Original paper

Microbial, Physicochemical, and Sensory Quality Evaluations of Salted Herring (*Sardinella fimbriata*) Subjected to Different Drying Processes

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Dried salted fishes are some of the more common high quality, but cheap protein sources in the Philippines. Furthermore, production of salted fishes is the most common livelihood activity in near-shore villages in the country. This work sought to characterize and compare quality attributes of sun- and mechanically dried salted herrings in order to determine whether such products comply with established national standards; and identify key quality attributes that need to be addressed and improved by processors. The microbiological quality parameters including Total Plate Counts, Yeasts and Molds, Coliforms and *Escherichia coli* of all sun- and mechanically dried samples were compliant with national standards. *Staphylococcus aureus* of one sun-dried sample was however 0.7 log CFU/g higher than the limit and should be addressed through good hygienic and manufacturing practices. Physicochemical quality attributes of the samples did not significantly vary; while the sun-dried samples from Quezon were consistently given higher sensory scores. The results established in this work can serve as baseline information for the continuous effort to improve and maintain quality and safety of such products, especially that the country has just ratified the Philippine Food Safety Act of 2013; and as the country prepares for the Association of Southeast Asian Nations (ASEAN) integration in 2015.

Keywords: fish processing, herring, mechanical drying, *Sardinella fimbriata*, sun drying

Introduction

Dried salted fishes are traditional products of the Philippines locally known as *tuyóng isda*. Consumed for taste, nutritional value, and affordability, these products have always played an essential role in the Filipino diet, especially among marginalized sectors of the population. According to statistics, 11.11% of the total Filipino diet per year is accounted to fish product consumption (Bureau of Fisheries and Aquatic Resources, 2002). Espejo-Hermes (2004) explained that dried salted fish production is the most common livelihood activity of near-shore villagers in the country. Dry salting of fishes is done in places in the Philippines where fishes are caught in abundance or there are large quantities of surplus of raw fish. Next to Indonesia, the Philippines is the largest dried-salted fish producer in Southeast Asia with almost 38% of the

total catch being processed into dried fish products. The preservation of dried salted fishes involves the reduction of water activity (a_w) due to the addition of large amounts of salt and water evaporation; that eventually suppress growth of spoilage microorganisms (Sikorski and Sun Pan, 1994).

The traditional sun-drying is considered the most conventional and economical method of salted fish processing, and is widely practiced in the Philippines and possibly in many developing countries. However, one of the major disadvantages of this traditional method is the susceptibility of the raw materials and products to microbiological contaminations that compromises product quality and safety (Zakhia, 2000; Espejo-Hermes, 2004). Although the lowering of a_w is sufficient to arrest the activity of several bacteria, growth and multiplication of some yeasts, molds

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Fig. 1. Dried salted herring process flows of the (a) Cavite and (b) Quezon Province processors, and previously developed (c) generic dried salted herring process flow.

and halophilic bacterial species have been reported (Lund *et al.*, 2000). Species of major halotolerant bacteria such as *Staphylococcus*, *Vibrio*, and *Pseudomonas* have been identified in dry-salted fishes (Hernandez-Herrero, Roig-Sagues, Rodriguez and Mora-Ventura, 1999). Consequently, some processors have shifted to the expensive mechanical drying methods that require large energy input. The use of mechanical dryers has exhibited advantages in terms of faster rate of drying time, controllable sanitary conditions and improved end-product quality (Desrosier, 1978). The use of mechanical dryers does not however assure the microbiological quality of the product since there are other factors that may introduce contaminations. Cognizant of this, it is therefore imperative that dried salted fish processors, regardless of the drying method employed, make sure that microbiological contaminations of raw materials are minimized to come up with acceptable products. This study was conducted to evaluate some quality parameters of dried salted *Sardinella fimbriata* subjected to different drying techniques, and determine if such quality parameters comply with set standards for the commodity. The production of an acceptable dried salted fish product can pave the way for possibilities in exporting another traditional Filipino product to a wider market and contribute to the country's income (Acevedo and Munar, 1980). Meeting quality standards will also ensure market competitiveness of such products, particularly that the country has just ratified its Food Safety Act in 2013, and at it prepares for the 2015 economic integration of the Association of Southeast Asian Nations (ASEAN).

