Alternative Feeds and Processing for Freshwater Aquaculture Species, Part I

SNAKEHEAD PROCESSING AND PRODUCTS

Enhanced Trade and Investment for Global Fishery Markets/Experiment/13SFT03UC

Truong Thi Mong Thu, Nguyen Thi Nhu Ha, Pham Minh Duc, Tran Minh Phu,
and Tran Thi Thanh Hien
College of Aquaculture and Fisheries, Can Tho University
Can Tho, Vietnam

ABSTRACT

Dried and fermented snakehead (*Channa striata*) fish production in An Giang province, Vietnam is growing, but product consumption is still mainly local with limited exports and it is difficult to finding outlets for the products. Most producers still base production on traditional fermentation processes that waste time, are laborious, and have low economic efficiency. Drying is a cheap, simple, and conventional method to preserve snakehead, and dried snakehead is an important protein source for Vietnamese. However, the quality and safety of these dried fish are not stable because improper processing, packaging, and preservation of dried snakehead are widespread, resulting in only short-term storage, as well as low economic returns for producers. Some immoral producers use harmful chemicals to produce snakehead products with the goals of good appearance and extending the products' shelf life.

We conducted surveys of processors, traders, and consumers to determine optimal practices for snakehead processing to meet consumer tastes. These results enabled us to tailor our research to developing certain types of processing and products. We then conducted 15 experiments to test several aspects of the drying and fermenting processes. Our experimental results showed that in the salty fermented snakehead processing, the application of mechanical treatment before mixing with salt helped shorten salting time from 30 days to 20 days, and adding crude bromelain at a rate of 3% fish weight shortened fermentation time from eight weeks to six weeks. The salty fermented snakehead product in treated treatments was similar in quality to control treatments that were fermented for eight weeks with no added bromelain. Overall, we have demonstrated processing techniques that allow safe consumption of snakehead for up to four weeks of storage, based on sensory, chemical, and microbiological parameters.

Finally, CTU researchers conducted a training course on processing of dried and fermented snakehead for women in An Giang province. Technical practices on processing of dried and fermented snakehead were introduced and a booklet describing processing of dried and fermented snakehead was released.

INTRODUCTION

Dried and fermented snakehead (*C. striata*) fish production in An Giang province, Vietnam is growing daily in the number of manufacturers and quantities produced. Previously, these products were primarily for family consumption or with a small amount to sell in small markets. Now, the production of dried and fermented fish is improved and is conducted at larger scale. Despite this growth, product consumption is still mainly local with limited exports and it is difficult to find outlets for the products. Therefore, we investigated the snakehead processing industry, types of snakehead products and market status, and consumer tastes.

In developing countries, traditional fermentation is one of the oldest food processing and preservation methods, helping not only to prolong preservation and usage time, but also to increase special flavor and taste (Anihouvi et al. 2006 and Nayeem et al. 2010) and nutritional quality of food (Stefánsson and Gudmundsdóttir, 1995; Dincer et al. 2010). Salty fermented fish and fish sauce are the two main products from fish fermentation process that are found in many countries. In Thailand, there are more than 16 different types of fermented fish (Saisithi et al. 1975). Fermented fish products are traditional foods in the Mekong Delta in particular and in Vietnam in general (Le et al. 2014). Vietnamese know how to process many types of fermented fish from many fish species such as snakehead, gourami and rohu, among which fermented snakehead is the most favored product because of its specific flavor and taste. Nowadays, fermented fish is not only a traditional food for daily meal but is also for exportation (Bui et al. 2014). In the Mekong Delta, the natural conditions are favorable for culturing snakehead (Le et al. 2014). Recently, some fermented fish producers have applied semi-industrial scale with more modern techniques and facilities. Although the producers have applied different recipes and techniques, most of them still base production on traditional fermentation processes that waste time, are laborious, and have low economic efficiency.

In the Mekong Delta, Vietnam, drying is a cheap, simple, and conventional method to preserve snakehead, and dried snakehead is an important protein source for Vietnamese. These days, there are two popular kinds of dried snakehead in the South of Vietnam including dried salted snakehead (without sucrose addition) and dried snakehead (with sucrose addition). The shelf life of dried salted snakehead depends entirely on moisture and salt contents. This product has traditionally been treated with high salt levels and drying well for long term preservation at room temperature, but consequently has a hard texture, dark color, salty taste. However, the quality and safety of these dried fish are not stable because improper processing, packaging, and preservation of dried snakehead are widespread, resulting in only short-term storage, as well as low economic returns for producers. While using less salt and not drying in a long period not only to satisfy the consumers but also to avoid weight loss for getting high economic returns, some immoral producers use harmful chemicals to produce snakehead products with the goals of good appearance and extending the products' shelf life. The use of these chemicals has led to toxicity to consumers (Khanh, 2014; Van, 2014). Therefore, microbial and chemical analyses for dried fish are necessary guarantees of food safety (Saritha et al. 2013). We wanted to enhance the sensory properties and safety of dried snakehead, with and without added sucrose, by improving the production processes based on evaluations of chemical, microbial, and sensory attributes. The consumer trend of choosing less salty dried fish for their diet is currently increasing to prevent illness, especially in old people, and sucrose addition to dried fish makes the flesh less salty, more flexible, and golden. As a result, there has been a remarkable price increase for dried snakehead with sucrose, which is a popular choice of smart customers now.

Women make up more than 50% of the population in the Lower Mekong Basin (LMB). Our previous studies showed that male labor was dominant in fish farming practices (78.4% of farmers), but the participation of women in farming snakehead species was high (21.6% of farmers) in comparison with other cultured fish species in Vietnam (often less than 10%) (AquaFish CRSP project 2010). The role of women in the value chain of snakehead fish in Vietnam is more important in trading and processing activities of snakehead products. AquaFish CRSP (2010) reported that in the LMB of Vietnam 26.7% of snakehead traders were female while the figures were much higher in the cases of processing and retailing activities with 90.9% and 93.3%, respectively. In addition, low educational level has been considered one of the constraints for improvement of the value chain of snakehead fish. About 10.1% of fish farmers were illiterate while the respective numbers for processers and retailers were 9.1% and 10.5% (AquaFish CRSP project 2010).

OBJECTIVES

- Conduct surveys to find the optimal products from snakehead, as well as the best processes to increase outlets and meet export requirements in order to increase the incomes of farm owners.
- Investigate new rapid production techniques for fermented snakehead that maintains the quality seen in traditional techniques.
- Improve processing without use of harmful chemicals based adjustments to the traditional method.
- Train women to produce dried and fermented snakehead using the new techniques.

MATERIALS AND METHODS

The survey study was conducted from December 2013 to April 2014 and consisted of:

- A survey of a representative sample of 21 processors about their technological processes and quality of products from snakehead;
- A trader survey of a representative sample of 32 traders about types of products and trade status of products from snakehead; and
- A consumer survey of a representative sample of 110 consumers about customer tastes for the products from snakehead. Surveys were conducted at Long Xuyen, Chau Doc and Cho Moi districts, An Giang province, Vietnam.

A total of 15 experiments were conducted for this study: two to determine a) the effects of mechanical treatment and salting time, and b) effects of bromelain enzyme supplementation and fermentation time on product quality; nine to determine optimal processes for dried salted snakehead with sucrose; and four to determine optimal processes for dried salted snakehead without sucrose.

The general procedure for processing fermented snakehead according to the methods of Nguyen (2011) and Bui et al. (2013) is shown in Figure 1.

Snakehead (700-800 g/fish) purchased in An Thoi local market was mechanically treated for 10 minutes (using a 1.5 kg bundle of reeds per 10 kg fish contained in a 30 L bucket). After that, fish heads, fins, scales, and viscera were removed; fish were then washed with 5% salt solution and split open along the back and abdomen. After being washed, fish were left for three minutes to remove excess surface water and then mixed with salt at a rate of 30% fish weight for two days, fish were weighted with stones at a rate of 20% of fish weight. The salting times were according to experiment one (see below). After being mixed with salt, the mixture was divided into two parts: salted fish and brine. Brine was boiled for 10 minutes, filtered, allowed to cool for 20 minutes, and crude bromelain enzyme was added at rate mentioned in experiment two (see below) and placed in vat containing salted fish mixed with 9% roasted rice powder and 6% salt. Mixture was weighed with stones a second time and gradually added fish sauce at a rate of 20% fish weight onto the surface of the mixture. After a fermentation time as mentioned in experiment two (see below), fermented fish was covered with sugar solution at a rate of 20% fish weight and kept for two weeks to become a final product.

Experiment 1: Effects of mechanical treatment and salting period on quality of salted snakehead. After mechanical treatment for 10 minutes, fish was mixed with salt following the general procedure given above. Fish was mixed with salt at a rate of 30% fish weight for different periods of time (five, 10, 15, 20, 25, and 30 days). In the control group, snakehead was not mechanically treated, but was mixed with salt at a rate of 30% fish weight for 30 days. The experiment was replicated three times. Fish weight after removal of head, fin, scales, and viscera was two kg. Analyzed parameters were texture, plus salt, moisture, and crude protein contents.

Experiment 2: Effects of crude bromelain supplement and fermentation time on quality of salty fermented snakehead product. Salted snakehead was selected from the optimal treatment of experiment 1 and fermented following general procedure given above. Bromelain was added to salted snakehead at 2%, 3%, 4% and 5% fish weight and fermented for either two, four, six, or eight weeks. In the control group, no bromelain was added and fermentation was for eight weeks. The experiment was replicated three times. Fish weight after removal of head, fin, scales, viscera was two kg. Analyzed parameters were sensory evaluation, texture, amino nitrogen content, plus salt, moisture, and crude protein contents.

