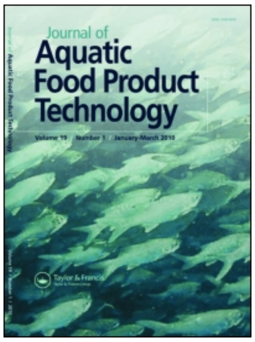

Journal of Aquatic Food Product Technology

ISSN: 1049-8850 (Print) 1547-0636 (Online) Journal homepage: https://www.tandfonline.com/loi/wafp20

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To cite this article: Maria Inez Espagnoli Geraldo Martins, Jesaias Ismael da Costa, Giovani Sampaio Gonçalves & Rose Meire Vidotti (2016) Feasibility Study of a Fish By-Product Recovery Plant with a Processing Capacity of 1,000 kg/Day, Journal of Aquatic Food Product Technology, 25:8, 1202-1212, DOI: 10.1080/10498850.2015.1046098

To link to this article: https://doi.org/10.1080/10498850.2015.1046098

Accepted author version posted online: 26 Apr 2016.
Published online: 14 Oct 2016.

JOURNAL OF AQUATIC FOOD PRODUCT TECHNOLOGY
2016, VOL. 25, NO. 8, 1202–1212
http://dx.doi.org/10.1080/10498850.2015.1046098

Feasibility Study of a Fish By-Product Recovery Plant with a Processing Capacity of 1,000 kg/Day

Maria Inez Espagnoli Geraldo Martins[a], Jesaias Ismael da Costa[b], Giovani Sampaio Gonçalves[c], and Rose Meire Vidotti[c]

[a]Department of Agricultural Economics, Faculty of Agricultural and Veterinary Sciences, Paulista State University "Julio Mesquita Filho" (UNESP), Jaboticabal, São Paulo, Brazil; [b]Aquaculture Center Faculty of Agricultural and Veterinary Sciences, Paulista State University "Julio Mesquita Filho" (UNESP), Jaboticabal, São Paulo, Brazil; [c]Fisheries Institute of São Paulo State, São José do Rio Preto, Brazil

ABSTRACT
This study evaluates the feasibility of producing hamburger, silage, and leather using fish by-products in a medium-sized recovery plant with total capacity of processing up to 1,000 kg/day of whole fish. The average volume of fish by-products generated daily was 673 kg. The investment necessary to introduce these three technologies was US$47,193.13 in 1 year. The average cost to produce 1 kg of hamburger, silage, and leather was 1.24, 0.17, and US$1.77, respectively. The return of the investment was 56.16%, and the net present value US$570,582.16. The investment pay back was realized in 3.88 years, with a benefit/cost relationship of 1.31. For all the studied scenarios, sale price variations most influenced the economical parameters analyzed.

KEYWORDS
Economic viability; tilapia; value-added products; silage; leather; hamburger

Introduction

The tilapia processing industry prioritizes fillet production in the factory production line. There is a very large amount of residues generated (Oetterer, 2002) because tilapia filleting yield is low (30 to 33%). The optimal use of these by-products (skin, scales, viscera, and carcass) can make the business more profitable. Effective industrialization of the by-products generated is of fundamental importance for the success of the productive chain as a whole (Boscolo and Feinden, 2007). Several studies have been done to promote alternative uses of these residues (skin, scales, viscera, and carcass)—such as silage, fish meal, oil production, compost, mechanically recovered meat (MRM), and others (Morais and Martins, 1981; Coelho et al., 2000; Boscolo and Feinden, 2007; Abimorad et al., 2009).

Mechanically recovered meat

Large-scale production of MRM allows production of high added value products that can reach specific segments of the market or even less valuable products that attend social needs such as the demand for high quality protein of animal origin (Kuhn and Soares, 2002). The main advantages of using MRM compared to fish fillet are the following: (a) cost reduction due to high yield; (b) possibility of using several species; and (c) a large line of products that can be commercialized such as fishburger, fishfranks, breaded or canned fish, fish fingers, nuggets, etc. (Marchi, 1997).

In order to obtain good quality MRM, it is necessary to begin with fresh and also good quality raw material, followed by careful processing that follows hygienic and sanitary rules necessary when dealing with highly perishable material such as fish meat (Morais and Martins, 1981).