Materials and Methods

Dried Salted Herring Samples Two sun-dried salted herring manufacturers were chosen to become sample sources based on

proximity to the laboratory where the study was conducted. A manufacturing plant from Ligdong, Cavite Province, Philippines and a community-based processing site from Dalahican, Quezon Province, Philippines were identified as sample sources. Both sample sources agreed to have their process flows documented but requested that information on formulations not to be reported in publications. Initial documentation works showed that these two sources had distinct process flows (Figure 1a-b). Both processors co-operate with fisher folk from nearby areas who supply freshly net-caught herrings of marketable sizes that range from 15 – 16 cm.

The Cavite process involves an initial 2 – 3 min washing of the herring, which is immediately followed by a 24-h salting in ice. The salted herrings were then again subjected to washing and sprinkling to remove residual salts before subjecting to sun-drying for 36 – 48 h at temperatures ranging from 32 to 34°C. At around 17:00 h, the fishes are brought inside a plant to prevent the fishes from reabsorbing moisture. Different from the Cavite process, the Quezon process does not involve initial washing of the herrings, and involves salting of the fishes without ice for 24 h. The salted fishes were then washed and drained before being subjected to sun-drying at 32 to 34°C for 36 – 48 h. Furthermore, unlike the Cavite processor, the Quezon processor does not have an indoor facility where they can keep the fishes at night time.

These process flows were used to develop a generic process employed in the laboratory preparation of salted herring for mechanical drying (Figure 1c). Mechanically dried samples were prepared in the Pilot Food Plant of the College of Home Economics, University of the Philippines, Diliman Campus, Quezon City, Philippines. Briefly, the developed generic process includes fish washing, salting and drying. Three thousand grams of fresh herring were purchased from Malabon New Market, Navotas

Fig. 2. Representative dried salted herring samples evaluated in this study included (a) sun-dried sample from Cavite, (b) sun-dried sample from Quezon, (c) cabinet-dried (CD) sample prepared in the lab, (d) high performance mechanical (HPM) dried sample prepared in the lab.

City, Philippines. The fishes were placed in an ice chest and immediately transported to the laboratory for processing. Rock salt was also purchased from the same market. The fishes were processed within 4 h of purchase. The fishes were washed with running tap water at 28°C for 2 min and drip-dried on a sanitized metal sieve for 2 min at the same temperature. A modified wet salting method based on the combined procedures of Espejo-Hermes (2004) and the identified processors were followed. Salting mixture composed of fish, ice and salt at 3:1:0.9 w/w/w ratio was prepared. The fishes, ice and salt were alternately distributed on a 76×51×23 cm³ plastic cooler (Coleman, USA). The mixture was allowed to stand for 24 h prior to drying.

Initial runs of salted herring drying using a cabinet (CD) and a high performance mechanical (HPM) dryer were conducted to establish the total drying times. Data gathered from the initial runs (data not presented) were used to determine the sampling points for the physicochemical and microbial quality evaluations. Prior to drying, the fishes were removed from the brine and drip-dried on a sanitized metal strainer for five minutes at 28°C. Two-1000 g portions were obtained for cabinet and high performance mechanical drying. The salted herrings were arranged in a metal chamber of the Sandvik (C.E.P.I. Elettrica, JNTABDBB0001AZ-1, Germany) high performance mechanical dryer and on the metal trays of the cabinet dryer. Both dryers were set and maintained at 60°C based on the protocol described by Rahman et al. (2004) for mechanical fish drying. The fishes were dried until the common

dried fish moisture content of about 40% wet basis (FNRI, 1997) was reached. Based on initial drying runs, samples were obtained from cabinet- and high performance dryers at the start, mid point, and endpoint of the drying process for quality evaluations. Quality attributes of final products (Figure 2) from sun-dried salted herring manufacturers and those prepared in the lab were also analyzed.