Dried salted snakehead with and without sucrose. Snakehead with mass 800-900 g/ fish were purchased at Tan An local market (Ninh Kieu District, Can Tho city, Vietnam). Raw fish samples were washed, heads removed, carcasses split and gutted, deboned, and descaled. After pretreatment, weight of the fish was determined and the fish were salted in containers. Salting methods and time were determined by doing experiments. Fish were stored in cool air (8-10^{o}C) for five hours to absorb the salt well, then mixed with sugar, MSG, fish sauce, sticky rice wine, glycerol, chili pepper, and pure garlic in cool air (8-10^{o}C) for six hours. Pepper (1% w/w) was used to cover the fish surface before drying. Fish were dried by an air dryer, or by air dryer plus tent dryer to obtain dried products. Dried fish was packed in polyethylene bags and frozen at -20^{o}C for long-term storage. Dried fish was taken out and heated under the sun for two hours. Then, dried fish was packed in polyamide (PA) bags under vacuum condition and stored refrigerated at 4-6^{o}C. After that, sampling was done as indicated below.

Nine experiments were carried out to examine the process of dried snakehead with sucrose.

Experiment 3: Salting method trials for dried snakehead. We used a Complete Randomized Design with three treatments and three replicates. Treatments were dry salting 5% (w/w), and brine salting (5%; 10% solution). Analyzed parameters were moisture content, salt content, water activity, a_w, and sensory evaluation.

Experiment 4: Salting time trials for dried snakehead. Needling was performed on the skin side of fish flesh. We used a Complete Randomized Design with five treatments, one controlled sample (no needling) and three replicates. Treatments were salting time of 20, 25, 30, 35, and 40 minutes. Control was salted for 30 minutes with no needling. Analyzed parameters were moisture content, salt content, a_w and sensory evaluation.

Experiment 5: Quality assessment of dried snakehead with different percentage of sucrose, fish sauce, and MSG. We used a Complete Randomized Design with three treatments and three replicates. Treatments were 1) 4% sucrose: 2% MSG: 1% fish sauce; 2) 5% sucrose: 1.5% MSG: 2% fish sauce; and 3) 6% sucrose: 1% MSG: 3% fish sauce. Analyzed parameters were moisture content, a_w and sensory evaluation.

Experiment 6: Quality assessment of dried snakehead corresponding to amount of mixing time with herbs and spices. We used a Complete Randomized Design with three treatments and three replicates. Treatments were mixing times of three, six, or nine hours. Analyzed parameters were moisture content, a_w and sensory evaluation.

Experiment 7: Quality assessment of dried snakehead with different percentage of sticky rice wine (30%). We used a Complete Randomized Design with three treatments and three replicates. Treatments were different percentages of 1, 2, and 3% (w/w) of wine. Parameters, measured over two weeks, were moisture content, a_w, TVB_N values, peroxide values, Total Plate Count, and sensory evaluation.

Experiment 8: Quality assessment of dried snakehead corresponding to methods of garlic addition. We used a Complete Randomized Design with three treatments and three replicates. Treatments were no garlic, pure garlic (2% w/w), and diluted garlic juice (50% water and 2% w/w) adding to fish flesh. Parameters, measured over two weeks, were moisture content, a_w, TVB_N values, peroxide values, Total Plate Count, and sensory evaluation.

Experiment 9: Quality assessment of dried snakehead with different percentages of glycerol. We used a Complete Randomized Design with four treatments and three replicates. Treatments were 0%, 1%, 2%, or 3% glycerol. Parameters, measured at week zero and week two were moisture content, a_w, TVB_N values, peroxide values, Total Plate Count, and sensory evaluation.

Experiment 10: Drying method trials for dried snakehead. We used a Complete Randomized Design with six treatments and three replicates. Treatments were drying in Air Dryer (AD) only at different temperatures or in both Air Dryer and Tent Dryer (TD). (AD)_65^{o}C: 28 hours; (AD)_60^{o}C: 31 hours; (AD)_65^{o}C: 15 hours and (AD)_60^{o}C: 13 hours; (AD)_65^{o}C: 22 hours and (TD): 6 hours; (AD)_65^{o}C: 18.5 hours and (TD): 9.5 hours; (AD)_65^{o}C: 14 hours and (TD): 14 hours. Analyzed parameters, measured at week zero and week two were moisture content, a_w, TVB_N values, peroxide values, and sensory evaluation.

Experiment 11: Storage methods for dried snakehead. Two treatments and three replicates were used. Treatments were storing dried fish at either chilled temperatures (4-6^{o}C) or room temperatures (27-30^{o}C), for four weeks. Analyzed parameters were moisture content, a_w, TVB_N values, peroxide values, and sensory evaluation.

Four experiments were conducted on dried salted snakehead without sucrose.

Experiment 12: Salting method trials for dried salted snakehead. Needling was performed on the skin side of the fish. Dry salting was used with salt levels of eight, 10, or 12% (w/w)) for either 20, 30, or 40 min. The experiment was in triplicate. Analyzed parameters were moisture content, a_w TVB_N values, peroxide values, and sensory evaluation.

Experiment 13: Quality assessment of dried salted snakehead with different percentages of fish sauce and MSG. We used a Complete Randomized Design with four treatments and three replicates were used. Treatments were 0% MSG: 0% fish sauce; 0% MSG: 2% fish sauce; 1% MSG: 0% fish sauce; and 1% MSG: 2% fish sauce. Analyzed parameters were moisture content, a_w, and sensory evaluation.

Experiment 14: Quality assessment of dried salted snakehead with different percentages of sorbitol. We used a Complete Randomized Design with four treatments and three replicates. Treatments were 0%, 1%, 2%, or 3% of sorbitol. Analyzed parameters, measured during four weeks were moisture content, a_w, TVB_N values, peroxide values, Total Plate Count, and sensory evaluation.

Experiment 15: Drying method trials for dried salted snakehead. We used a Complete Randomized Design with six treatments and three replicates. Treatments were drying snakehead in Tent Dryer vs. open-air drying at drying times of 33, 36, or 39 hours. Analyzed parameters were moisture content, a_w, TVB_N values, peroxide values, and sensory evaluation.

Analytical methods. Methods for chemical, microbiological, and sensory evaluations are given in Table 1.

Statistical analysis. Difference in means among treatments were statistically analyzed by one-way ANOVA and two-way ANOVA followed by Tukey test at $p < 0.05$, and t-test using SPSS 18.0.

RESULTS AND DISCUSSION

Survey results. Results of the fermented snakehead processor survey (Table 2) indicate that the majority of the participating processors had a capacity range of three to five tons product/year (55.6%), followed capacity ranges of one to two tons product/year (22.2%), 5–10 tons product/year (11.1%) and >10 tons product/year (11.1%). Their markets included local markets (100%) and export (11.1%). The quality of raw fish, salting, and fermenting steps had effects on the quality of fermented fish, so the input materials were selected very carefully. Raw material for companies of three to five tons product/year and >5 tons product/year must be bought in areas with well-controlled antibiotics, metals, and chemicals (85.7% of processors) while only 50% of processors with the capacity of manufactory of one to two tons product/year had access to those sources. In addition, in companies with three to five tons product/year and >5 tons product/year, fish was mixed with salt at 28-30% of fish weight (100% of processors), the production time (salting and fermenting) was around six months and storage time ranged from six to 12 months. In companies with capacity of one to two tons product/year, fish was mixed with salt at only 20-22% of fish weight (50% of processors), the production time (salting and fermenting) was around three to four months and storage time was six to nine months.

Results from the dried snakehead processor survey (Table 3) indicated that the majority of the participating processors had production capacity of one to two tons product/year (58.3%), followed <1 ton product/year (25%) and >2 tons product/year (16.7%). Their markets included local markets (100%) and export (0%). The quality of raw fish, drying and storing steps had effects on the quality of dried fish. Raw fish for companies of one to two tons and >2 tons product/year must be bought in areas with well-controlled antibiotics, metals, chemicals (77.8% of processors) while that was true for only 33.3% of processors with capacity of one to two tons product/year. Dried snakehead was produced from cultured snakehead (100% of processors). In addition, in companies with capacity of one to two tons product/year and >2 tons/year, drying time was three to four days (eight to nine hours/day) (88.9% of processors) while only 11.1% of processors produced dried snakehead in one to two days (eight to nine hours/day). In companies with <1 tons/year, drying time was three to four days (eight to nine hours/day) (66.7% of processors) while 33.3% of processors produced dried snakehead in one to two days (eight to nine hours/day). The storage time was five to six months in freezer (77.8% of processors) while only 22.2% of processors produced dried snakehead with storing time was two to three months without freezing.