CONTACT Jesaias Ismael da Costa jesaiaslbr@gmail.com Paulista State University "Julio Mesquita Filho" (UNESP), Road Prof. Paulo Donato Castellane, s/n 14884-900 Jaboticabal, SP, Brazil.

The "Ministerio da Agricultura e do Abastecimento" defines hamburger as an industrialized meat product obtained from minced meat with or without added animal fat and other ingredients (e.g., vegetable fat, water, salt, animal or vegetable proteins, powdered milk, sugars, additives, condiments, and spices); which is then molded and submitted to the appropriate technological process. It may also contain some type of filling, such as cheese or vegetables. This product might be raw, semifried, cooked, fried, frozen, or refrigerated. According to the same principles, up to 30% MRM can be added to cooked hamburgers and up to 4% of protein can be added as an aggregate. As for the physicochemical characteristics, the hamburger must contain maximum 23% fat content, 15% minimum protein, and 3% total carbohydrates. The final product is denominated hamburger followed by the name of the animal species that originated the hamburger (Ministério da Agricultura e do Abastecimento, 2001).

It should also be noted that all the meat used to make hamburgers should be inspected and approved according to the procedures described in the RIISPOA—"Regulamento de Inspeção Industrial e Sanitária de Produtos de Origem Animal"—Decree n° 30.691, from March 29, 1952.

Silage

Fish silage is defined as the liquid product obtained from the whole or part of the fish fillet residues with addition of mineral or organic acids (acid silage) or use of microorganisms capable of producing lactic acid in the presence of a carbohydrate source, where the mass is liquefied by the enzymes present in the meat (Tatterson and Windsor, 1974; Vidotti and Gonçalves, 2006). Oetterer (2002) reports that the nutritional value of silage lies in the high protein digestibility, which should be preserved by avoiding long storage periods that cause excessive hydrolysis. It is a simple process, practical, and economical that does not require expensive equipment or procedures, such as those necessary to produce fishmeal (Arruda, 2004), making it a viable alternative for a small amount of residues. Silage has high nutritional and biological value as animal feed, because it preserves the protein value, particularly for amino acids such as lysine, methionine, and cystine (Coelho et. al., 2000; Ristic et al., 2002; Vidotti et al., 2003).

Leather

Fish is mostly commercialized in Brazil as skinless fillet, which makes the skin another by-product of the industry. Treating and industrializing this skin can generate extra income for the sector, thus preventing this raw material from becoming a problem for the producer (Boscolo and Feinden, 2007). The skin represents between 4.50 to 10.00% of the fish body weight, varying according to fish species and filleting method used. When the skin of Nile tilapia was separated manually, these values varied between 6.30 and 6.71% (Souza, 2004). According to Ingram and Dixon (1994), fish skin is considered exotic and results in an innovative leather that is well-accepted by several segments of the market to manufacture among others things, briefcases, key rings, watch wristbands, handbags, shoes, as well as clothing articles.

The market price (US$/m^2) of fish leather is greater than the market price of cow leather. According to Grizzo (2006), the market value of fish leather can reach US$115.05/m^2. To produce 50 m^2 of leather, it is necessary to process 5,000 fish skins, which can be used to manufacture 850 pairs of womens shoes.

Currently, the quantity of value-added products derived from fish processing residues is low, primarily because economic and financial information regarding production is limited. Increasing awareness and promoting alternative use of by-products requires demonstrating the economic feasibility and viability of such enterprises. Therefore, this work aimed at studying the current uses of fish by-products generated in a plant that processes up to 1,000 kg of tilapia/day and presenting the economic feasibility study.

Materials and methods

Residue production

The plant where the study was carried out is located in Garça, midwestern São Paulo State, Brazil. The processed fish are either own reared or partnership cultures. This partnership allows the company to operate the entire production chain, from fingerling all the way to fish processing. The tilapias were transported to the depuration tanks and slaughtered at the harvesting place by thermal shock using icy water. After that, the fish were transported in ice filled polyethylene tanks.

The process to obtain the fillet involves several steps. First, the heads are cut off, and the fish is then eviscerated in the "dirty area." The fillet is obtained by peeling off the skin from the clean carcass using pliers ("clean area"). These fillets are then deboned by performing "V-cutting." From the clean carcass, the dorsal, ventral, and anal fins are taken out, and then the leftover meat is extracted from the bones.

