of choice for smoking freshwater fish at the coast is *Acacia*, other trees can be used alongside it to smoke marine fish with production of acceptable products. The use of waste tree products like sawdust and coconut husks with acceptable results is a means of reducing the cost of initial input for trees used in fish smoking and provides a way for environment conservation because less wood fuel shall be used. The utilization of *Prosopis juliophora* which is an alien invasive species considered a nuisance as a wood fuel in fish smoking will considerably reduce its population in fish smoking areas. The open air storage period of 39 days achieved for hot smoked *Taffi* is commendable considering that marine fish species contain highly saturated fatty acids that lead to spoilage. The invasion by moulds by day 39 of storage is due to the moisture content and humidity during storage. The apparent weakness of the Neem tree in controlling mould attack could be due it inactivation of its bioactive components in smoke probably by heat

8.0 Recommendations

More work needs to be done to analyze the intrinsic properties of the smoke produced by the trees used in fish smoking to understand more about their interaction with fish muscle for desirable organoleptic effects especially flavouring action of the various smokes. Studies need to be carried out further on shelf storage with packaging so as to avoid moisture increase during storage. Most marine fish should be brought on board and smoked as new products stand a better chance in the market for more income generation and food security than standard fish commonly available. Further evaluation of the Neem tree in microbial control during storage needs to be studied. Use of mangrove stumps in fish smoking can be discouraged as other trees at the coast and tree products are available some for free for fish smoking.

9.0 Acknowledgement

*The authors would like to so far thank the **Lighthouse Foundation-Germany** for funding the project, Director-KMFRI for providing the work space, Mr. Maurice Obiero, Maurice Omega, Cyprian Odoli, all of KMFRI, Mpaaji ni Mungu group in Gazi for their tireless assistance and Moa BMU staff for availing working space.. May God reward them all abundantly.*

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