Effect of Raw Material Quality on Quality and Yield of Dried Fish Products

Peter Odour-Odote[1], Bangalore A. Shamasundar[2], Alejandro C. Booman[3], Nazlin K. Howell[4], María A. Parin[5] and Aurora Zugarramurdi[5,6,*]

[1]*Kenya Marine and Fisheries Research Institute (KMFRI)*

[2]*Department of Fish Processing Technology, Karnataka Veterinary, Animal and Fisheries Sciences University (KVAFSU)*

[3]*National Institute of Industrial Technology (INTI)*

[4]*University of Surrey, Faculty of Health and Medical Science*

[5]*College of Engineering, National University of Mar del Plata (UNMdP)*

[6]*Scientific Research Commission of the Buenos Aires Province (CIC)*

Abstract: Dried fish products were prepared from siganid (*Siganus sutor*) and anchovy (*Stolephorus sp.*) using solar drying and from flounder (*Paralichthys patagonicus*) using atmospheric freeze-drying. Very good correlations were obtained between raw material quality and dried fish quality, in a dimensionless scale. A lower slope was obtained for flounder (R^2 = 0.971) when comparing with siganid and anchovy (R^2 = 0.892), indicating that raw material quality influences the quality of final products, being higher in fatty than in lean fish. This information is useful to reject unsuitable raw material before processing. A correlation between quality of raw material and process yield is presented.

Keywords: Quality, Fish, Solar drying, Freeze drying, Process yield.

INTRODUCTION

The consumption of fish is increasing worldwide as more information about its health benefits and nutritional qualities expand. Fresh fish contains nearly 80% of water and is highly perishable, with a short storage life [1]. As chilling and freezing facilities are often lacking in many developing countries, drying is one of the most common methods to preserve fish since it is an efficient technique to improve stabilization and storage [2]. In countries like Kenya, fish drying is common in artisanal fish landing sites that are far flung from infrastructure such as roads, electricity for refrigeration and ready market [3].

The traditional processing technologies used in drying, salting or combinations, lead to deterioration in end product quality. Artisanal sun drying is undesirable as the fish is commonly placed in the open, on rocks, beach or sand, exposed to birds, vermin and insects, which are sources of microbial contamination. Microbial contaminants also come from personnel, on-board fishing vessels, water, and processing environments along the entire chain of processing. The main problems attributed to dried-salted fish are the variable and often low quality of the finished product, a high salt content and a rapid rate of deterioration during transport, distribution and storage of some products. Despite quality issues, studies have shown dried fish to be a highly nutritious food containing highly unsaturated fatty acids, fat-soluble vitamins, vital minerals as well as proteins containing essential amino acids [4, 5].

Drying technologies other than sun drying can improve quality by speeding up the process or reducing drying temperature. Freeze-drying is generally considered a superior way to dry food products as more of the texture and flavour is preserved, but at high energy and investment cost. This process requires vacuum chambers capable of withstanding 10 t/m^2, which implies high investments in equipment. An alternative is atmospheric freeze drying (AFD), a process that has been proposed as not requiring the vacuum chamber and pump investment [6], and also offering the advantage of a quasi-continuous operation. Fish dried below freezing temperatures without the aid of vacuum are usually referred as AFDried fish, although some melting and shrinkage may occur due to relaxation of the frozen structure when the temperature is not kept well below -5ºC.

A recent EU funded research project, *Securefish*, scoped in developing safer and sustainable drying

*Address correspondence to this author at the College of Engineering, UNMdP, Juan B. Justo 2050. 7600, Mar del Plata, Argentina; Tel: +54-223-4827705; Fax: +54-223-4827705; E-mail: auroraz@mdp.edu.ar

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technologies that included improved solar drying tunnels drying and AFD. Data gathered in this project is hereby used to fulfil the information gap in the relation product to raw material quality, for several fish drying processes [7].

The objective of this paper is to investigate the influence of improving initial quality of fresh siganid (*Siganus sutor*), anchovy (*Stolephorus sp.*) and flounder (*Paralichthys patagonicus)*, on the quality of both solar dried and atmospheric freeze-dried products made by sustainable technologies, to get safety and high quality products. Changes in process yield due to different raw material quality level are also evaluated.