The data for identification and quantification of the residues were collected during three consecutive days: March 20–22, 2008 (Table 1). These values were extrapolated for the maximum capacity of the plant: 1,000 kg of tilapia processed per day. The products manufactured in the plant were developed taking into account the amount of residues generated daily: 673 kg after the extrapolation. These residues were used to produce the following: 33% of fish hamburger, 10.97% skin for leather treatment, and 56.03% of acid silage.

Technology for hamburger production

This production unit was designed to process approximately 222 kg of residue/day for hamburger production. The residues used in this unit were the trimmings resulting from the ventral, dorsal, and "v"-cuttings and the mechanically recovered meat.

The MRM was obtained by removing the leftover meat from the bones using a special type of equipment. This equipment consists of a transporting screw that gradually presses the carcass against a knife system equipped with a set of blades with millimeter sized dents. These blades are shaped in a way that allows separating the meat from the bones as they are expelled from the machine. The bones are transported by the screw and collected at the end. This equipment does not require previous breaking or cooling of the raw material. The fast and continuous feeding avoids a temperature increase and therefore possible contamination. The equipment also allows maximum extraction yield. Moreover, this equipment requires cutting off the fins, because their pigments give unwanted color and appearance to the final product.

The MRM was then homogenized and mixed with a commercially available extender, Romariz (Romariz, São Paulo, Brazil), to reach the desired texture and increase water retention capacity. A mechanical mixer was used due to the mass volume.

After homogenization, the 100-g hamburgers were shaped using the appropriate machine. The hamburgers were frozen in a shelf-type freezer for quick and efficient freezing. After that, they were individually wrapped in a poliolefinic plastic by an automated system. Figure 1 shows all the steps involved in this process.

Table 1. Amount of tilapia fillet and the residues generated in a processing plant of 1,000 kg daily.

Product	Total (kg)[1]	Average (kg)[2]	Average (%)
Whole fish	590.84	196.95	—
Fillet	191.40	93.89	32.34
Head+ entrails	222.76	74.20	37.70
Carcass, "V" cut and ventral chip	131.55	43.85	22.26
Skin + scales	43.61	14.54	7.38
Total residue	397.93	132.64	67.35

[1]Total production sampled in 3 days. [2]Daily average of production sampled.

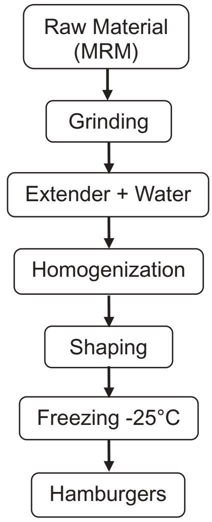

Figure 1. Hamburger production.

Technology to produce acid silage

Acid silage was produced using the continuous process methodology proposed by Vidotti and Gonçalves (2006). This plant was designed to produce 377-kg silage/day. The residues (head, carcass, and viscera) were finely ground using a meat grinder with two rimmed plates with 22- and 6-mm diameter holes, respectively.

A 230 kg of finely ground mass was placed in one 250-kg-capacity polypropylene lidded container and left to rest until the next day. The following day, the remaining volume was filled up with 20 kg of the residue produced during that day, and the remaining 210 kg of residue was then used to start a new container. Additives and acid quantities were calculated taking into account the total residue production (Figure 2). The total capacity of the container cannot be used because there are gases formed during the process that require head space.

This production line requires four polypropylene containers per week and a total of 16 per month as an investment. The advantage of the continuous process is the better use of equipment, storage, and space. After 5 days, the product was homogenized and ready for commercialization.

Technology for leather production

This plant was designed to produce natural colored (without dyeing agent) leather from 73.8 kg of fish skin. Skin treatment was carried out in a 25-m^2 warehouse built next to the factory where the residues were being generated, thus avoiding transportation costs. Silage was also produced in the same warehouse. Skin processing is time consuming; therefore, this unit worked full time. Average yield of this process was 60%, considering losses during filleting and skin that cannot be processed.

