Current and potential alternative food uses of the Argentine anchoita (*Engraulis anchoita*) in Argentina, Uruguay and Brazil

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SUMMARY

A comparative assessment between the use of the Argentine anchoita (*Engraulis anchoita*) for reduction fisheries and human food and/or value-added products is the focus of this case study. General biological aspects, spatial and seasonal distribution and available biomass estimates of the target species are examined. Currently applied and promising potential methods of processing anchoita in Argentina, Brazil and Uruguay are described and compared in terms of economic and nutritional impact.

Engraulis anchoita is a small pelagic fish that occurs in the South West Atlantic Ocean (SWAO) with Brazil, Uruguay and Argentina sharing the so-called anchoita "Bonaerense" stock. Annual abundance estimates vary between 600 000 tonnes and 4.5 million tonnes, with significant regional and yearly variations in biomass estimates along the shelves of the three countries. Fishing takes place predominantly between July and November. Catches in 2006 were reported to be around 30 000 tonnes in Argentina and 17 000 tonnes in Uruguay. It is estimated that up to 135 000 tonnes of anchoita could be sustainably exploited along the southern Brazilian coast. However, despite its abundance, this species is not fished there.

The three countries exhibit different approaches to the utilization of *E. anchoita*. Argentina is the pioneer in the exploitation and manufacture of anchoita and the main manufacturer of different kinds of products for human consumption directed to both the domestic and export markets. More than 80 percent of this production is salted fish and the remainder is prepared as value-added food. In 2005, Argentine exported anchoita-based products at a value of US$26 million. At present, Uruguay processes its anchoita catch exclusively as fishmeal for export, although the preparation of products for human consumption is planned for the near future.

Due to its unexploited fishery resources as well as considerable demand, Brazil has great potential for manufacturing new products that could contribute to both the domestic and export markets. Trial products have been developed that could address food security and poverty alleviation in the region and elsewhere. Alternative potential uses for new products from anchoita were assessed on the basis of prototypes developed in Brazil. It is concluded that novel products such as dehydrated risotto, soup and sausage have considerable strategic marketing value.

An assessment of the costs and benefits of the production of fishmeal and new products for human consumption in Brazil revealed that the transformation of anchoita for human consumption results in significantly higher direct positive impacts on poverty and food security. Governmental social programmes supporting school meals and hospital diets are a promising entry point for the introduction of novel products to nutritionally challenged parts of society. The search for common solutions for improved utilization of anchoita should evolve from a strong technical-scientific interaction and mutual collaboration among the governments of the three countries.

1. THE BIOLOGICAL ASPECTS AND DISTRIBUTION OF ANCHOITA IN THE SOUTH WEST ATLANTIC OCEAN

1.1 Distribution

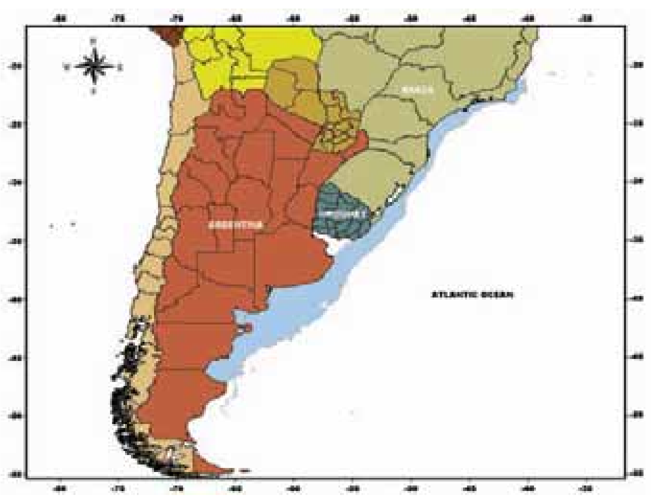
The Argentine anchoita (*Engraulis anchoita*) (Figure 1) is a small pelagic fish that occurs in the South West Atlantic Ocean (SWAO), from around Vitória (20°19' S) in Brazilian waters to San Jorge Gulf (47º S) in Argentine waters (Figure 2) (FAO, 1988). The species is found throughout this region, including in Uruguayan waters, at a depth of between ca. 10 and 200 m and, especially in Uruguay and Argentina, down to the continental slope. Preferred temperature and salinity range from 8 to 23 °C and 14 to 35 ppt. The highest concentrations of anchoita usually occur where sharp gradient sea fronts are recorded (Hansen, Cousseau and Gru, 1984; Hansen and Madirolas, 1996). The thermo-saline preferences may change according to the time of the year, latitude and developmental stage of the species, larvae and juveniles being environmentally more tolerant than adults. Like other engraulids, anchoita forms compact schools in different strata during the diurnal cycle. The individuals disperse at night, forming layers near the surface (Angelescu, 1982; Hansen and Madirolas, 1996; Castello, 1997).