Results from the fermented and dried snakehead consumer survey (demographic information in Table four; other results in Figures two and three indicate that most of the participants were in the age range of 30–40 years old (63.6%), followed by those 20–30 years old (27.3%) and 40–50 years old (7.3%). The lowest percentage of participants (1.8%) was 50–60 years old. The percentage of female (63.6%) was higher than male (36.4%). For fermented snakehead, consumers often bought from the local market (87.3%), whereas others bought from the producer (64.5%) or from supermarket (10.0%). Consumers bought fermented snakehead according to the quality attributes of brand (44.5%), followed by its flavor (28.1%) and price (10.9%), respectively, they did not pay much attention on appearance, taste, or texture (Figure 2). For dried snakehead, consumers bought from the local market (86.4%), but also from producers (70.0%) and from supermarket (24.5%). Consumers bought dried snakehead based on quality attributes of brand (38.2%), texture (34.5%) and taste (15.5%), respectively; they did not pay much attention to appearance, taste, or flavor (Figure 3).

Experiments on processing techniques on snakehead quality

Experiment 1. Salt content and hardness of salted snakehead significantly increased (from 0.15% and 19273 g force to 20.62% and 20091 g force, respectively), whereas decrease in moisture and crude protein contents significantly decreased (from 77.53% and 18.94% to 55.53% and 18.94%, respectively) when salting time increased from 0 days to 20 days (Table 5). However, when salting time increased from 20 days to 30 days, the differences of salt, moisture and crude protein contents among treatments were not statistically significant (P>0.05) whereas hardness slightly decreased (Table 5).

Experiment 2. Fermentation time and level of crude bromelain significantly ($p \leq 0.05$) affected moisture, crude protein, amino nitrogen contents and hardness of fermented snakeheads, but not salt content (Table 6). As fermentation time increased from two to six weeks, moisture content increased and crude protein content decreased significantly at all levels of crude bromelain. As crude bromelain increased from 2% to 4%, moisture content was not significantly different, with figures rising at 5% crude bromelain whereas crude protein content decreased slightly when rate of crude bromelain increased from 2% to 5% at all fermentation times. In addition, there was a significant increase in amino nitrogen content, but a significant decrease in hardness ($P<0.05$) and no significant difference ($P>0.05$) in salt content during eight weeks of fermentation at all fermentation times and all levels of crude bromelain. For fermentation using treatment M7 (added 3% crude bromelain and fermented for six weeks), the salty fermented snakehead had the highest salt and amino nitrogen content (20.67% and 8.02 mg N/100 g, respectively), hardness, moisture, and crude protein contents (16607 g force, 56.46% and 19.79%, respectively), but the differences had no statistical significance ($p \geq 0.05$) compared with control treatments. Fermentation time and bromelain levels significantly ($p \leq 0.05$) affected the sensory scores of fermented snakeheads (Table 7). When fermentation time increased from two weeks to six weeks and bromelain increased from 2% to 3%, sensory scores of color, flavor, taste, and overall increased. However, when fermentation time increased from six weeks to eight weeks and bromelain increased from 3% to 5%, sensory scores of color, flavor, taste and overall decreased. In treatment M7 (3% crude bromelain and six weeks fermentation), the final product had the highest sensory scores of color, flavor, taste, and overall parameters (6.13; 6.07; 6.00; and 6.20, respectively), but the differences had no statistical significance ($p \geq 0.05$) compared to the control.

In conclusion, applying mechanical treatment on snakehead fish can shorten the period for soaking them in salt from 30 days to 20 days and supplementation of 3% bromelain enzyme can shorten the period for fermentation from eight weeks to six weeks. These techniques can shorten the processing period of the salty fermented fish product from commercial snakehead fish and ensures nutritional quality and sensory properties compared with traditional methods.

Experiments 3–6. For these experiments, besides dry salting method with 5% (w/w) of clean dried salt in 30 minutes, the combination of 5% sucrose, 1.5% MSG, and 2% fish sauce were chosen for the mixing time of six hours, based not only on the significantly highest points of overall acceptability ($P<0.05$), but also the low water activity and moisture (Table 8).

***Experiment** 7*. Wine is able to enhance the sensory properties of dried fish due to reduce fishy odors by wine aroma. Besides, based on the alcohol levels, wine addition is used to inhibit bacteria growth as protein denaturation and lipid dilution (Mcdonnell and Denver, 1999). One percent of wine was too low to decrease the free water content and slow down microbial activity of dried snakehead, leading to limited ability to prolong the shelf life, as compared to 2 and 3% of wine adding (Table 9). Therefore, parameters of water activity, moisture content, TVB-N, peroxide values and total plate count of dried fish samples with 1% wine added were higher than those with 2 or 3% wine added at day zero and the second week ($P<0.05$). The product qualities of the 2% vs. 3% additions were not different. More importantly, dried fish samples with 2% wine yielded the lowest chemical parameters and total plate count at day zero and the fourth week due to the most appropriate supplement to combine free water present in fish flesh to decrease high water activity and moisture content. In addition, 2% wine is sufficient to induce a stressful environment for bacteria because ethanol is a toxic compound that impairs the integrity of bacterial (Hallsworth, 1998). Therefore, the growth of bacteria was restrained and the breakdown of proteins and lipids was slowed, resulting in a decrease in spoilage compounds (NH_3, H_2S, ketones, esters, CH_3SH, $(CH_3)_2S$). As a result, the levels of TVB-N, peroxide values and total plate count of the treatment of 2% of wine adding were low at day zero and the second week. Regarding organoleptic evaluation ($P<0.05$), overall acceptability of 2% of wine (6.17 and 6.04) had significantly higher scores because of the typical flavor, aroma, color and texture of dried snakehead, as well as almost no changes in appearance and taste after two weeks. At the same time of sampling, smell of wine for the samples of 3% of wine were obvious, whereas those of 1% were changed most in two weeks of preservation.

Experiment 8. The recent trend of preservative supplements is toward natural products and garlic is an outstanding plant for inhibition of bacteria. In fact, allicin in garlic has not only antibacterial, antifungal, but also antiparasite activities (Ankri and Mirelman, 1999). Compared to the case of no garlic, pure garlic, and diluted garlic juice supplements made water activity of fish flesh be stable (Table 10). The fish sample with added pure garlic showed its important role in reducing the TVBN and peroxide values and the amount of aerobic bacteria for two weeks. Based on the highest scores of overall acceptability, pure garlic addition to snakehead was the chosen treatment for the next experiments.

Experiment 9. Glycerol (E422), a humectant, with three hydroxyl groups has the function of binding free water and controlling water activity in order to enhance food stability (U.S Food and Drug Administration, International Food Information Council- IFIC). The dried fish product qualities of four dried fish groups treated by 0, 1, 2, 3% of glycerol in four-week preservation indicated significant differences based on chemical, microbiological, and organoleptic analyses ($P<0.05$) (Table 11). In fact, moisture content, water activity, TVB-N, peroxide values, and total plate count of the samples with 2 and 3% of glycerol addition were lower than the remaining treatments from the first week to the fourth week. This resulted from retarding of bacteria growth, protein, degradation, and lipid oxidation over a month when adding the suitable amount of glycerol. Therefore, glycerol addition could be used in dried snakehead processing to obtain better product properties. Furthermore, the differences between dried fish samples with 2 and 3% added glycerol could not be discerned in chemical and microbial analysis. However, for sensory evaluation, samples with 2% added glycerol showed higher organoleptic points than those of 3% through one-month storage because of the typical flavor, aroma, color, and texture of dried snakehead. Adding 3% of glycerol made dried fish flesh sweeter and decreased the dried fish taste in comparison with 2% addition. In addition, because all glycerol was not absorbed, excess glycerol caused a thin layer covering the fish flesh making the dried fish less dry. The color of dried fish was also darker due to Maillard reactions (Figure 4). Hence, 2% of glycerol was the most suitable preservative not only to maintain dried fish qualities but also for long-term storage.

***Experiment 10**.* The significant difference in chemical and sensory properties among samples treated with various drying method were due to temperature, time, and equipment used during drying periods ($P<0.05$) (Table 12). The temperatures, time and equipment selected for the next experiment mainly relied on the low chemical parameters analyzed and the high points of sensory evaluation of the eight panelists. For air dryer, chosen temperatures and drying time were 60^{o}C and 31 hours. In case of combination between drying in the dehydrator and tent dryer, in order to obtain the best product, temperatures and time for the former were 65^{o}C and 18.5 h while drying time for the latter were 9.5 h. These two dried snakehead products had an attractive appearance (Figure 5).

Experiment 11. The relatively constant sensory characteristics, chemical indices determination and total plate count were recorded for refrigerated storage (4-6^{o}C) over four weeks. In contrast to low temperature preservation, product stored at room temperature showed a significant reduction in chemical and microbial quality, starting in the second week (Table 13), although sensory properties remained the same (Table 14). The parameters of water activity, moisture content, TVB-N, peroxide values, and total plate count of dried fish samples at room temperature storage were more accelerated than chilled storage from the second week to the fourth week. However, both storage conditions had the levels of water activity, moisture content, TVB-N, peroxide values, and total plate count in the range of acceptability limits of dried fish over a period of one month. Therefore, the safe consumption of dried snakehead products was illustrated over four weeks for both stored cases. The significant difference in sensory evaluation between the two storage conditions in terms of color and overall acceptability appeared in the third week and one week later the additional change of aroma could be recognized. Refrigeration is the proper storing method to increase the shelf life of vacuum-packaged dried snakehead.