The prepared skin was treated with a natural agent, tannin, and the commercially available basic agent, Dekalon (Quimifinish Industria e Comercio de Produtos Quimicos Ltda, Franca, Brazil). Muriatic acid was used during pickling to lower the pH. After production, the leather was water-proofed and stored in boxes ready to be commercialized. The skin of one fillet resulted in one piece of leather. Figure 3 presents the steps used during the skin treatment.

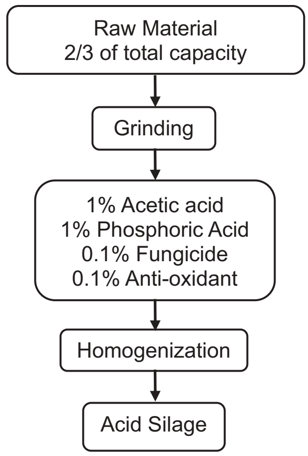

Figure 2. Acid silage production.

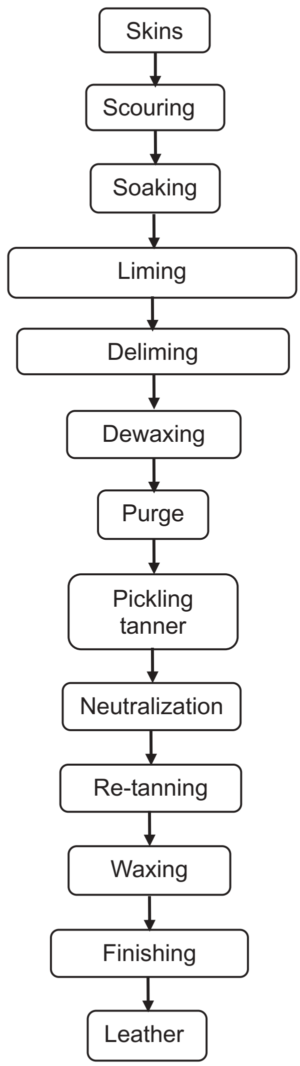

Figure 3. Steps in leather production.

Economic analysis

The economic analysis determines the production cost of each product, the profitability indicators according to Scorvo Filho et al. (2004), and the economic feasibility of the investment to make all different products including risk assessment for high risk variables, based on Kassai et al. (1999). Economic feasibility indicators were determined from the liquidity, based on the monetary value of the income minus the expenses that occurred along the study. The projected cash flow was elaborated for a 10-year period, which takes into account the useful life of the equipment, considering the implementation of the project as the starting point. Price quotes were taken in October 2008, and were converted into American dollars at that time (US$1.00 = R$2.1729).

Production costs

Production costs took into account the fixed and variable costs. Fixed costs were determined by taking into account depreciation of the equipment and remuneration of the investment. Depreciation was calculated by linear methodology, which consists of devaluation of the investment along the useful life at a constant rate, as given by the following formula:

$$\mathrm{D} = \frac{(Vi - Vf)}{n},$$

where D is the depreciation in US$/year, V_i is the initial value of the investment, V_f is the salvage value of investment in US$, and n is the useful life in years.

The opportunity cost of the fixed capital was calculated at a 6% yearly rate, this is the interest rate of savings and considered the safest investment. The costs of chemical products, labor, equipment maintenance, packaging, and interest rates of the circulation capital were considered as variable costs. Labor costs were calculated considering the number of working hours necessary to manufacture each product at a minimum monthly wage of US$211.70 plus the compulsory labor charges, which represents an increase of 73% for the entrepreneur. The interest rate considered over the net cash flow, was the yearly interest rate of 4% given by the Programa Nacional de Agricultura Familiar (PRONAF). The cost of raw material was zero because the discarded residues did not have any commercial value, and the present work was conducted at the factory where the residues are generated.

Profit indicators

The profitability of residue use was evaluated by the following indicators: gross income (GI), profit, average costs, and breakeven price, according to Scorvo Filho et al. (2004).

Selling prices were slightly lower than current market prices, because the introduction of new products requires a whole new process to introduce them successfully in the market. The price of tilapia hamburger considered in the economic study was 40% lower than that of beef hamburger (US$2.74/kg). Leather prices in the study were the current prices practiced by companies already in the market and 80% higher than production costs. Silage prices were the same as production costs. However, beyond economics, the advantages of such a product are the ability to manufacture fish feed to be used on the farm using the acid silage, thus diminishing fish production costs and environmental impact.