Microbiological Quality Evaluations The Total Plate Count (TPC) and Yeast and Molds Count (YMC) of the samples were determined following the procedures similarly adapted by Ventura (2001). Briefly, 25 g samples were homogenized with 225 mL Peptone Water Saline (PWS) composed of 0.85% NaCl prepared in 0.1% peptone (Himedia, Mumbai, India). The homogenates were then subjected to 10-fold serial dilution with PWS prior to surface plating onto specific growth media. The Standard Methods Agar (SMA, Becton Dickinson Biosciences, Sparks, MD21152 USA) was used in the enumerations of TPC while acidified Potato Dextrose Agar (Difco, USA) was used in the YMC enumerations. Halophiles were enumerated using 3% NaCl-supplemented SMA, while thermophiles were isolated on SMA incubated at 60°C following the procedures detailed by Rahman et al. (2003). Manufacturer-specified procedures for the use of 3 M Petrifilms *E. coli*/Coliforms Count plates (3 M, St. Paul, Minn. USA) were followed in the analyses of Total Coliforms and *Escherichia coli*.

Following the procedures adapted by Azanza et al. (2001), *Staphylococcus aureus* counts and the presence of *Salmonella enterica* were also determined. For the enumeration of

Staphylococcus, 25 g sample was homogenized with 225 mL PWS before further subjecting the homogenate to 10-fold dilutions and surface-plating onto Baird-Parker agar base (BBL, Becton Dickinson, city USA) enriched with egg yolk-tellurite solution. Typical round, black colonies with clear opaque zones were enumerated after incubation at 37°C for 24 h. For *Salmonella* detection, 25 g of samples were dispersed in 225 mL buffered peptone water (BPW, Himedia) and incubated for 18 h at 37°C. Selective enrichment was then conducted by introducing 1 mL BPW cultures into 10 mL Selenite Cystine Broth (SCB, BBL, Becton Dickinson) and re-incubating for another 18 h at 37°C. Loop inocula of the SCB cultures were then streaked onto Bismuth Sulfite Agar (BSA, Pronadisa, Hispanlab) and incubated at 37°C for 24 – 48 h. Typical *Salmonella* colonies, which appeared brown, grey, or black were then subjected to biochemical tests including glucose fermentation, lysine decarboxylation, H₂S production, Simmon's citrate utilization, and urease activity.

Physicochemical Quality Evaluations Sun- and mechanically dried samples were subjected to pH, a_w , % moisture, % NaCl analyses. pH measurements were conducted using pH meter (Cyberscan 500, Singapore) with the electrode calibrated using pH 4.00 and 7.00 buffer solutions (Merck, Germany). The Novasina ms1 set a_w (Novasina, Pfaffikon, Switzerland) was used to measure the a_w of the samples following manufacturer-detailed procedures. Moisture content was determined using a Yeasten (Matsushita Electric Works, Ltd., Japan) Infrared Moisture Analyzer while the Mohr AgNO₃ titrimetric method described by Day and Underwood (1991) was used in the determination of % NaCl.

Sensory Quality Evaluations Uncooked dried salted fish samples were subjected to consumer acceptance test. The evaluators were composed of 50 untrained consumer-type members who were regular consumers of dried salted fishes. The samples were evaluated for general acceptability as well as consumer acceptability of color, aroma and texture by touch using 9-point hedonic scales (Meilgaard *et al.*, 1999). Individual whole fish samples were placed in identical paper plates coded with randomly selected 3-digit numbers prior to random monadic presentation to each of the evaluators. Sensory evaluations were conducted in a food laboratory where lighting and ventilation conditions were deemed appropriate for such tests.

Statistical Analyses Data gathered from the quality evaluations were subjected to Single-factor Analyses of Variance (ANOVA) using the General Linear Model Procedure (PROC GLM) of the SAS statistical software version 8.0 (SAS Institute, Cary, N.C.) with Duncan Multiple Range Test for post-hoc determinations of significant differences ($P < 0.05$).