Experiment 12. Salting is a method of treating fish with salt to reduce water activity in fish flesh and to elevate flavor. In general, the salt penetration depends on amount of salt and salting time. Increased salt addition and extension of salting time raised the sodium chloride content in dried fish flesh, but lowered water activity and moisture content (Table 15). Fish samples treated with 10% salt for 30 minutes was optimal because this product had the highest points for overall acceptability as well as the low moisture content and water activity. Specifically, the water activity of this product (0.634) met the Vietnam Standard (TCVN, 2014) which was lower than 0.75. This value also satisfied the acceptable limit of The Codex Alimentarius Commission (2012) for smoke-dried fish which could minimize the mold or pathogen growth. In addition, the sodium chloride content in dried fish (9.42%) did not exceed 15%, meeting the requirement of dried fish products according to Vietnam Standard (TCVN, 2014).

Experiment 13. For dried and salted snakehead, monosodium glutamate (MSG) proved to enhance taste more than fish sauce. The salty taste could be decreased by MSG use whereas adding fish sauce into fish flesh was not able to be recognized by consumers. As a result, overall acceptability of sample with only 1% of MSG supplement got the highest points, significantly different from the other treatments ($P<0.05$). Water activity and moisture content of this sample were also the lowest among these treatments. Therefore, this dried fish product was chosen for the next experiments.

Experiment 14. Sorbitol is widely used as a sweetener, humectant, and texturing agent, and is currently permitted as a safe food additive in many countries with E number E420. More importantly, although it is approximately 60% as sweet as sucrose, it provides about one-third fewer calories, making it beneficial for people with diabetes. According to The Joint Food and Agriculture Organization/World Health Organization Expert Committee on Food Additives (JECFA), no limits for sorbitol's use are proposed. However, the U.S Food and Drug Administration's regulation states that sorbitol-food that may lead to daily consumption of 50 g of sorbitol must be labeled with the statement to prevent a laxative effect. Sorbitol addition played an important role in maintaining not only the sensory quality but also the safety of the dried products throughout the storage, indicated by the significantly unstable characters of fish sample without sorbitol in terms of microbial, sensorial, and chemical aspects as opposed to dried fish with sorbitol ($P<0.05$) (Table 16). The chemical and sensory properties of dried fish products belonging to the two groups with 2% and 3% of sorbitol showed significant difference compared to the remaining groups ($P<0.005$). For instance, moisture content, water activity, TVB-N, peroxide values, and total plate count of the samples with 2% and 3% of sorbitol addition were lower than the remaining two from the first week to the fourth week. The difference in chemical and microbial quality between dried fish samples with 2 and 3% sorbitol could not be distinguished. Nevertheless, for sensory evaluation, samples with 2% sorbitol showed better organoleptic points than those of 3% through one-month storage in terms of the typical flavor, aroma, color and texture of dried snakehead (Figure 6). Supplying 3% of sorbitol made dried fish flesh moist and sweeter to reduce the dried salted fish taste in comparison with 2% addition. Therefore, 2% addition of sorbitol was optimal preservative from this four-group comparison not only to maintain dried fish qualities but also for long-term storage.

Experiment 15. In general, with the longer dehydrating time both of sun drying and tent dryer, the peroxide values and TVBN of these treatments tended to increase (Table 17). The moisture loss was also recorded with longer drying time, resulting in lower moisture content and water activity. Moreover, total plate count data (Table 18), tent drying reduced bacterial contamination. Drying time of 36 h for dried salted snakehead was applied for both tent dryer or dehydrating in sun directly. Chemical and microbiological parameters between these two applications showed no difference, but the eight panelists scored higher points for the fish sample produced by tent dryer ($P<0.05$). Dried salted snakehead dehydrated by tent dryer for 36 h also significantly lowered peroxide and TPC values in contrast to other treated methods (P<0.05). For production of dried salted snakehead with high quality and safety, dehydrating in the tent for 36 h ranked first followed by drying in open air with the same time. This study was carried out in the rainy season, so it was difficult to recognize the drying time difference between tent dryer and sun drying directly. Appearances of these two dried snakehead products are shown in the Figure 7.

CONCLUSION

Products from snakehead have traditionally been processed as dried snakehead and salty fermented snakehead, done mainly by traditional methods in fermented snakehead processing factories (3 to 5 tons/year) and dried snakehead factories (1 to 2 tons/year). Customers purchase fermented snakehead product based on company brand (44.5%), flavor (28.1%) and price (10.9%), but based on company brand (38.2%), texture (34.5%), and taste (15.5%) for dried snakehead products.

Our experimental results showed that in the salty fermented snakehead processing, the application of mechanical treatment before mixing with salt helped shorten salting time from 30 days to 20 days, and adding crude bromelain at a rate of 3% fish weight shortened fermentation time from eight weeks to six weeks. The salty fermented snakehead product in treated treatments was similar in quality to control treatments that were fermented for eight weeks with no added bromelain.

Overall, we have demonstrated processing techniques that allow safe consumption of snakehead for up to four weeks of storage, based on sensory, chemical, and microbiological parameters. For a dried snakehead (with sucrose) production line, the optimal processing parameters are illustrated in Figure 8 and for dried salted snakehead production the parameters are illustrated in the Figure 9.

Finally, CTU researchers conducted a training course on processing of dried and fermented snakehead for women in An Giang province (Figure 10). Technical practices on processing of dried and fermented snakehead were introduced and a booklet describing processing of dried and fermented snakehead was released.

QUANTIFIED ANTICIPATED BENEFITS

This investigation has led to development of a manual of the processes of dried and fermented snakehead (*C. striata*). It supported dissertations of four undergraduate students (three female and one male). Three faculty members (female) at CTU and two local staff (female) participated in this project. Thirty women were trained on the processes of dried and fermented snakehead. One-hundred manuals of the processes of dried and fermented snakehead (in Vietnamese) were delivered to farmers.

ACKNOWLEDGMENTS

This research was funded by AquaFish Innovation Lab under USAID CA/LWA No. EPP-A-00-06-00012-00.

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TABLES AMD FIGURES

Table 1. Parameters and methods for analyzing and evaluating samples for the various experiments.

Parameters	**Methods**
Crude protein content	Kjeldahl method as described by AOAC (2000)
Moisture content	Moisture content was determined using AOAC (2000)
Salt content	Salt content as described by Zeng et al. (2013)
Amino nitrogen content	Formol titration method as described Besas and Dizon (2012)
Lipid content	Soxhlet method (AOAC, 2000)
Ash	Baking at 560^{o}C overnight (AOAC, 2000)
Water activity	Physic method (AOAC, 2000)
Peroxide values	Titration method (TCVN 6121: 1996)
Texture (Hardness)	Hardness was measured by using a Texture Analyser TA-XT.Plus with a double compression test. Eight samples of each treatment were allowed to 40% of original height, test speed 0.8 mm/s and time of 3 s was allowed to elapse between the two compression cycles.
Sensory evaluation	Sensory quality was evaluated on 7 point descriptive scale in hedonic scale scoring method as described Petrus et al. (2013)

Table 2. Results of the fermented snakehead processor survey (n = 9).

Criteria	Percentage (%)
Hired labors	
Hired labors	66.7
Family resources	23.3
Capacity	
< 1 tons/year	0
1-2 tons/year	22.2
3-5 tons/year	55.6
5-10 tons/year	11.1
>10 tons/year	11.1
Raw material	
Well-controlled antibiotics, metals, chemicals	88.9
Without controlled antibiotics, metals, chemicals	11.1
Market for product consumption	
Local market	100
Supermarket	11.1
Export	11.1

Table 3. Results of the dried snakehead processor survey (n=12).

		Percentage (%)
Hired labor		
	Hired labor	41.7
	Family resources	58.3
Capacity		
	< 1 tons/year	25
	1-2 tons/year	58.3
	> 2 tons/year	16.7
Raw material		
	Well-controlled antibiotics, metals, chemicals	66.7
	Without controlled antibiotics, metals, chemicals	33.3
Market for product consumption		
	Local market	100
	Supermarket	25
	Export	0

Table 4. Results of the fermented and dried snakehead consumer survey (n=110).

Criteria		Percentage
Gender		
	Male	36.4
	Female	63.6
Age		
	20-30	27.3
	30-40	63.6
	40-50	7.3
	50-60	1.8
Occupation		
	Student	6.4
	Housewife	59.1
	Employee	31.8
	Entrepreneur	2.7
Income (USD/month)		
	< 50	9.1
	50-150	60.9
	150-250	27.3
	250-350	0.9
	>350	1.8

Table 5. Hardness, salt, moisture and crude protein contents of salted snakeheads in experiment 1. Values (mean ± SD; n = 3) followed by the same letter in a column are not significantly different (P<0.05). RM: Raw material; TM: treatment.

TM	Salting time (Days)	Salt (%)	Moisture (%)	Crude protein (%)	Hardness (g force)
RM	0	0.15	77.53	18.94	19273
M0	**30**	**19.08±0.26^{b*}**	**58.60±0.14^{ab}**	**19.01±0.51^{c}**	**14568±42.6^{e}**
M1	5	16.11±0.11^{d}	59.01±0.42^{a}	21.45±0.22^{a}	18936±38.9^{d}
M2	10	18.01±0.29^{c}	58.02±0.19^{bc}	20.09±0.18^{b}	19789±41.0^{c}
M3	15	19.06±0.23^{b}	57.73±0.18^{c}	19.07±0.09^{c}	19924±39.4^{b}
M4	**20**	**20.62±0.17^{a}**	**55.53±0.59^{d}**	**18.94±0.21^{c}**	**20091±43.9^{a}**
M5	25	20.28±0.33^{a}	56.08±0.65^{d}	19.03±0.55^{c}	19941±46.4^{b}
M6	30	20.67±0.33^{a}	55.42±0.65^{d}	18.79±0.46^{c}	18961±10.3^{d}

Table 6. Hardness, salt, moisture, crude protein and amino nitrogen contents of salty fermented snakeheads in experiment 2. Values (mean ± SD; n = 3) with the same letter in a column are not significantly different (P<0.05). TM: treatment.