Sensitivity and feasibility indicators

The following feasibility indicators were determined from the net cash flow: net present value (NPV), internal rate of return (IRR), benefit/cost relationship (B/C), and simple and economical pay-back periods (SPB and EPB); all indicators were calculated as described by Shang (1981). The NPV, IRR, EPB, and SPB are indicators that present different views of the same results but are expressed in different units, where: NPV is expressed in monetary value, IRR expressed as a percentage, and EPB and SPB in unit time. In the cash flow, the investment of structure deployment (zero moment) and outlay for production of by-products were considered as outputs (Years 1 to 10). Cash inflows were the amount of revenue from sale of products, the residual value of the investment at the end of 10 years, and the scrap value of fixed assets at the end of its useful life.

NPV is estimated as the difference between the present value of cash inflow and output at a given discount rate. The project is feasible when NPV > 0, and the invested amount was recovered when NPV = 0. The NPV is estimated as:

$$\mathrm{NPV} = \sum_{t=0}^{n} \frac{NCFt}{(1+i)^t}.$$

IRR is the discount rate that equates the price of entry to the outlet box. It is estimated as the rate at which the NPV is zero. Thus, a project or investment is considered attractive when presenting IRR greater or equal to "i" (discount rate). The B/C is used to evaluate if invested resources are returned given predetermined selling prices. An estimate of B/C = 1 would indicate that the enterprise is financially viable:

$$\mathrm{B/C} = \sum_{t=0}^{n} \frac{\frac{Income}{(1+i)^t}}{\frac{Expenses}{(1+i)^t}}.$$

The payback period is the time period required for the amount invested in an asset to be repaid by the net cash outflow generated by the asset. The payback period is expressed in years and fractions of years (Shang, 1981). The simple payback as indicator does not consider that money has "time value," and the economical payback is based on a discounted flow and considers that money has "time value."

For all formulas, the abbreviations are:

NCF = net cash flow
Income = cash inflows
Expenses = cash outflows
i = discount rate
n = number of years in operation (0, 1, 2, ... 10)
t = year

Feasibility indicators were determined taking into account the best estimates of the cash flow. The original assumption in the economic study was that the final product's sale capacity would increase over the years (60, 65, 70, and 75% in the Years 1, 2, 3, and 4, respectively; and 80% from the 5th to the 10th year). The sensitivity analysis of these same values was calculated taking into account different scenarios. The three proposed scenarios were determined according to the most significant risk factors in these production lines as follows:

(1) Sale prices are equal to total average production cost plus 20% in the 10 years of the project, and sales at 100% of the production.
(2) In the first two years, the sale price equals the average total cost, and in the following years, equals to the original assumption, and sales at 100% of the production.
(3) In the first three years, production is 20% lower, in order to adjust technology, but after production stabilizes, sale prices are the same as in the original assumption, and sales are at 100% of the production.

Results and discussion

The use of the extender in the hamburger production allowed processing yield of 167% and expected production of 254.3-kg hamburger/day. The continuous acid silage production using acetic and phosphoric acids lasted 5 days. The production of 377 kg/day pointed to a processing yield of 100%. And, the additional 44.3 kg of leather production indicated a 60% yield.

Economical evaluation

The investment values for each producing unit are displayed in Table 2. The investment for the hamburger production unit was the largest (55.22%), followed by the leather treatment unit (41.68%), and silage (3.10%). The total investment for all three units was US$47,193.13. The operational expenses for all three units were US$101,673.84 annually.

Table 3 presents detailed technical coefficients for labor, materials, and other incurred expenses to obtain the products, because there is limited available information about the proposed technologies in the literature. The percent composition varied according to the product. This fact was accentuated in hamburger production, where the materials represent the bulk of the expenses.

Production costs and profitability indicators

Table 4 presents production costs and gross income for leather, silage, and hamburger production units. Hamburger was more expensive to produce compared to the other products; however, it generated higher income and profit. The total cost for silage production was the lowest.

The silage selling price was considered to be equal to total production cost, therefore, implying a zero return. However, silage production has large advantages that are difficult to be incorporated in a feasibility study. Moreover, the silage can be inserted in the feed production to be used on the farm.

Table 2. Investment to implement production unit (US$1.00 = R$2.17, October 2008).