MATERIALS AND METHODS

Fish Source and Characteristics

The raw material comprised different quality levels ranging from best to acceptable quality fish, which were produced by variations in handling after catch and before processing. Fresh fish were kept iced for 0, 2, 4, and 6 days.

Siganid

It was purchased from artisanal fishermen during 2012-2013 at Shimoni, South Coast of Kenya. Earlier, fishermen had been instructed to gut fish immediately after capture and group it based on capture time. Upon landing, fish of the same size and time from capture, and handled similarly on board fishing vessels, were sampled. Fresh siganid usually ranged from 11 to 44 cm total length. For this work, 200 to 400 g in weight range was used.

Anchovy

It was caught from the artisanal fisheries along the west coast of India near Mangalore, and was purchased from a local fish market. The mass and length of the whole fish ranged from 12 to 15 cm and 20 to 25 g, respectively. Fish was iced at 1:1 ratio using flake/crushed ice with fish and ice as alternative layers.

Flounder

It was obtained from the coastal fleet at Mar del Plata port, Argentina. Samples were collected during 2012-2013 period. Whole fish was kept in ice until arrival to the laboratory in an early post-rigor condition (approximately 48 h after catch). The fish was arranged in perforated plastic boxes, covered with ice, and stored at 4ºC for up to 6 days. The draining and addition of ice was done every 24 h. The fish ranged from 35 to 50 cm in length. In order to compute yields, 400g to 600g in weight range was used.

Chemical characteristics

At 0, 2, 4 and 6 days from capture, six fish were removed from ice storage and used for chemical analyses. Muscle from each fish constituted one sample. Each sample was processed in triplicate. Moisture and lipid were determined using standard procedure [8].

Siganid and Anchovy

Total volatile bases (TVB-N, mgN/100g sample), peroxide values (PV, meq O_2/kg sample) of the extracts and thiobarbituric acid value (TBA, mg of malonaldehyde/kg sample) were determined using standard procedures [9]. In fresh fish, it is considered that acceptable limits no longer suitable for human consumption for TVB-N, PV, and TBA are 30-35 mg N /100g sample (Huss, 1988), 10-20 meq O_2/kg sample [10], and 1-2 mg of malonaldehyde/kg sample [11].

Flounder

The K value is defined as the ratio (%) of non-phosphorylated ATP-breakdown products to the total ATP-breakdown products [12]. Other authors [13, 14] described that very fresh fishery products with K values lower than 20% is regarded as "sushi" or "sashimi" grade (optimal grade of freshness), moderately fresh with K values lower than 50%, and not fresh with K values higher than 70%.

Yield Studies

For siganid, weights for whole, beheaded and gutted fish were recorded, and the percentage weight loss due to beheading and evisceration were calculated. For flounder, filleting yield was calculated as weight of fillets divided by weight of whole fish.

Process

Solar Dried Siganid

Fish were beheaded, eviscerated and washed, then placed in the solar tunnel dryer developed for *Securefish* project [7] at an average temperature of 46ºC for 30 hours. The drying tunnels incorporated solar panels and windmills, which allow continuous drying day and night, even during the rainy season.

Solar Dried Anchovy

The fish was eviscerated, beheaded and washed, and salted in the ratio of 4:1 (fish: salt) for 6-8 h. After salting, the fishes were rinsed in tap water and dried in solar biomass hybrid dryer [7]. The solar biomass hybrid dryer has the provision of drying during day using solar energy and during night by burning biomass. The temperature was maintained at 40-45ºC. The total duration of drying was 23-24h (both solar and biomass drying).

Atmospheric Freeze Dried Flounder

The raw flounder were filleted and washed. Fillets were individually quick frozen, allowed to temper at -10ºC, sliced to 3.8mm strips and placed in trays into the custom built dryer at INTI's facilities in Mar del Plata, Argentina, at sub-zero (-2ºC) temperature and normal atmospheric pressure for three days [7].

Product Analysis

Chemical Characteristics

TVB-N, PV and TBA values were obtained for solar dried siganid and anchovy, using standard procedures [9].