Results and Discussion

Microbial and Physicochemical Characteristics During Mechanical Fish Drying Changes in the microbiological and physicochemical quality indicators during mechanical fish drying

are summarized in Figure 3. Results showed that the TPC (Figure 3a) significantly decreased from 4.51 log CFU/g in the fresh fish to 2.79 log CFU/g after the 24-h salting process. Further reductions in the TPC were observed at the mid- and end-point of both CD- and HPM-dried fishes, although not statistically significant. The initial TPC in the freshly caught fishes is similar to a study cited by Jay (2000) for raw seafood that contain total microbial counts of <5.88 log CFU/g. Nickerson and Sinskey (1972) described the microflora of freshly caught fishes to be composed of both Gram-positive and negative bacteria. The decrease in the TPC is also similar to that described in Rahman *et al.* (2003). The continuous reduction in the TPC after salting and during the drying process can be attributed to the significant reduction in the a_w that was accompanied by significant reduction and increase in moisture and NaCl, respectively (Figure 3 g-h). Jay (2000) explained that the reduction of a_w due to the removal of water by drying, and binding of water to salt might result in microbial inactivation as important cellular processes take place in an aqueous milieu. The CD salted herring samples were found to always have higher TPC than the samples dried in HPM dryer during the process. The relatively slower rate by which water is removed by cabinet drying from the fish systems could possibly explain the differences in the TPC.

However, a different trend in the YMC during the mechanical drying process was observed (Figure 3b), although the changes observed were not significantly different. By the end of the drying process the CD- and HPM samples had YMC of 1.88 and 1.65 log CFU/g, respectively. The increase in population enumerated as the process progressed may be attributed to the significant reduction in the moisture, hence the amount the weight of the analyzed sample dry matter containing the contaminating fungi. Furthermore, yeasts and molds are known to be more tolerant to changes in the osmotic conditions than bacteria (Ventura, 2001).

Halophile populations (Figure 3c) similarly continuously and significantly decreased during the progress of both mechanical drying processes. Finished CD and HPM dried products had halophile populations of 2.26 and 1.78 log CFU/g, respectively. Lakshmanan *et al.* (2002) identified halophilic species in salted fishes, which included *Staphylococcus* spp, *Vibrio* spp, and *Pseudomonas* spp. Rahman *et al.* (2003) similarly reported the sensitivity of halophiles towards dehydration in minced tuna. Thermophilic contaminant populations (Figure 3e) enumerated in all samples were below detection limit (<1.0 log CFU/g). The absence of thermophiles in all samples analyzed was similar to those reported by Rahman *et al.* (2003) and Ventura (2001), who explained that this could indicate adequacy of the drying process.

The total coliforms (Figure 3d) of the unprocessed fishes was 3.70 log CFU/g. Possible sources of this group of microorganisms include improperly cleaned and sanitized equipment and unhygienic handling practices (Jay, 2000). Coliform counts significantly decreased as the drying processes progressed. At drying midpoint, CD samples had coliform count almost 3-fold

Fig. 3. Microbiological and physicochemical changes in salted herring dried in cabinet (CD)- and high-performance mechanical (HPM) drier (a) Total Plate Count, (b) Yeast and Molds, (c) Halophiles (black bars) and Thermophiles (grey bars), (d) Coliforms, (e) Generic *Escherichia coli*, (f) *Staphylococcus aureus*, (g) a_w (grey bars) and %moisture (dry basis) (black bars), and (h) %NaCl (grey bars) and pH (black bars). Dashed lines indicate detection limits. Values for microbial analyses are averages of 4 values from 2 independent runs. For physicochemical tests values are averages of 3 measurements. Values followed by the same letter are not significantly different ($p > 0.05$).

Fig. 4. Microbiology of different dried salted herring samples. Cavite, sun-dried (black bars), Quezon, sun-dried (dark grey bars), laboratory-prepared, cabinet-dried (light grey bars), laboratory-prepared, high-performance mechanically dried (white bars). Dashed lines indicate detection limits. Values are averages of 4 values from 2 independent runs. Values followed by the same letter are not significantly different ($p > 0.05$).

greater than the HPM samples. However, by the end of the drying processes, populations in both samples were below detection limit. Generic *E. coli* was only isolated in the unprocessed fresh fish. Azanza *et al.* (2003) reported a similar proportion in the total coliform and generic *E. coli* in oysters. Craven *et al.* (1997) further discussed that coliforms grow in microcosm associated with food usually in the absence of enteric pathogens such as *E. coli*.