Investment	Quantity	Price US$	Total value (US$)	Useful life (years)	Salvage value (US$)	%[1]
Hamburger						
Deboner	1	12,425.79	12,425.79	10	2,485.16	26.33
Mixer	1	2,669.24	2,669.24	10	266.92	5.66
Formatter	1	2,296.47	2,296.47	10	459.29	4.87
Freezer	1	7,287.04	7,287.04	10	2,186.11	15.44
Scale	1	423.51	423.51	10	42.35	0.90
General tools	1	46.02	46.02	5	0.00	0.10
Packaging machine	1	911.22	911.22	10	182.24	1.93
Subtotal			26,059.30		5,622.08	55.22
Silage						
Polyprop. container	16	11.51	184.09	10	0.00	0.39
Grinder CAF-22	1	727.14	727.14	15	72.71	1.54
Scale 25 Kg	1	552.26	552.26	10	55.23	1.17
Subtotal			1,463.48		127.94	3.10
Leather						
Warehouse	1	14,036.54	14,036.54	25	4,210.96	29.74
Scale 15 kg	1	423.51	423.51	10	42.35	0.90
Analytical scale	1	1,212.57	1,212.57	10	121.26	2.57
pH meter	1	288.85	288.85	10	0.00	0.61
Tannery	1	2,899.35	2,899.35	10	579.87	6.14
Table	1	174.88	174.88	10	34.98	0.37
General tools	1	36.82	36.82	5	0.00	0.08
Freezer	1	597.82	597.82	10	119.56	1.27
Subtotal			19,670.35		5,108.98	41.68
Total			47,193.13		10,859.00	100.00

[1]Percentage participation of the items in total investment.

Table 3. Annual operational expenses for leather, silage, and hamburger production (US$1.00 = R$2.17, October 2008).

Description	Unit	Quantity	Price per unit(US$)	Total US$/year	%
A. Labor					
Hamburger	hour/men	8	2.10	4,025.35	3.96
Leather	hour/men	8	2.10	4,025.35	3.96
Silage	hour/men	5.3	2.10	2,666.80	2.62
B. Materials					
Hamburger					
Extender	kg/day	50.86	3.50	42,690.67	41.99
Packaging	Unit/day	4	0.01	5,589.11	5.50
Leather					
Salt	kg	1.6	0.13	49.48	0.05
Lime	kg	0.7	0.23	38.66	0.04
Soda	kg	0.4	0.18	17.67	0.02
Detergent	kg	1.6	0.30	114.87	0.11
Basic agent	kg	0.4	1.06	101.62	0.10
Batan	kg	0.2	2.99	143.59	0.14
Kerosene	kg	0.6	2.60	374.43	0.37
Muriatic acid	kg	0.6	0.55	79.53	0.08
Tanning agent	kg	2.8	1.99	1,339.11	1.32
Pellita oil	kg	1	5.29	1,270.19	1.25
Sulfated oil	kg	1	1.61	386.58	0.38
Fungicide	kg	0.04	8.05	77.32	0.08
Waterproofing	kg	0.01	12.56	30.15	0.03
Silage					
Acetic acid	kg	11.69	1.66	4,648.24	4.57
Phosphoric acid	kg	12.67	0.69	2,099.13	2.06
Fungicide	kg	0.38	1.80	163.23	0.16
Anti-oxidant	kg	0.38	1.63	147.82	0.15
C. Others Expenses					
Cleaning material	Unit	10	1.61	3,865.80	3.80
Electrical energy	kW/h	184.52	0.20	9,639.55	9.48
Maintenance				1,344.56	1.32
Telephone	Unit.	1	52.66	631.89	0.62
Distribution expenses	%	3		2,587.78	2.55
Taxes	%	6.61		13,525.35	13.30
TOTAL				101,673.84	100

Table 4. Production costs and income generated by hamburger, silage, and leather production units by year (US$1.00 = R$2.17, October 2008).