FIGURE 1
Argentine anchoita (*Engraulis anchoita)*

Courtesy of INIDEP, Argentina

Evidence suggests the occurrence of three subpopulations of anchoita (see latitudinal coordinates in Figure 2): (i) Patagonian, between 47° and 41° S; (ii) Bonaerense, between 41° S and southern Brazil; and (iii) a population occurring between the capes of Santa Marta Grande (29° S) and Vitória (20° S), Brazil (Hansen, Cousseau and Gru, 1984).

FIGURE 2
Distribution of anchoita on the shelf waters of the South Western Atlantic Ocean



Source: Modified from Castello (2007)

1.2 Abundance estimates

Abundance has been calculated on several occasions by Brazilian, Uruguayan and Argentine researchers. With one exception abundance was estimated with acoustic methods (Table 1). As expected for a small pelagic fish, there are regional and yearly variations in biomass estimations.

TABLE 1
Acoustic estimates of anchoita abundance for different regions and years in Argentina, Brazil and Uruguay

Country	Region	Year	Abundance (thousand tonnes)
Brazil[a]	32°–34°40´S	2005 (August)	601.2–753.9
Brazil[a]	32°–34°40´S	2005 (September)	597–744
Brazil[b]	27°– 30°S	1997 (May)	468
Uruguay[c]	34°40´– 36°S	1975–1988	231–1720
Argentina*[d]	35°–41°S	1990–2005	800–4 500
Argentina[e]	41°–47°S	2006	600–2 200

*Estimates combined commercial data with acoustic indexes.
Source: [a]Brazilian National Council for Scientific and Technological Development (pers. com., 2007);
[b]Madureira *et al.* (2004, 2005); Castello *et al.* (1991); [c]Nion and Rios (1991);
[d,e]Hansen, Buratti and Garciarena (2006)

In Brazilian waters, the oceanic limit of anchoita distribution is related to the Subtropical Shelf Front (STSF) that divides the cold, low-salinity Subantarctic Platform Waters (SAPW) from the warm, high-salinity Subtropical Shelf Waters (STSW). High anchoita biomass values were restricted to areas under the influence of SAPW. In Uruguay and Argentine waters, anchoita schools occur in shelf waters with coastal and sub-Antarctic waters.

1.3 Age structure

In Argentine and Uruguayan waters, five-year-old anchoitas occur frequently, whereas in Brazilian waters the maximum age is four years. Thus, life expectancy seems to rise according to latitude and lower water temperature. As a multiple spawner, anchoita may have up to three cohorts in a single year, growing at different rates.

1.4 Condition factor, length, weight and sizes

The condition factor (K), calculated as $K = W(g) * 10^5 / Lt\ (mm)^3$, where W = weight and Lt = total length, slightly increases with individual sizes in all populations. The mean value is at its maximum during the months that precede reproduction (spring in Argentine waters and winter-spring in southern Brazil), when gonads reach their largest size (Hansen, 2004). The condition factor is lower in the post-spawning period and in autumn (Castello, 1997). The weight-length relationship shows a latitudinal trend. Length exponentials are higher at southern latitudes and lower at northern positions. The anchoita, being a partial spawner, shows relatively short gonadal resting periods, spawning every 15 days on average (Christiansen and Cousseau, 1985). The size gradient at first maturation ($L_{50\%}$) is 85 mm in southern Brazilian waters, approximately 100 mm in Argentine waters off Buenos Aires and 120 mm for the Patagonian population.

In southern Brazil, the reproductive peak is in winter and spring. Nakatani (1982) identified two spawning peaks in the southeast, one between the end of winter and beginning of spring and another, of higher intensity and in clear association with low-temperature waters of the South Atlantic Central Waters (SACW), between the end of spring and beginning of summer (Matsuura, Spach and Katsuragawa, 1992; Kitahara, 1993; Katsuragawa *et al*., 1993; Matsuura and Kitahara, 1995). In Argentine waters, the reproductive peak occurs in spring.