The unprocessed fishes were found to contain 3.08 log CFU/g *Staphylococcus aureus* (Figure 3f), which might have been introduced in the handling of the fishes after catching and during distribution in the market. Salting for 24 h resulted in the inactivation of only 1.0 log CFU, indicating the relatively high resistance of the cells towards reduction of a_w . Continuously decreasing populations in the samples from both dryers were observed, indicating inactivation. By the end of the drying processes, the salted herrings from CD and HPM had *S. aureus* counts of 1.30 and 1.15 log CFU/g, respectively. The IFT (2001) explained that *S. aureus* could be generally isolated from food systems with reduced competing microbial flora.

Salmonella spp. were not isolated from any of the samples analyzed (data not presented). Forsythe (2000) explained that *Salmonella* spp. are usually found in raw and processed foods and is associated with poor hygiene and unclean conditions. Furthermore, *Salmonella* spp. are not usually isolated from marine sources since the organism is not able to tolerate the physicochemical conditions of such environments. The salting and drying processes to which the fishes were exposed are similarly not favorable for *Salmonella* survival (Roberts *et al.*, 1996).

These aforementioned changes in the microbiology of the fishes during processing are related to the changes in the intrinsic and extrinsic physicochemical factors similarly monitored as the drying processes progressed (Figure 3 g-h). No significant changes in pH were observed in all samples analyzed. However, a_w values and moisture contents of CD- and HPM dryer samples significantly

decreased during the drying process. Final CD and HPM fish products had a_w values of 0.73 and 0.70, respectively. The observed significant reduction in the a_w is also related to the significant reduction the moisture content, and increased in the %NaCl of the fish samples as the drying processes progressed (Yunizal, *et al.*, 1990). By the end of the drying processes, CD and HPM fishes had 38.2 and 37.50% moisture (dry basis), respectively; and 13.81 and 14.35% NaCl, respectively. The non-significant differences in these physicochemical quality indicators of the CD and HPM fishes are indicative of comparative efficiencies of the two mechanical drying processes.

Microbiological Quality Attributes of Sun- and Mechanically Dried Salted Herrings The microbiological, physicochemical and sensory quality attributes of sun- (Cavite and Quezon Provinces samples) and mechanically- (CD and HPM samples) dried were similarly analyzed and compared. To control other variables that may confound the results, only samples obtained 3 d after sun- and mechanical drying were analyzed. Figure 4 summarizes the microbiology of the different samples analyzed. The TPC of the samples ranged from 2.65 (HPM) to 3.68 (Quezon) log CFU/g. The populations enumerated in the sun-dried samples were relatively greater compared to those from fishes subjected to mechanical drying. Only the TPC enumerated from the Quezon sample was statistically greater from all other samples. All the enumerated TPC were however well within the Philippine National Standards (PNS) for Aerobic Plate Counts of dried fishes of 5.0 – 5.7 log CFU/g (PNS/BAFPS, 2008).

Yeasts and molds populations ranged from 1.66 to 1.81 log CFU/g, with a trend reflecting that observed for TPC. The Cavite sun-dried and both mechanically dried samples had YMC not significantly different from each other. All the yeast and mold populations enumerated from all samples were lower than the range stipulated in the PNS of 3.0 – 4.0 log CFU/g (PNS/BAFPS, 2008). Halophile populations enumerated from all samples were

not statistically different, while thermophilic populations in all samples were below detection limit ($<1.0 \log \text{CFU/g}$).