TM	Crude bromelain (%)	Time (weeks)	Salt (%)	Moisture (%)	Crude protein (%)	Amino nitrogen content (mgN/100g)	Hardness (g force)
M0	0	8	**19.11±0.33^{c}**	**56.55±0.59^{abc}**	**19.19±0.43^{ef}**	**8.07±0.32^{b}**	**16565±17.9^{h}**
M1	2	2	20.39±0.12^{b}	55.64±0.54^{efg}	21.97±0.41^{a}	5.00±0.16^{f}	18285±7.09^{a}
M2	2	4	20.43±0.19^{b}	55.43±0.53^{g}	21.07±0.16^{b}	5.88±0.00^{e}	17639±40.2^{d}
M3	2	6	20.54±0.11^{b}	56.10±0.48^{cdef}	20.08±0.24^{c}	7.28±0.37^{c}	17797±36.3^{c}
M4	2	8	20.53±0.11^{b}	56.21±0.14^{cde}	19.71±0.24^{cd}	7.84±0.14^{b}	16914±41.5^{g}
M5	3	2	20.44±0.19^{b}	55.53±0.24^{fg}	20.88±0.20^{b}	5.02±0.07^{f}	17890±35.6^{b}
M6	3	4	20.45±0.00^{b}	55.42±0.34^{g}	20.69±0.13^{b}	6.58±0.14^{d}	17125±33.9^{f}
M7	3	6	**20.67±0.19^{ab}**	**56.45±0.17^{bcd}**	**19.79±0.36^{cd}**	**8.02±0.08^{b}**	**16607±10.1^{h}**
M8	3	8	20.67±0.22^{ab}	56.47±0.22^{bcd}	19.46±0.41^{de}	8.16±0.08^{ab}	15953±32.7^{i}
M9	4	2	20.46±0.00^{b}	56.06±0.13^{cdefg}	20.08±0.13^{c}	5.32±0.42^{f}	17571±40.4^{e}
M10	4	4	20.47±0.19^{b}	55.83±0.33^{defg}	19.90±0.24^{cd}	6.95±0.4^{cd}	17082±31.5^{f}
M11	4	6	20.64±0.20^{ab}	56.70±0.25^{abc}	19.57±0.01^{de}	8.07±0.21^{b}	15884±22.6^{j}
M12	4	8	20.66±0.39^{ab}	56.58±0.65^{abc}	19.39±0.26^{de}	8.21±0.42^{ab}	14920±47.2^{l}
M13	5	2	20.47±0.19^{b}	56.38±0.31^{cd}	19.56±0.41^{de}	4.93±0.11^{f}	15872±35.7^{j}
M14	5	4	20.48±0.20^{b}	56.41±0.07^{cd}	19.07±0.20^{efg}	7.04±0.21^{c}	15691±43.6^{k}
M15	5	6	20.67±0.33^{ab}	57.08±0.04^{ab}	18.78±0.23^{fg}	8.16±0.16^{ab}	14055±47.1^{m}
M16	5	8	20.71±0.58^{a}	57.12±0.20^{a}	18.62±0.10^{g}	8.58±0.29^{a}	13381±24.4^{n}

Table 7. Sensory evaluation of salty fermented snakeheads in Experiment 2.

TM	Crude bromelain (%)	Time (weeks)	Color	Flavor	Taste	Overall
M0	0	8	$5.80±0.00^{abc}$	$5.87±0.11^{ab}$	$5.80±0.00^{ab}$	$5.93±0.11^{ab}$
M1	2	2	$5.33±0.11^{def}$	$4.93±0.12^{h}$	$5.47±0.23^{bc}$	$5.40±0.20^{cde}$
M2	2	4	$5.47±0.12^{cdefg}$	$5.07±0.23^{h}$	$5.60±0.20^{bc}$	$5.53±0.11^{cde}$
M3	2	6	$5.53±0.23^{bcdef}$	$5.20±0.20^{fgh}$	$5.67±0.11^{abc}$	$5.67±0.30^{bcd}$
M4	2	8	$5.60±0.20^{bcde}$	$5.40±0.2^{efg}$	$5.73±0.12^{ab}$	$5.73±0.23^{bc}$
M5	3	2	$5.60±0.20^{bcde}$	$5.47±0.23^{def}$	$5.60±0.20^{bc}$	$5.67±0.11^{bcd}$
M6	3	4	$5.67±0.30^{bcd}$	$5.53±0.23^{cde}$	$5.60±0.20^{bc}$	$5.73±0.23^{bc}$
M7	3	6	$6.13±0.11^{a}$	$6.07±0.11^{a}$	$6.00±0.00^{a}$	$6.20±0.20^{a}$
M8	3	8	$5.87±0.23^{ab}$	$5.80±0.20^{abc}$	$5.80±0.20^{ab}$	$5.73±0.23^{bc}$
M9	4	2	$5.13±0.12^{gh}$	$5.20±0.20^{fgh}$	$5.47±0.23^{bc}$	$5.40±0.00^{cde}$
M10	4	4	$5.20±0.20^{fgh}$	$5.53±0.11^{cde}$	$5.60±0.00^{bc}$	$5.53±0.30^{cde}$
M11	4	6	$5.40±0.20^{defg}$	$5.87±0.12^{ab}$	$5.73±0.23^{ab}$	$5.73±0.11^{bc}$
M12	4	8	$5.60±0.34^{bcde}$	$5.73±0.11^{bcd}$	$5.80±0.20^{ab}$	$5.73±0.12^{bc}$
M13	5	2	$4.93±0.11^{h}$	$5.13±0.11^{gh}$	$5.33±0.11^{c}$	$5.27±0.11^{e}$
M14	5	4	$5.13±0.12^{gh}$	$5.47±0.12^{def}$	$5.60±0.20^{bc}$	$5.33±0.23^{de}$
M15	5	6	$5.20±0.20^{fgh}$	$5.60±0.20^{bcde}$	$5.67±0.23^{abc}$	$5.40±0.20^{cde}$
M16	5	8	$5.27±0.11^{efgh}$	$5.67±0.11^{bcde}$	$5.67±0.11^{abc}$	$5.47±0.11^{cde}$

Table 8. Effect of salting methods on moisture content, salt content and a_w of dried snakehead. Values (mean ± SD) with the same letter within a column are not significantly different ($p < 0.05$). a_w: water activity.

Treatment	Moisture (%)	Salt (%)	a_w	Overall Acceptability
Dry salting (5% salt w/w)	$31.3^{b} ± 0.29$	$6.4^{a} ± 0.29$	$0.772^{b} ± 0.00$	$5.96 ± 0.07^{a}$
Brine salting (5% solution)	$34.2^{a} ± 0.29$	$2.6^{b} ± 0.29$	$0.791^{a} ± 0.00$	$5.32 ± 0.17^{c}$
Brine salting (10% solution)	$31.3^{b} ± 0.41$	$6.7^{a} ± 0.29$	$0.764^{b} ± 0.00$	$5.65 ± 0.09^{b}$

Table 9. Effect of differing percentage of sticky rice wine (30%) on moisture content, a_w, TVB_N values, peroxide values and Total Plate Count (TPC) of dried snakehead. Values (mean ± SD) with the same letter within a column are not significantly different ($p < 0.05$). a_w: water activity, TPC: Total plate count, TVB-N: Total volatile base nitrogen.

Parameters	Treatment	Wine 30%– 1% (w/w)	Wine 30% - 2% (w/w)	Wine 30% - 3% (w/w)
Moisture (%)	Week 0	30.54± 0.15^{a}	30.12 ± 0.04^{b}	30.11 ± 0.14^{b}
	Week 2	32.23 ± 0.16^{a}	31.16 ± 0.09^{b}	31.26 ± 0.05^{b}
a_w	Week 0	0.696± 0.01^{a}	0.690 ± 0.01^{b}	0.687± 0.01^{b}
	Week 2	0.719 ± 0.01^{a}	0.703 ± 0.01^{b}	0.705 ± 0.01^{b}
TVBN (mgN/100g)	Week 0	30.70 ± 0.40^{a}	29.86 ± 0.24^{b}	29.92 ± 0.25^{b}
	Week 2	32.85 ± 0.46^{a}	30.81 ± 0.31^{b}	30.85 ± 0.24^{b}
Peroxide (m.eq/Kg oil)	Week 0	1.50 ± 0.03^{a}	1.41 ± 0.02^{b}	1.41 ± 0.02^{b}
	Week 2	2.99 ± 0.05^{a}	2.74 ± 0.06^{b}	2.79 ± 0.01^{b}
TPC (log/CFUg)	Week 0	4.5 ±0.08^{a}	4.2 ± 0.06^{b}	4.3 ± 0.07^{ab}
	Week 2	5.3 ± 0.01^{a}	4.8 ± 0.01^{b}	4.8 ± 0.01^{b}
Overall Acceptability	Week 0	5.88 ± 0.65^{c}	6.17 ± 0.70^{ab}	5.92 ± 0.77^{bc}
	Week 2	5.25 ± 0.68^{b}	6.04 ± 0.69^{a}	5.58 ± 0.50^{b}

Table 10. Effect of methods of garlic addition on moisture content, salt content and water activity of dried snakehead. Values (mean ± SD) with the same letter within a column are not significantly different ($p < 0.05$). a_w: water activity, TPC: Total plate count, TVB-N: Total volatile base nitrogen.