1.5 Growth and mortality rates

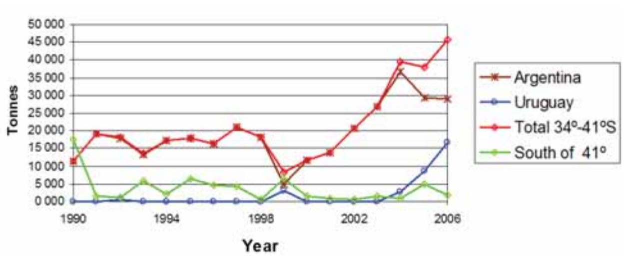
Castello (1997) and Hansen (2004) demonstrated that anchoita reaches larger body sizes in Patagonian waters and tends to be smaller in the warmer waters of southern Brazil. Instantaneous natural mortality rates are high (0.9–1.0), as expected for a small pelagic fish.

1.6 Commercial exploitation in Argentina and Uruguay

Fish captured south of 41°S are landed in Puerto Madryn and those captured north of that region are landed in the ports of Necochea and Mar del Plata (95.5 percent of the total landed anchoita), both in Argentina. Recent data on the commercial exploitation of anchoita were provided by Garciarena and Hansen (2006) in their analysis of anchoita captured between 34° and 41°S and south of 41°S (Figure 3). From 1990 to 2006, a 303 percent increase in anchoita catches was recorded for the Bonaerense population compared to 9 percent for the Patagonian anchoita.

In the Argentine-Uruguayan Common Fishing Zone (ZCPAU), captures took place predominantly between July and September. Eighty-one mid-water trawlers operated around 700 fishing trips in the region. Artisanal coastal vessels (approximately 30) were responsible for a small fraction of the total captures. Capture samples indicated average sizes of 160 mm total length (~ three years of age). In Uruguay, industrial captures are landed in the port of La Paloma.

FIGURE 3
Catches of the Bonaerense population of anchoita by Argentina and Uruguay and captures of Patagonian anchoita (south of 41°S), 1990-2006



Source: Garciarena and Hansen (2006)

1.7 Perspectives on sustainable exploitation and capture in Brazil

Information on anchoita in southern Brazil, including acoustic abundance estimates, seasonal movements and behaviour, environmental preferences, stock, mortality rates and the role of anchoita as forage species in the neritic ecosystem was used to simulate the impact of fishing exploitation using the "Ecopath with Ecosim" model (Christensen and Walters, 2000). The results of this simulation showed that at annual exploitation rates of 0.2 and 0.4 for a five-year period, the original biomass of anchoita would suffer a reduction of 10 and 20 percent, respectively (Velasco and Castello, 2005).

Considering an exploitation rate of 0.10, the impacts of this fishing effort on the ecosystem could be summarized as follows:

- moderately negative impacts for juvenile and adult nectophagous fish, with a 15–20 percent reduction of the current biomass, since anchoita is an important part of their diet;
- 30–35 percent reduction of current biomass of tuna and tuna-like fish;
- approximately 20 percent increase in biomass of juvenile and adult benthophagic fish; and
- 10 percent increase of benthic invertebrate biomass.

The most recent estimates of anchoita biomass in southern Brazilian waters indicate an average of 675 500 tonnes (Brazilian National Council for Scientific and Technological Development, Personal Communication, 2007). This estimation did not fully cover the distribution area of anchoita. A cautious exploitation rate of yield/biomass (Y/B) of 0.2 would represent a theoretical capture of 135 000 tonnes per year, which is a significantly high figure. It is unlikely that an exploitation rate of 0.2 would be achieved in the short term, because anchoita fishing does not occur in southern Brazil.

2. ANCHOITA PROCESSING IN SOUTH AMERICA

2.1 General considerations

Anchoita is a species with high-lipid content with significant variations in concentration according to the time of the year (Bertolotti and Manca, 1986; Yeannes and Casales, 1995). The maximum lipid values are found between January and August and the minimum from August to December, with moisture levels ranging from 66.1 to 76.3 percent, lipids from 4.1 to 15.1 percent, protein from 16.1 to 17.9 percent, and ash from 3.5 to 15.1 percent (Bertolotti and Manca, 1986). One of the parameters of raw material quality for preserved and salt-cured products is the lipid content, which is best at 10–15 percent levels.