Colour Measurements

A Nippon Denshoku NR-3000 Handy Colorimeter, with a D65 illuminant and the observer at 2º, was used to measure the colour of freeze-dried portions of flounder. The colorimeter was calibrated with a white calibration board (X = 82.81, Y = 87.09, and Z = 91.50). For each lot, six readings of lightness (L), redness (a) and yellowness (b), were obtained. Results were given as L^*, a^* and b^* values and also as total colour differences (ΔE^*_{ab}), defined by:

$$\Delta E^*_{ab} = \sqrt{((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)}$$

Statistical Analysis

To facilitate development of an overall regression, data obtained for this work were compared with literature data. In most of the cases analysed, the value of the parameter corresponding to the best quality observed (maximum value) was used as the denominator in order to obtain each dimensionless parameter. When the related variables had a negative correlation slope, the minimum value of the variable was subtracted in both the numerator and denominator. Using this for all variables, the scale ranges between 0 for the worst quality to 1 for the best quality.

Least squares regression analysis was applied to the collected data. The Park test [15] was performed for detecting heteroscedasticity and Durbin-Watson d Test was used to detect autocorrelation [16, 17].

RESULTS AND DISCUSSION

Raw Material Quality

Water content of siganid ranged from 76.8 to 78.5%, depending on the date of capture, and for anchovy the water content ranged from 74.8 to 76.8%. The lipid content was close to 3.8% for siganid, and ranged from 3.04% to 4.88% for anchovy, both species within the range of fatty fish [12].

TVB-N, PV and TBA results for siganid and anchovy are shown in Figures **1**, **2** and **3**, along with other values from the literature [18-21].

For flounder, the moisture ranged from 79.5% to 80.0% and the lipid content from 0.718% to 0.724%, falling into the range of lean fish (< 2%) [12].

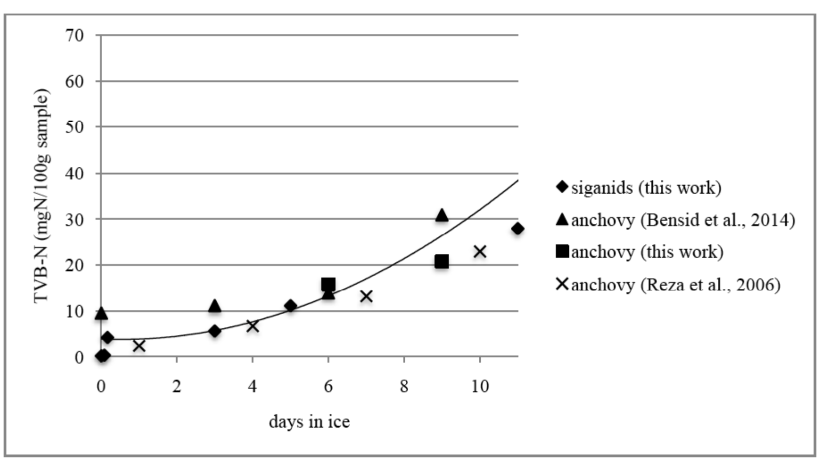

Figure 1: Variation of TVB-N (mgN/100 g sample) during ice storage period.

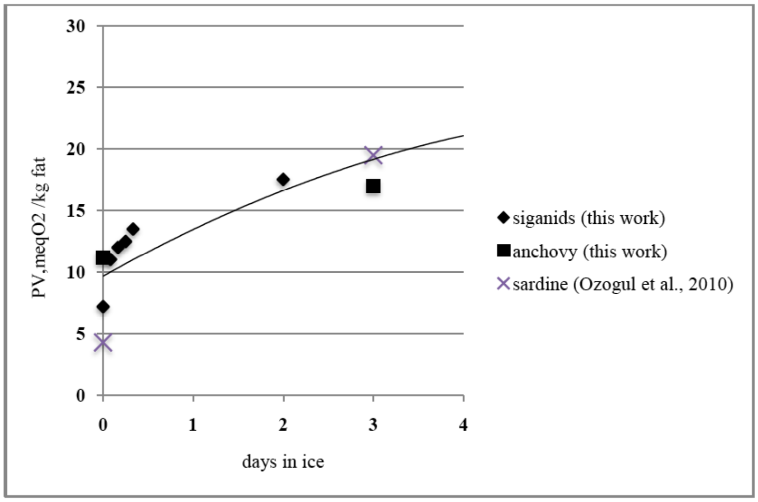

Figure 2: Variation of PV (meq O_2 /kg sample) during ice storage period.