While coliforms were not isolated from the mechanically dried samples ($<1.0 \log \text{CFU/g}$), populations of 1.63 and 1.74 $\log \text{CFU/g}$ were respectively isolated from the sun-dried samples from Cavite and Quezon Provinces. The more controlled environmental conditions to which the fishes were subjected during salting and drying in the laboratory could explain the observed difference. Generic *E. coli* was not isolated from any of the sun- and mechanically dried samples. The enumerated coliform and *E. coli* populations are similarly within the ranges stipulated in the PNS of 1.0 – 2.0 $\log \text{MPN/g}$ and 1.04 $\log \text{MPN/g}$, respectively (PNS/BAFPS, 2008).

Staphylococcus aureus counts from the sun-dried Cavite and both mechanically dried fishes were not significantly different. All these populations are also within the maximum allowable level of 3.70 $\log \text{MPN/g}$ stipulated in the PNS (PNS/BAFPS, 2008). The sun-dried sample from Quezon province exceeded this level by 0.7 $\log \text{CFU/g}$, which may indicate lapses in the hygienic practices during salting, drying, and post process handling, as *S. aureus* occurs widely as commensal of the skin and mucous membranes of warm-blooded animals, including humans (Baird-Parker, 2000). *Salmonella* was not isolated from any of the samples analyzed (data not presented). The relatively larger microbiological populations, particularly the TPC and *Staphylococcus* enumerated in the sun-dried samples obtained from the Quezon province manufacturers may be attributed to nature of the process flow of the product (Figure 1b). One very apparent difference of the process flow of the Quezon province manufacturer from the Cavite province manufacturer is the absence of a pre-salting washing of the fishes in the former. It should be noted that the fishes come from the supplying fisher folk who might similarly have poor hygienic practices. Hence a preliminary washing of the fishes before salting may result in significant reduction of the microbial load of the raw fishes. Furthermore, unlike the Cavite province manufacturer, the Quezon province process flow involves salting of the fish without ice. Despite the lowering of a_w of the fish during salting, salt-tolerant organisms including *Staphylococcus aureus* can survive and multiply, resulting in a product with poor microbial quality (Baird-Parker, 2000; Jay, 2000). Aside from the process flows, the environment to which the fishes are subjected during drying can similarly influence finished product quality. Due to lack of indoor storage facilities, the Quezon province manufacturer keep the salted fishes outside the plant even during night time, exposing the fishes to environmental contamination, and conducive microbial growth conditions when the fishes reabsorb moisture in the cooler times during the night.

The microbiological quality of dried salted herrings may be improved if the fisher folk and manufacturers shall apply and follow principles of Good Aquaculture and Good Manufacturing Practices. Raw materials and equipment should always be cleaned

and sanitized to reduce the risk of contaminating the commodity with microorganisms from the environment. The raw materials, especially the fishes should be kept in ice immediately after catching to slow down deteriorative physicochemical and microbiological changes. If possible, the salting process should be done in ice to prevent salt-tolerant microorganisms from multiplying. The drying environment should also be clean in order to prevent cross contamination of the commodity.

Physicochemical and Sensory Quality Attributes of Sun- and Mechanically Dried Salted Herrings Comparisons of the physicochemical and sensory quality attributes of the sun- and mechanically dried samples are also summarized in Figure 5. The moisture contents of the samples did not significantly vary, and ranged from 35.33% (sun-dried, Cavite) to 38.25% (CD). The pH values of the samples were also not significantly different. The a_w values of the samples analyzed were similarly not significantly different from each other, and ranged from 0.7 (HPM-dried) to 0.77 (sun-dried, Quezon). It should be noted that among the samples analyzed, only those of the sun-dried Quezon Province had a_w that did not conform with the maximum allowable value of 0.75 (at 25°C) stipulated by the PNS/BAFPS (2008). This observation could explain the generally lower microbiological quality of the sun-dried Quezon Province sample as a_w accounts for the major preservative effects in dehydrated products (Jay, 2000; Lakshmanan *et al.*, 2002; Nickerson and Sinskey, 1972). The differences in the a_w of the samples can be related to their salt contents, which ranged from 12.85% (sun dried, Quezon) to 14.35% (HPM). All of the determined NaCl levels % are higher than the recommended minimum level of 12% (PNS/BAFPS, 2008).