The high polyunsaturated fatty acids characteristic of the species, a nutritional factor of excellence, makes it suitable for use in a diverse range of products. The unsaturated fatty acids, a positive feature that characterizes this raw material as very healthy, also implies that this species is highly perishable due to lipid oxidation.

Table 2 shows the chemical composition of anchoita captured in September in different locations and analysed by three laboratories representing the participant countries. Table 3 also shows the proximal chemical composition of the raw material at different times of the year (Yeannes and Casales, 1995).

2.2 Anchoita exploitation and manufacturing in Argentina

Of the three countries assessed, Argentina is the pioneer in the exploitation and manufacture of anchoita and the main manufacturer of products for human consumption. Commercialization started with salted raw material before the First World War, opening new perspectives to fishery exploitation.

TABLE 2
Chemical composition of anchoita captured in September in different locations and analysed by three laboratories in Uruguay, Argentina and Brazil

g/100g	A (Uruguay)	B (Argentina)	C (Brazil)
Moisture	72.20	78.07	77.33
Protein	16.90	17.95	16.36
Lipid	6.90	4.25	3.36
Ash	3.50	1.26	2.62

Source: A: Mattos, Torrejon and Rodriguez (1977); B: Cabrera, Casales and Yeannes (2002); C: Garcia and Queiroz (2007)

TABLE 3
Proximal chemical composition of anchoita in different months

Month	Moisture	Lipid	Protein	Ash
May	69.47	9.43	19.24	2.05
June	71.05	6.79	19.00	3.16
July	77.26	4.13	17.80	1.45
September	75.75	3.93	18.59	1.73
October	76.99	3.55	16.38	3.08
November	79.59	1.68	15.83	1.18

Source: Yeannes and Casales (1995)

Anchoita fishing transformed the port of Mar del Plata, where the largest quantity of this fish is landed, into the processing center (Table 4; INDUPESA, 2006). Anchoita processing plants started proliferating by the 1970s, when the fishery for the European anchovy (Engraulis encrasicolus) declined in Europe. Producer countries, particularly Spain and Portugal, resorted to importing salt-cured anchoita (Bertolotti and Manca, 1986), and Argentina was encouraged to expand the plants (Zugarramurdi and Lupin, 1977).

Anchoita fishing grounds are over the shelf at distances between 10 and 80 km from Mar del Plata. The fleet operates in dedicated fishery from August to November, when minimum lipid contents are recorded (Table 3). Anchoita is easily detected by standard echo sounders because they aggregate in dense schools during the day. Capture is by suction and bycatch is minimal. Anchoita landings in Argentina totaled 37 276 tonnes in 2004 (Table 4).

TABLE 4
Landings of anchoita in the ports of Argentina, 2004

	Landings (tonnes)						
Ports	Bahía Blanca	Mar del Plata	Quequén	Comodoro Rivadavia	Madryn	Rawson	Total
Amount	0.5	35 580	800	6	481	399	37 276
Percentage	<1	96	2	<1	1	1	100

Source: INDUPESA, Mar del Plata

Companies such as INDUPESA in Mar del Plata and Engraulis S.A. Industrialization in Quequén supply a wide range of products, such as anchovy fillets in oil, vacuum-packed anchovy fillets, anchovies in brine, salt-cured anchovies, anchovy fillets marinated in vinegar (or boquerones), whole frozen anchovies and tinned Argentine sardines.

2.3 Anchoita exploitation and manufacturing in Uruguay

According to data collected in La Paloma in 2007, ca. 54 000 tonnes of anchoita were fished in 2001, with main catches of approximately 200 tonnes/day and landings every 48 hours. The entire catch was destined for fishmeal production. This estimate is far below earlier estimates by Mattos, Torrejon and Rodriguez (1977), who reported that in 1977 a projection of the utilization of pelagic species for fishmeal, oil and preserves indicated that 240 000 tonnes/year would be processed in the port of La Paloma, with a minimum of 5 percent destined for human consumption.[1]

The production of fishmeal from anchoita stopped in 2005, and resumed in 2006, with exports mainly to Germany, Italy, Russian Federation and China.

A processing plant for anchoita-based products for human consumption began operations in early 2006. With Spanish investment, this plant will manufacture salt-cured anchoita and marinated fillets. The company will start production based on the results achieved from trials with large volumes of anchoita. The trials were performed to produce salt-cured, "boquerón"-type marinated and block-frozen anchoita. The process was adapted to the climatic conditions of Uruguay to achieve the desired quality and productivity according to the demands of the European market.