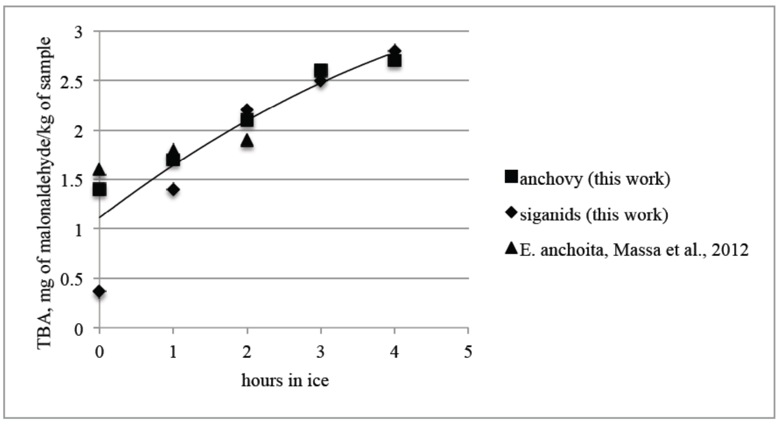

Figure 3: Variation of TBA (mg of malonaldehyde/kg sample) during ice storage period.

The K value increased with storage time from 0% (day 0) to 60% (day 8). Using the K values categories, iced flounder would be considered with an optimal grade of freshness for the first 2 days of storage, moderately fresh until day 7, and thereafter with low quality. Results are shown in Figure **4**, along with data from [22].

Influence of Raw Material Quality on Product Quality

The influence of raw material quality on the final quality of solar dried siganid and anchovy was investigated by TVB-N, PV and TBA. Values of TVB-N for the corresponding dried sample in the full quality

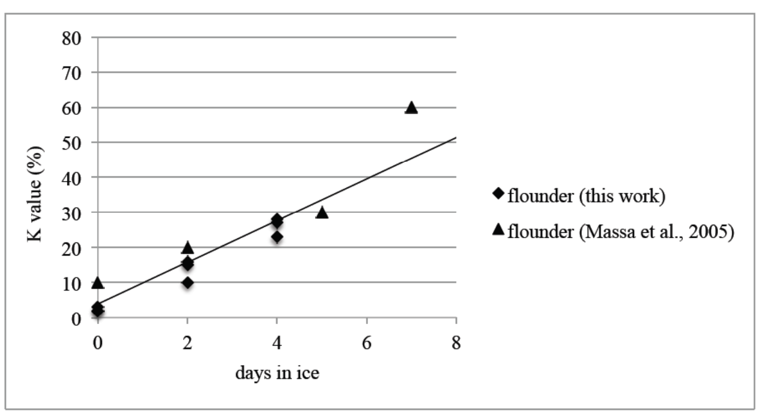

Figure 4: Changes in the K-value in flounder (*Paralichthys patagonicus*) stored in ice.

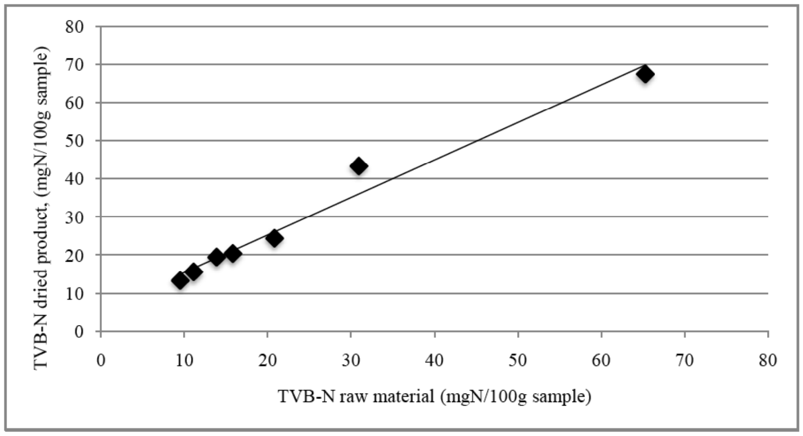

Figure 5: TVB-N values (mgN/100g sample) for solar dried and fresh siganid and anchovy.

range, according to different raw material qualities selected, are shown in Figure **5**. With the same methodology used to obtain Figure **5**, values of PV and TBA of raw material and dried product were also analyzed.