Parameter	Treatment	No Garlic	Garlic	Garlic juice: Water (1:1)
Moisture (%)	Week 0	29.87± 0.02^{b}	30.1 ± 0.08^{ab}	30.35± 0.28^{a}
	Week 2	32.31 ± 0.10^{a}	31.15 ± 0.33^{b}	31.92 ± 0.22^{a}
a_w	Week 0	0.678 ± 0.01^{b}	0.681 ± 0.01^{b}	0.686 ± 0.01^{a}
	Week 2	0.725± 0.01^{a}	0.697 ± 0.01^{b}	0.700 ± 0.01^{b}
TVBN (mgN/100g)	Week 0	26.99 ± 0.4^{a}	25.03 ± 0.5^{b}	26.03 ± 0.4^{ab}
	Week 2	33.08 ± 0.86^{a}	30.55 ± 1.14^{b}	32.61 ± 0.48^{a}
Peroxide (m.eq/Kg oil)	Week 0	1.55 ± 0.19^{a}	1.39 ± 0.02^{ab}	1.41 ± 0.02^{b}
	Week 2	3.21 ± 0.19^{a}	2.66 ± 0.19^{b}	2.79 ± 0.10^{b}
TPC (log/CFUg)	Week 0	4.7 ± 0.14 ^{a}	4.3 ± 0.07^{b}	4.4 ± 0.08^{b}
	Week 2	5.3 ± 0.02 ^{a}	4.6 ± 0.20 ^{b}	4.8 ± 0.18^{b}
Overall Acceptability	Week 0	4.58 ± 0.65^{c}	6.22 ± 0.59 ^{a}	5.88 ± 0.74 ^{b}
	Week 2	4.33 ± 0.64 ^{c}	6.08 ± 0.65 ^{a}	5.63 ± 0.74 ^{b}

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Table 11. Effect of differing percentage of glycerol on moisture content, a_w, TVB_N values, peroxide values and Total Plate Count (TPC) of dried snakehead. Values(mean ± SD) with the same letter within a column are not significantly different ($p < 0.05$). NS: not significant. a_w: water activity, TPC: Total plate count, TVB-N: Total volatile base nitrogen.

Parameter	Treatment	Glycerol 0% (w/w)	Glycerol 1% (w/w)	Glycerol 2% (w/w)	Glycerol 3% (w/w)
Moisture (%)	Week 0	30.13 ± 0.18^{NS}	29.98 ± 0.10^{NS}	29.37 ± 0.56^{NS}	30.02 ± 0.37^{NS}
	Week 4	33.70 ± 0.06^{a}	32.77 ± 0.40^{b}	30.85 ± 0.17^{c}	32.10 ± 0.38^{cb}
a_w	Week 0	0.681 ± 0.01^{NS}	0.675 ± 0.01^{NS}	0.673 ± 0.01^{NS}	0.669 ± 0.01^{NS}
	Week 4	0.745a ± 0.01^{a}	0.710 ± 0.01^{b}	0.692 ± 0.01^{c}	0.700 ± 0.01^{c}
TVBN (mgN/100g)	Week 0	29.91 ± 0.03^{a}	28.06 ± 0.60^{b}	27.77 ± 0.67^{b}	26.4 ± 0.30^{c}
	Week 4	31.90 ± 0.04^{a}	30.40 ± 0.19^{b}	29.44 ± 0.01^{c}	29.26 ± 0.19^{c}
Peroxide (m.eq/Kg oil)	Week 0	1.38 ± 0.04^{a}	1.33 ± 0.06^{a}	1.20 ± 0.02^{b}	1.11 ± 0.05^{b}
	Week 4	4.19 ± 0.09^{a}	3.81 ± 0.29^{ab}	3.24 ± 0.13^{c}	3.40 ± 0.14^{bc}
TPC (log/CFUg)	Week 0	4.3 ± 0.33^{NS}	4.2 ± 0.28^{NS}	4.1 ± 0.13^{NS}	4.0 ± 0.05^{NS}
	Week 4	5.8 ± 0.01^{a}	5.5 ± 003^{b}	5.0 ± 0.13^{c}	5.2 ± 0.13^{c}
Overall Acceptability	Week 0	4.79 ± 0.72^{c}	5.71 ± 0.69^{b}	6.25 ± 0.44^{a}	4.88 ± 0.74^{c}
	Week 4	3.58 ± 0.50^{d}	4.67 ± 0.48^{b}	5.75 ± 0.44^{a}	4.08 ± 0.65^{c}

Table 12. Effect of the drying methods on moisture content, a_w, TVB_N values and peroxide values of dried snakehead. Values (mean ± SD) with the same letter within a column are not significantly different ($p < 0.05$). NS: not significant. a_w: water activity.

	Moisture (%)	aw	TVB_N (mg/100g)	Peroxide (m.eq/kg oil)	Overall Acceptability
(AD)_65^{o}C: 28hours	29.4^{c} ± 0.56	0.673^{cd} ± 0.00	29.15^{NS} ±1.33	1.2 ^{b} ± 0.02	5.46 ± 0.55^{b}
(AD)_65^{o}C:15 h+ (AD)_60^{o}C: 13h	32.1^{a} ± 0.15	0.691^{a} ± 0.00	29.38^{NS} ± 0.02	1.2^{b} ± 0.05	4.96 ± 0.20^{c}
(AD)_60^{o}C: 31h	29.1^{c} ± 0.49	0.670^{d} ± 0.00	29.43^{NS} ± 0.25	1.2 ^{b} ± 0.05	6.33 ± 0.48^{a}
(AD)_65^{o}C: 22 h+ (TD): 6 h	31.7^{ab} ± 0.26	0.683^{ab} ± 0.00	29.69^{NS} ± 0.09	1.3^{ab} ± 0.04	5.42 ± 0.50^{b}
(AD)_65^{o}C: 18.5 h + (TD): 9.5 h	30.9^{ab} ± 0.41	0.673^{cd} ± 0.00	29.72^{NS} ± 0.07	1.3^{ab} ± 0.04	6.63 ± 0.49^{a}
(AD)_65^{o}C: 14 h + (TD): 14 h	31.19^{b} ± 0.32	0.679^{bc} ± 0.00	29.77^{NS} ± 0.30	1.3^{a} ± 0.04	4.42 ± 0.50^{c}

Parameter

altTime
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Table 13. Effect of the storage temperatures on moisture content, a_w, TVB_N values and peroxide values of dried snakehead. Values (mean $\pm$ SD) with the same letter within a column are not significantly different ($p < 0.05$). NS: not significant. a_w: water activity, TPC: Total plate count, TVB-N: Total volatile base nitrogen.

Treatment	Parameter	Moisture (%)	a_w	TVBN (mgN/100g)	Peroxide (m.eq/Kg oil)	TPC (log/CFUg)
Week 0	Room temp.	29.41 ± 0.09^{NS}	0.673 ± 0.00^{NS}	28.1 ± 0.59^{NS}	1.22 ± 0.04^{NS}	4.1 ± 0.10^{NS}
	4°C – 6°C	29.40 ± 0.53^{NS}	0.671 ± 0.00^{NS}	28.1± 0.72^{NS}	1.20 ± 0.03^{NS}	4.0 ± 0.08^{NS}
Week 4	Room temp.	30.54 ± 0.20^{a}	0.691 ± 0.00^{a}	32.4 ± 0.56^{a}	2.35 ± 0.04^{a}	5.0 ± 0.05^{a}
	4°C – 6°C	30.14 ± 0.04^{b}	0.682 ± 0.00^{b}	30.7 ± 0.33^{b}	2.12 ± 0.09^{b}	4.7 ± 0.05^{b}

Table 14. Sensory evaluation of dried snakehead. The values are based on a 7-point scale of 8-person panel response to each attribute. Means with the same letter within column are not significantly different ($p < 0.05$). NS: not significant.

Treatment	Parameter	Color	Texture	Aroma	Flavor	Overall Acceptability
Week 0	Room temperature	3.92 ± 0.65^{NS}	3.92 ± 0.41^{NS}	3.92 ± 0.65^{NS}	3.88 ± 0.68^{NS}	6.25 ± 0.53^{NS}
	4°C – 6°C	3.96 ± 0.55^{NS}	4.04 ± 0.55^{NS}	3.96 ± 0.36^{NS}	3.92 ± 0.65^{NS}	6.29 ± 0.55^{NS}
Week 4	Room temperature	5.00 ± 0.30^{a}	3.33 ± 0.48^{NS}	4.62 ± 0.50^{a}	4.46 ± 0.51^{NS}	5.62 ± 0.50^{b}
	4°C – 6°C	4.62 ± 0.50^{b}	3.54 ± 0.51^{NS}	4.29 ± 0.46^{b}	5.29 ± 0.46^{NS}	6.08 ± 0.50^{a}

Table 15. Effect of salting methods on moisture content, salt content and a_w of dried snakehead. Values (mean ± SD) with the same letter within a column are not significantly different ($p < 0.05$). NS: not significant. a_w: water activity.