Finally, consumer scores ($n = 50$) summarized in Figure 5c illustrate the Hedonic Ratings for uncooked salted herring samples. The overall acceptability scores of the samples ranged from 4.64 ('Neither Liked Nor Disliked,' sun-dried, Cavite) to 6.8 ('Liked Moderately,' sun-dried, Quezon). Color, aroma, and texture by touch were similarly rated with Hedonic Scores ranging from 'Neither Liked Nor Disliked' to 'Liked Moderately.' The relatively low consumer scores may be attributed to the uncooked form of the sample, which is of course, not the usual form that this product is consumed. Interestingly, the acceptability scores given the sun-dried samples from Quezon province were consistently greater than the other samples. Qualitative evaluations of the samples revealed that the Quezon province sample appearance of were described as more 'organic' and that the consumer panel considered presence of scales a desirable appearance of the product (Figure 2). This trend in the sensory quality is opposite of those observed in the microbiological and physicochemical quality evaluation and may predispose consumers to foodborne infections. Unfortunately, consumers often base their choice of commodities on external quality attributes such as appearance, color, shape and size; and often neglect internal quality such as physicochemical and microbiological parameters.

Fig. 5. Physicochemical and sensory quality attributes of different dried salted herring sample. (a) a_w (grey bars) and %moisture, dry basis (black bars), (b) %NaCl (grey bars) and pH (black bars), (c) acceptability score of different sensory attributes (Hedonic Scale Score: 1 = Disliked Extremely, 5 = Neither Liked nor Disliked, 9 = Liked Extremely). Cavite, sun-dried (black bars), Quezon, sun-dried (dark grey bars), laboratory-prepared, cabinet-dried (light grey bars), laboratory-prepared, high-performance mechanically dried. Values for physicochemical analyses are averages of 3 measurements. Values for Hedonic scores are averages of responses of 50 members of evaluating panel. Values followed by the same letter are not significantly different ($p > 0.05$).

Continuous consumer and manufacturer education on basic hygienic food manufacturing shall protect both parties from losses and diseases due to microbial contaminations.

Conclusion

To sum up, this study was able to demonstrate the efficacy of cabinet- and high performance mechanical dryers to produce dry

salted herrings with specifications and quality attributes in accordance to Philippine National Standards. This work was also able to establish that sun- and mechanical drying of salted herring can result in products with almost similar microbiological, physicochemical, and sensory quality attributes. With some improvements in the hygienic and food safety practices, and possibly minor changes in the process flow of sun-dried salted herring manufacturers (e.g. additional washing step of the raw materials prior to salting), products with quality attributes similar to those of mechanically dried ones can be produced. The results established in this work can serve as baseline information for the continuous effort to improve and maintain quality and safety of such products, especially that the country has just ratified the Philippine Food Safety Act of 2013; and as the country prepares for the Association of Southeast Asian Nation (ASEAN) integration in 2015.