The colour of the freeze-dried flounder pieces were influenced by the raw material quality and process conditions [23]; the white component increased and the yellow component decreased with lowering number of days in ice.

Results for colour difference are influenced by raw material quality as shown by Eq. 1, obtained using least squares, where raw material quality values are dimensionless.

$$\Delta E^{*}_{ab} = -13.645 \times RMQ_{flounder} + 15.566 \quad (1)$$

(R^2= 0.986, Student's t test, $P < 0.01$)

where: ΔE^{*}_{ab}, total colour differences for freeze-dried flounder; $RMQ_{flounder}$, raw material quality when processing flounder, dimensionless.

Least squares regression analysis has been applied to the collected data for solar dried siganid and anchovy, and Eq. 2 was obtained.

$$PQ_{s\&a} = 0.918 \times RMQ_{s\&a} + 0.105 \quad (2)$$

(R^2 = 0.892; Student's t test; $P < 0:01$)

where: $PQ_{s\&a}$, product quality when processing siganid and anchovy, dimensionless; $RMQ_{s\&a}$, raw material quality when processing siganid and anchovy, dimensionless.

When least squares regression analysis was applied for freeze dried flounder, Eq. 3 was obtained.

$$PQ_{flounder} = 0.814 \times RMQ_{flounder} + 0.006 \quad (3)$$

(R^2 = 0.971; Student's t test; $P < 0:01$)

where: $PQ_{flounder}$, product quality when processing flounder, dimensionless; $RMQ_{flounder}$, raw material quality when processing flounder, dimensionless.

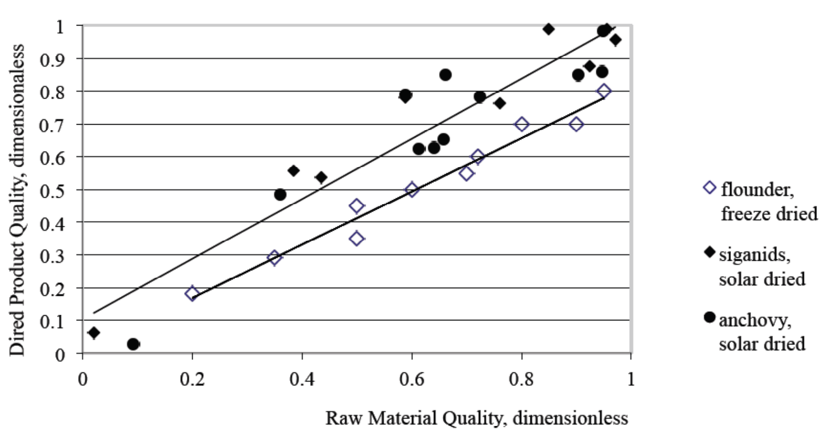

Figure 6: Influence of raw material quality on product quality for flounder, siganid and anchovy.

Statistical tests were performed for Eq. 2 and 3, the assumption of homocedasticity was confirmed, and at the same time, linear correlation was not violated.

All the parameters previously mentioned were normalized in the range from 0 to 1, where the value 1 corresponds to the best quality and jointly analysed as shown in Figure **6**, where good raw material quality corresponded to a value of ≥ 0.5, while values > 0.3 matched up with a safety level.

It can be seen from Eq. 2, that the behaviour for solar dried siganid and anchovy is similar to that found for cured fatty fish in previous work [24]. Likewise, the behaviour found for freeze-dried flounder (Eq. 3) is similar to the results found for iced and frozen lean fish reported in previous work [25]. The high regression coefficients obtained not only for solar dried siganid and anchovy (R^2 = 0.892) but also for freeze dried flounder (0.971) indicate that the lipid content of the raw material has more influence than the type of process on the product quality and that the final quality of any processed product is strongly influenced by the initial quality of the fish.