		Moisture (%)	a_w	Sodium chloride content(%)	Overall Acceptability
8%	20 minutes	30.83 ± 0.06^{a}	0.677 ± 0.01^{a}	7.28 ± 0.06^{g}	4.67 ± 0.56^{c}
8%	30 minutes	30.61 ± 0.06^{ab}	0.669 ± 0.01^{a}	7.91± 0.06^{f}	4.75 ± 0.68^{c}
8%	40 minutes	30.41 ± 0.07^{bc}	0.662 ± 0.01^{a}	8.39 ± 0.07^{e}	4.92 ± 0.58^{bc}
10%	20 minutes	30.27± 0.09^{c}	0.657 ± 0.01^{a}	8.41 ± 0.08^{e}	5.33 ± 0.70^{b}
10%	30 minutes	29.82 ± 0.02^{d}	0.634 ± 0.00^{b}	9.42 ± 0.02^{d}	6.25 ± 0.61^{a}
10%	40 minutes	29.51 ± 0.06^{e}	0.612 ± 0.00^{cd}	10.51 ± 0.06^{c}	4.71 ± 0.55^{c}
12%	20 minutes	29.58 ± 0.14^{de}	0.625 ± 0.00^{bc}	9.58 ± 0.12^{d}	4.42 ± 0.58^{c}
12%	30 minutes	28.92 ± 0.08^{f}	0.603 ± 0.00^{de}	10.92 ± 0.07^{b}	3.21 ± 0.72^{d}
12%	40 minutes	27.67 ± 0.13^{g}	0.584 ± 0.01^{e}	11.58 ± 0.12^{a}	2.83 ± 0.64^{d}

Table 16. Effect of different percentages of sorbitol on moisture content, a_w, TVB_N values, peroxide values and Total Plate Count (TPC) of dried snakehead. Values (mean ± SD) with the same letter within row are not significant different ($p < 0.05$). a_w: water activity, TPC: Total Plate Count, CFU: Colony Forming Unit.

Parameter \ Treatment		Sorbitol 0% (w/w)	Sorbitol 1% (w/w)	**Sorbitol 2% (w/w)**	Sorbitol 3%(w/w)
Moisture (%)	Week 0	28.77 ± 0.48^{b}	29.10 ± 0.14^{b}	29.70 ± 0.01^{a}	29.92 ± 0.09^{a}
	Week 4	30.73 ± 0.17^{a}	30.26 ± 0.15^{b}	30.08 ± 0.11^{b}	30.30 ± 0.12^{b}
a_w	Week 0	0.630 ± 0.00^{a}	0.626 ± 0.00^{a}	0.614 ± 0.00^{b}	0.610 ± 0.01^{b}
	Week 4	0.658 ± 0.00^{a}	0.646 ± 0.00^{b}	0.628 ± 0.00^{c}	0.628 ± 0.00^{c}
TVBN (mgN/100g)	Week 0	28.95 ± 0.12^{a}	28.29 ± 0.06^{ab}	27.18 ± 0.04^{bc}	27.03 ± 0.09^{c}
	Week 4	31.66 ± 0.06^{a}	30.72 ± 0.11^{a}	28.99 ± 0.09^{b}	29.13 ± 0.02^{b}
Peroxyde (m.eq/Kg oil)	Week 0	1.27 ± 0.03^{a}	1.21 ± 0.02^{b}	1.14 ± 0.01^{c}	1.12 ± 0.02^{c}
	Week 4	1.82 ± 0.04^{a}	1.68 ± 0.03^{b}	1.47 ± 0.04^{c}	1.49 ± 0.01^{c}
TPC (log/CFUg)	Week 0	4.3 ± 0.04^{a}	4.1 ± 0.01^{b}	4.0 ± 0.01^{c}	3.9 ± 0.01^{c}
	Week 4	5.4 ± 0.00^{a}	5.2 ± 0.07^{b}	4.5 ± 0.05^{c}	4.6 ± 0.01^{c}
Overall Acceptability	Week 0	5.25 ± 0.44^{c}	5.71 ± 0.69^{b}	6.25 ± 0.44^{a}	5.38 ± 0.50^{bc}
	Week 4	4.83 ± 0.38^{c}	5.29 ± 0.46^{b}	5.96 ± 0.20^{a}	5.04 ± 0.20^{bc}

Table 17. Effect of the drying methods on moisture content, a_w, TVB_N values and peroxide values of dried snakehead. Values (mean ± SD) with the same letter within a column are not significantly different ($p < 0.05$). NS: not significant. a_w: water activity.

Drying time	Moisture (%)	a_w	TVBN (mgN/100g)	Peroxyde (m.eq/Kg oil)	TPC (log/CFUg)	Overall Aceptalility
33 h (open air drying)	31.25 ± 0.87^{a}	0.633 ± 0.00^{a}	26.25 ± 0.04^{bc}	1.18 ± 0.04^{c}	5.3 ± 0.07^{a}	4.67 ± 0.57^{c}
36 h (open air drying)	29.50 ± 0.15^{b}	0.622 ± 0.00^{cd}	27.02 ± 0.06^{b}	1.33 ± 0.04^{b}	5.1 ± 0.02^{b}	6.25 ± 0.44^{b}
39 h (open air drying)	28.06 ± 0.34^{c}	0.616 ± 0.00^{d}	30.17 ± 0.06^{a}	1.64 ± 0.06^{a}	5.1 ± 0.06^{b}	5.92 ± 0.72^{b}
33 h (tent dryer)	31.92 ± 0.38^{a}	0.636 ± 0.00^{ab}	25.78 ± 0.06^{c}	1.12 ± 0.06^{c}	5.2 ± 0.05^{a}	4.75 ± 0.44^{c}
36 h (tent dryer)	29.91 ± 0.37^{b}	0.626 ± 0.00^{bc}	26.72 ± 0.07^{bc}	1.20 ± 0.04^{c}	4.9 ± 0.03^{c}	6.71 ± 0.46^{a}
39 h (tent dryer)	28.89 ± 0.17^{bc}	0.618 ± 0.00^{d}	29.95 ± 0.03^{a}	1.60 ± 0.03^{a}	5.1 ± 0.03^{b}	6.08 ± 0.50^{b}

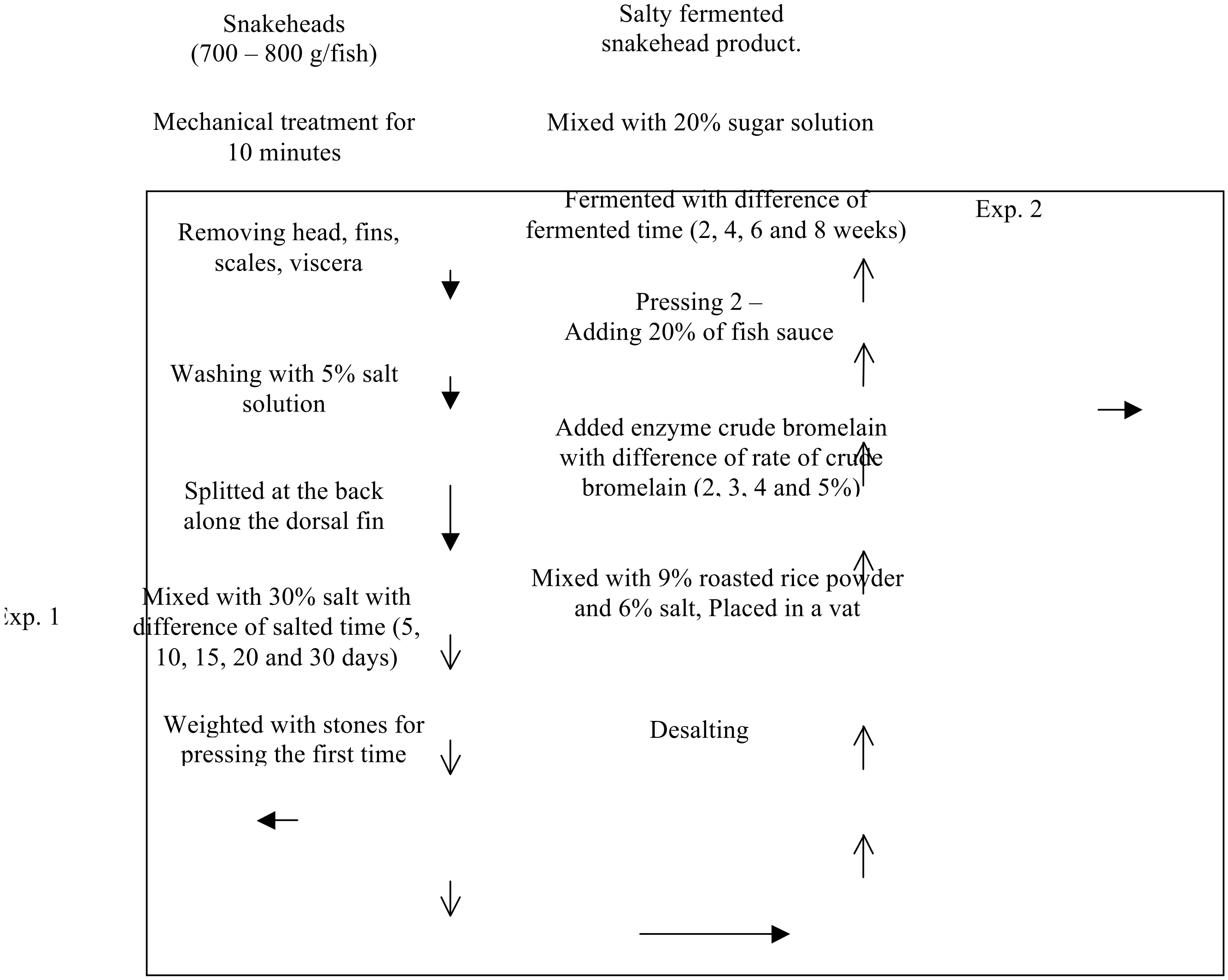

Figure 1. General procedure for processing fermented snakehead.