References

- Acevedo, T.P. and Munar, J.I. (1979). Quality improvement and storage study of salted and dried siganid. *Phil. J. Food Sci. Technol.*, **3**, 39-71.
- Azanza, M.P.V., Azanza, R.V., and Ventura, S.R. (2003). Effect of chlorinated wash water on quality of heat shocked mussel meat. *J. Muscle Foods*, **14**, 320-341.
- Azanza, M.P.V., Ortega, M.P., and Valdezco, R.G. (2001). Microbial quality of *rellenado* milkfish (*Chanos chanos*, Forskal). *Food Cont.*, **21**, 365-371.
- Baird-Parker, T.C. (2000). *Staphylococcus aureus*. The Microbiological Safety and Quality of Food. Vol. 2. Ed. B. Lund, T.C. Baird-Parker, G.W. Gould. Maryland: Aspen Publishers.
- Bureau of Fisheries and Aquatic Resources, BFAR. (2002). Philippine Fish Marketing and Distribution Study. Statistics on Catch and Consumption and Processing. Manila, Philippines.
- Craven, H.M., Eyles, M.J., and Davey, J.A. (1997). Enteric Indicator Organisms in Foods. In *Foodborne Microorganisms of Public health Significance*, 5th ed., Eds. A.D. Hocing, G. Arnold, I. Jenson, K. Newton, and P. Sutherland. Australian Institute of Food Science and Technology (AIFST) Ltd., New South Wales.
- Day, R.A. and Underwood, A. L. (1991). Quantitative Analysis, 6th ed. Prentice-Hall International Editions. Philippines: Goodwill Bookstore.
- Desrosier, J. (1978). The Technology of Food Preservation. Connecticut, USA : AVI Publishing Co. Inc.
- Espejo-Hermes, J. (2004). Fish Processing Technology in the Tropics. Philippines: Tawid Publications.
- Forsythe, S. J. (2000). The Microbiology of Safe Food. Cambridge: Blackwell Science, Ltd.
- Hernandez-Herrero, M.M., Roig-Sagues, A.X., Rodriguez, J.J., and Mora-Ventura, M.T., (1999). Halotolerant and halophilic histamine-forming bacteria isolated during the ripening of salted anchovies (*Engraulis encrasicolus*). *J. Food Prot.*, **62**, 509-514.
- Institute of Food Technologists. (2001). Evaluation of potentially hazardous foods. Comprehensive Reviews in Food Science and Food Safety. Institute

- of Food Technologists Report for the Food and Drug Administration of the United States Department of Health and Human Services.
- Jay, J. (2000). Modern Food Microbiology 6th ed. Singapore: APAC Publishers.
- Lakshmanan, R., Shakila, R., and Jeyasekaran, G. (2001). Changes in halophilic amine forming bacterial flora during salt-drying of sardines (*Sardinella gibbosa*). *Food Res. Int.*, **35**, 541-546.
- Lund, B. M., Baird-Parker, T. C., and Gould, G. W. (2000). The Microbiological Safety and Quality of Foods Vol 1. Ed. B. Lund, T.C. Baird-Parker, G.W. Gould. Maryland: Aspen Publishers.
- Meilgaard, M., Ceville, G.V., and Carr, B.T. (1999). Sensory Evaluation Techniques, 3rd ed. New York: CRC Press.
- Nickerson, J.T. and Sinskey, A.J. (1972). Microbiology of Food and Food Protection. New York: America Elsevier Publishing Company Inc.
- Food and Nutrition Research Institute (FNRI). (1997). The Philippine Food Composition Tables. Food and Nutrition Research Institute, Department of Science and Technology. Bicutan, Taguig, Metro Manila.
- Philippine National Standard, Bureau of Agriculture and Fisheries Product Standard (PNS/BAFPS). (2008). PNS/BAFPS 68:2008, Department of Agriculture, Philippines.
- Rahman, M.S., Guizana, N., and Al-Ruzeik, M. H. (2003). D- and Z- values of microflora in tuna mince during moist and dry- heating. *LWT-Food Sci. Technol.*, **37**, 93-98.
- Roberts, T.A., Baird-Parker, A.C., and Tompin, R.B. (1996). Microorganisms in Foods 5. Great Britain: Blackie Academic and Professional.
- Sikorski, Z.E. and Sun Pan, B. (1994). Seafood Chemistry: Processing, Technology and Quality. Great Britain: Blackie Academic and Professional.
- Ventura, S.R. (2001). Establishment of a Thermal Process for Dried Salted Herring (*Sardinella fimbriata*) in Oil. BS FT Thesis. College of Home Economics. University of the Philippines, Diliman, Quezon City.
- Yunizal, W.T., Anggawati, A.M., and Putro, S. (1990). Histamine formation in dried salted mackerel. Papers presented at the 7th session of the IPEC Workers Party on Fish Technology and marketing, Indio-Pacific Fishery Commission, Bangkok Thailand, 19-22 April 1988 (FAO Fisheries Report No. 401, Suppl. F11 U/R 401). Rome: Food and Agricultural Organization.
- Zakhia, N. (2000). Adaptation of a Quality Assurance Methodology to Traditional Fish Drying in Mali. Proceedings of the International Workshop. Montpellier, France.