These correlations are useful not only to predict the product quality in terms of raw material quality, but also to estimate the minimum quality value in order to reject raw material not suitable to obtain dried products of acceptable quality.

A lower slope (0.814) was observed in the case of flounder when compared with fatty species (siganid and anchovy, 0.918). Lean fish keep longer than fatty fish under aerobic storage due to intrinsic factors like size, fat content, and skin properties [26]. White fish have very low oil contents and generally reduced oil oxidation problems, although lipid oxidation has been reported previously for frozen cod and haddock [27].

Eqs. 2 and 3 are the first step to apply a quality cost model because its components not only depend on the initial level of raw material quality but also on its resultant level of product quality [28].

Influence of Raw Material Quality on Process Yield

Raw material quality level is also important in terms of yield. The process yields as a function of raw material quality level for flounder and siganid are presented in Eqs. 4 and 5 and shown in Figure **7**.

$$Y_{siganid} = 14.102\ RMQ_{siganid} + 41.35 \quad (4)$$

(R^2 = 0.9735; Student's t test; P < 0:01)

Where: $Y_{siganid}$, heading and gutting yield (%) when processing siganid, dimensionless; $RMQ_{siganid}$, raw material quality when processing siganid, dimensionless.

$$Y_{flounder} = 9.657\ RMQ_{flounder} + 28.851 \quad (5)$$

(R^2= 0.810; Student's t test; P < 0:01)

Where: $Y_{flounder}$, filleting yield (%) when processing flounder, dimensionless; $RMQ_{flounder}$, raw material quality when processing flounder, dimensionless.

As quality level rose, overall processing yield increased. For dried siganid and flounder, yields increased by more than 13% and 6%, respectively, when the quality level of raw material was increased from good to very good. Poor raw material quality

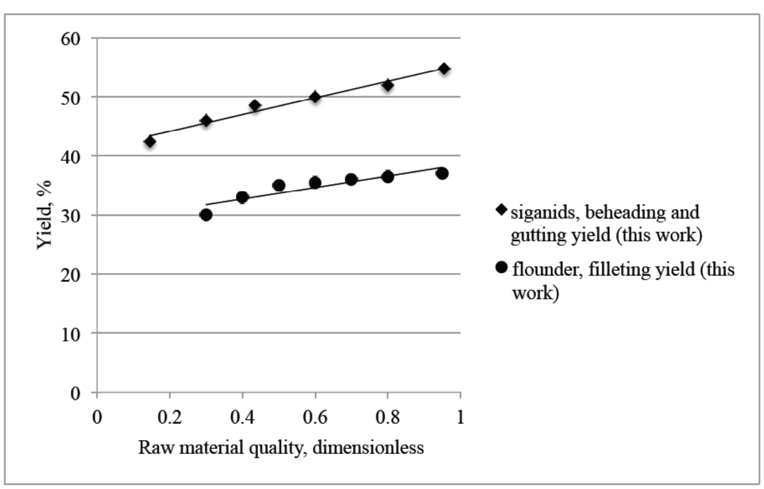

Figure 7: Raw material yield as a function of raw material quality.

causes an additional increase in labour and a reduction in production capacity.

CONCLUSIONS

Very good correlations were obtained between raw material and dried fish, using a normalized dimensionless scale, not only for dried siganid and anchovy (R^2 = 0.892) but also for dried flounder (R^2 = 0.971). The results of this research allow the prediction of the quality of the finished product to be obtained, by assessing the raw material quality.

In the case of white fish, a lower slope was found when compared with fatty species in a dimensionless scale, indicating that raw material quality influences on the quality of final products are higher in fatty than in lean fish. Also, it is observed that the raw material's lipid content has more influence on the dried product quality than de type of process.

Increases in yield were also analysed as a result of better raw material quality. For dried flounder and siganid, process yields increase nearly 6% and 13%, respectively, when the raw material quality level increase from good to very good.

The results indicate that the quality of raw material has a direct and linear effect on the quality of the product. Moreover, poor raw material quality may cause an additional increase in labour and a reduction in production capacity.

The results of this research allow processors to easily determine the quality value for rejecting the raw material that is not suitable to obtain dried products of acceptable quality, and to estimate the quality costs associated with a specific product quality level.

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