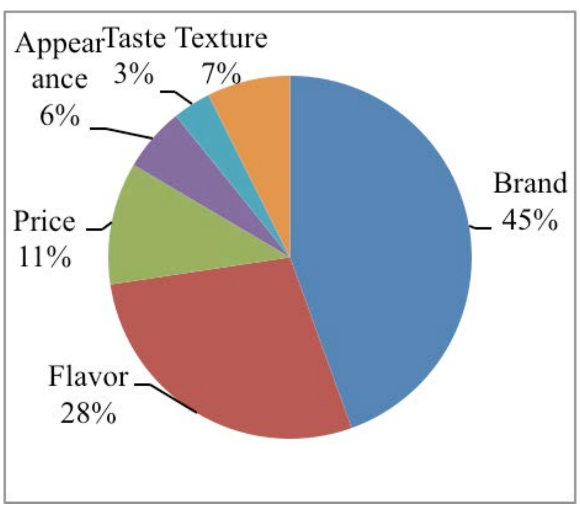

Figure 2. Quality of fermented snakehead influencing purchased intent.

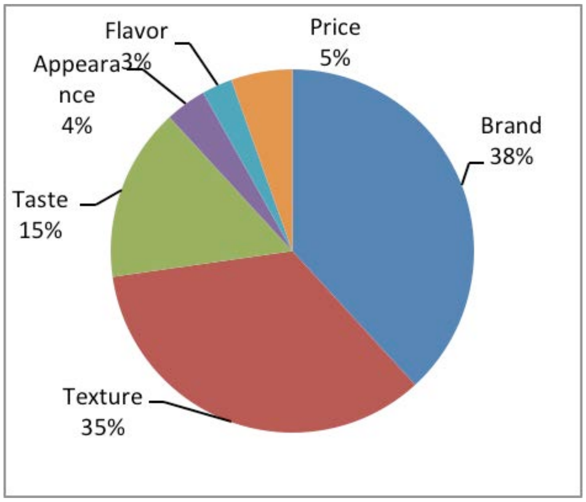

Figure 3. Quality of dried snakehead influencing purchased intent.

Figure 4. Colors of dried snakehead with different percentages of glycerol at the initial week

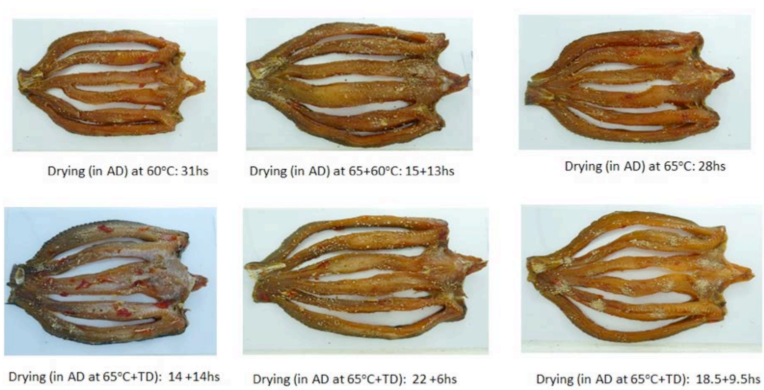

Figure 5. Colors of dried snakehead with different drying methods.

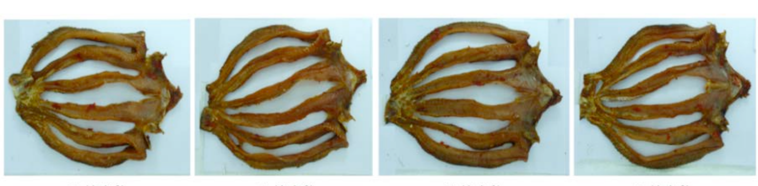

Figure 6. Appearances of dried snakehead with differing percentage of sorbitol at the initial week.

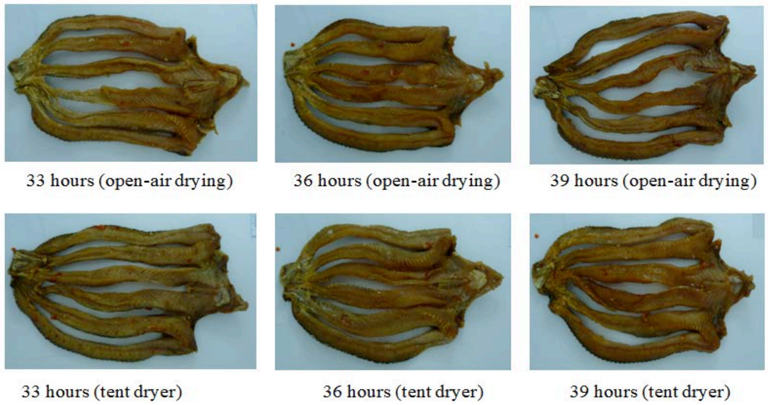

Figure 7. Appearances of dried snakehead with different drying methods.

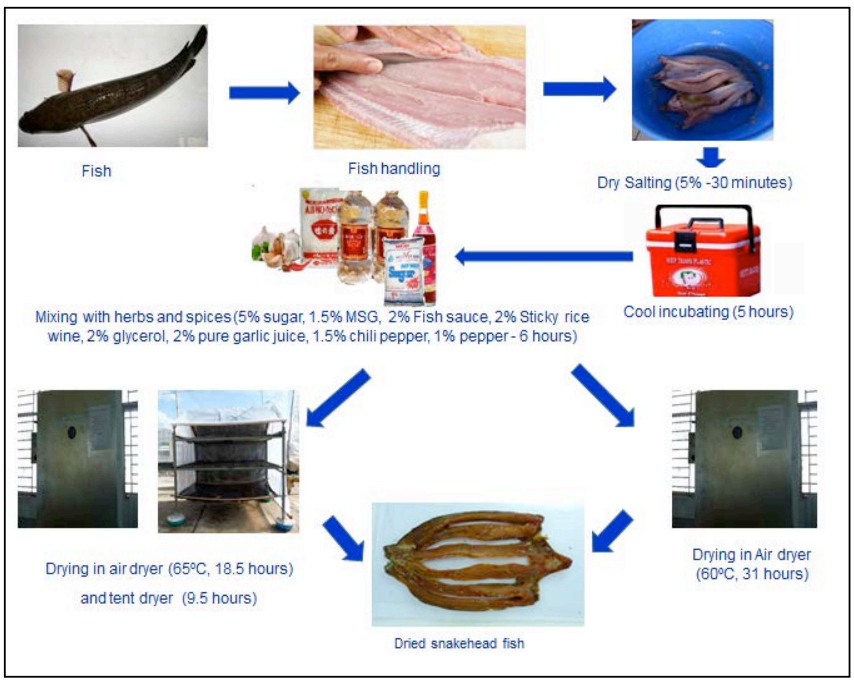

Figure 8. Process of dried snakehead with added sucrose.

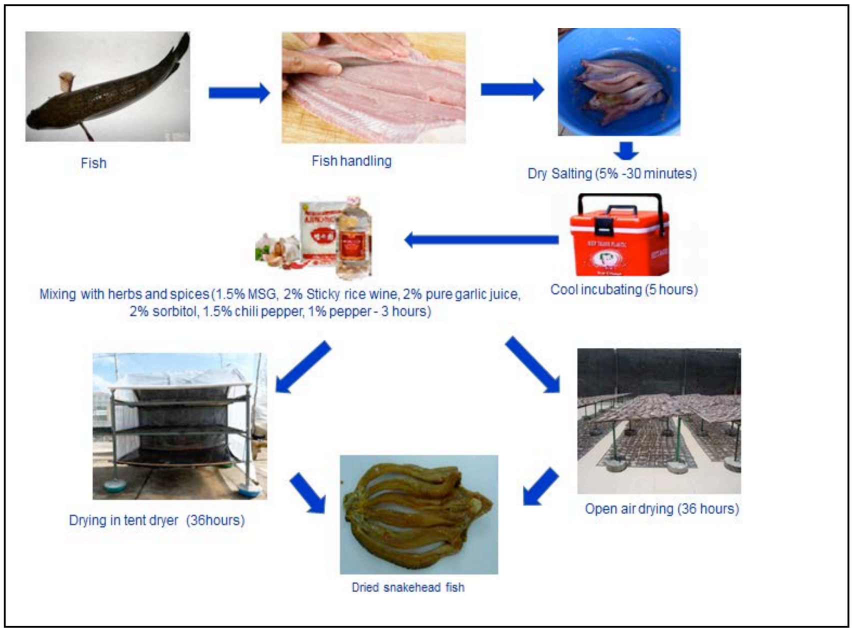

Figure 9. Process of dried salted snakehead without sucrose.

Figure 10. Training course on snakehead aquaculture for women in An Giang province.