	Production units		
Item	Hamburger	Silage	Leather
Variable costs	72,416.32	14,965.16	17,000.07
Labor	4,025.35	2,666.80	4,025.35
Materials	48,279.78	7,058.42	4,023.19
EE + maintenance + tributes	17,252.26	4,945.76	8,618.18
Interest rate over working capital	1,419.93	294.19	333.33
Fixed costs	2,998.77	166.03	1,789.25
Depreciation	2,048.32	111.74	870.28
Interest rate over fixed capital	950.44	54.29	918.97
Total production costs	75,415.08	15,169.57	18,789.32
Production (kg)	61,028.00	90,483.50	10,631.25
Average variable cost (US$/kg)	1.19	0.17	1.60
Average total cost (US$/kg)	1.24	0.17	1.77
Selling price	2.53	0.34	2.80
Gross Income	154,472.82	30,764.39	29,796.26
Net Income	79,057.74	15,594.82	11,006.94
Breakeven point			
Breakeven price (US$/kg)	1.24	0.17	1.77
Breakeven quantity (kg)	29,794.44	44,616.39	6,703.99

The breakeven values found in the economic analysis show that for the hamburger and leather, potential production is well above the breakeven value and price, which gives the producer the leverage necessary to initiate, create, and establish the market for these new products.

Feasibility and sensitivity analysis for the investment

The cash flow for the production units is presented in Table 5. From the cash flow, it is possible to calculate the feasibility indicators presented in Table 6.

The results from the feasibility study show that the proposed solutions for the use of tilapia residue discarded from the processing industry can be considered as an attractive alternative for the producer, because the invested capital can be recovered in less than 2 years (SPB and EPB). The indicators presented in Table 6 also show that the return rate was considerably higher than the interest rate considered of 6% annually. Over a 10-year period, the capital of the business increased by US$570,582.16.

The fact that the products are relatively new and need a well-established market was taken into account with the assumption that commercialization will increase over the first 4 years to stabilize after the 5th year at 80% of production capacity. The results displayed in Table 6 show that the proposed solutions to use discarded by-products is very attractive from the view point of economics alone. In addition to this, there are other benefits more difficult to measure, such as the impact on the environment and the job creation in the area where the plant is established.

The studied scenarios show that this entrepreneurship has little risk. The activity was economically attractive for all studied scenarios: 1, when sale prices considered were based on the average total cost with a profit margin of 20%; 2, prices considered are the ones in the original situation from the 3rd year; and 3, or during the entire period, when a production drop was taken into account.

Table 5. Cash flow for the producing units.

Year	Expenses US$	Income US$	Net cash flow US$	Net cash flow accumulated US$
0	−47,193.13	0.00	−47,193.13	−47,193.13
1	−107,491.10	119,663.19	12,172.09	−35,021.04
2	−107,491.10	129,635.13	22,144.02	−12,877.01
3	−107,491.10	139,607.06	32,115.96	19,238.94
4	−107,491.10	149,578.99	42,087.89	61,326.83
5	−107,491.10	159,550.92	52,059.82	113,386.65
6	−107,491.10	159,550.92	52,059.82	165,446.48
7	−107,491.10	159,550.92	52,059.82	217,506.30
8	−107,491.10	159,550.92	52,059.82	269,566.12
9	−107,491.10	159,550.92	52,059.82	321,625.94
10	−107,491.10	187,340.07	79,848.97	401,474.91

Table 6. Feasibility and sensitivity analysis to implement the studied technologies, considering different scenarios of market.

		Scenarios		
Economic indexes	Original	1*	2*	3*
NPV (US$)	262,590.16	143,182.67	241,607.15	538,445.80
IRR (%)	56.19%	49.98%	47.17%	118.38%
SPB (years)	2.40	1.99	3.09	0.91
EPB (years)	2.59	2.18	3.30	0.96
B/C	1.31	1.17	1.29	1.64

*1: selling price equals to total average production cost plus 20% during the project. *2: in the first 2 years, selling price equals total average production cost and in the following years equals to original assumption. *3: the first 3 years considers lower production (20%) due to implementation of production technologies. NPV: net present value; IRR: internal rate of return; B/C: benefit/cost relationship; SPB: simple pay-back; EPB: economical simple pay-back.

Conclusion

The production of fish hamburger, acid silage, and leather from residues generated during the tilapia filleting process is economically feasible for the 1,000-kg processing plant, considering the production technology shown in this work. Even in higher risk situations, the entrepreneurship was still feasible.

Funding

Funding was provided by Fundação de Amparo à Pesquisa do Estado de São Paulo, grant ID 2007/00224-5.

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