Future exploitation and manufacture of this small pelagic fish is likely to focus not on fishmeal production, but rather on products for human consumption. However, fishmeal production using waste from the processing lines is likely to continue.

2.4 Anchoita exploitation and manufacturing in Brazil

Of the three countries assessed, Brazil is the only one where this potential fishing resource is not currently exploited. In 2005, the Conselho Nacional de Ciência e Tecnologia do Brasil (CNPq) financed a project for the assessment and processing of anchoita. The implementation of the project resulted in the production of four anchoita-based prototypes: 1) risotto-type dehydrated product obtained from anchoita protein base; 2) fermented anchoita fillet; 3) soup-type dehydrated product formulated with hydrolyzed protein; and 4) surimi-based emulsified fish sausage. Fishmeal production was also tested.

[1] This projection used data collected during 1975 and 1976 by the National Fisheries Institute (INAPE), assisted by the Food and Agriculture Organization of the United Nations (FAO), as part of a programme of exploitation and assessment of pelagic resources. This report gathered basic information for the projection of a fishery industry based on these resources and the major effort was devoted to anchoita.

In Brazil, the trend is for the development of anchovy-based alternative products that would open new markets and could be directly included in governmental social programmes to fight poverty, similar to the Fome Zero Programme (see www.fomezero.gov.br). School meals, hospital diets, and programmes providing nutritional advice to workers could incorporate the products developed. Research for optimizing a formula to respond to specific demands is necessary, especially regarding processed dehydrated products.

As an example, the risotto-type dehydrated product is characterized as a high-protein, calorific product with low-fat levels. Nutritionally, this product can be compared with foods traditionally consumed, such as eggs, milk and meat. This consideration becomes relevant, because the protein requirement of a 70-kg person is 56 g of protein per day (Sgarbieri, 1987). If an individual had a 30 percent protein-based rice product as the only source of protein, his/her daily protein requirement would be met with 170 g of the anchoita-based risotto, as shown in Table 5. This means that a meal with 170 g of anchoita risotto would meet the daily protein requirements of the consumer.

TABLE 5
Daily amounts of products manufactured with rice and anchoita protein base (APB) necessary to meet the daily protein and caloric requirements of a 70-kg person

APB percentage	Risotto weight (g)	Protein (g)	Kcal
15	341	56	327
30	170	56	351
66	85	56	399

Source: Brazilian National Council for Scientific and Technological Development (2007)

The intake of anchoita-based risotto is thus recommended both as a protein and calorie source. Another relevant factor is the quality of the available protein, which can be verified by the data in Table 6 that compares the essential amino acid contents of rice and fish with the FAO/WHO (1973) reference standard for the daily requirements of a healthy 70-kg male adult. It shows that the lysine content in rice (3.8 g/16 g nitrogen) is much lower than in fish (8.96 g/16 g nitrogen), where the concentration is higher than that recommended by FAO. In this way, the balance of amino acids resulting from the association between rice and anchoita protein base (APB) meets the food security requirements and can contribute to poverty alleviation.

Products like dehydrated risotto, soup and sausage have a strategic marketing value when the world's low intake of fish protein is considered. In Brazil, this factor is even more significant, because the national intake of 8 kg/year is lower than the minimum value of 12 kg/year recommended by FAO (Parmigiani and Torres, 2005). The socio-economic situation of consumers and their eating habits are among the factors that explain this low intake (Trondsen *et al.*, 2003). Therefore, a meat-flavoured convenience product with regional characteristics that associates the energetic value of carbohydrates with fish protein without the fish taste could increase the intake of this

TABLE 6
Estimate of essential amino acids (g/16 g N) for anchoita-based risotto and recommended intake suggested by FAO/WHO (1973)

Amino acids	Rice	Fish	Recommended intake
Isoleucine	4.89	5.12	4.2
Leucine	7.84	7.52	4.8
Lysine	3.80	8.96	4.2
Methionine	3.37	2.88	2.2
Meionine + Cysteine	4.97	4.00	2.8
Phenylalanine	6.02	3.68	2.8
Threonine	4.34	4.48	1.4
Tryptophan	1.21	1.12	2.8

Source: FAO/WHO (1973)

kind of food by the market segment that rarely consumes fish protein. Furthermore, including such products in governmental programmes and hospital diets could raise the possibility of offering a healthy diet to the population.

2.5 Manufactured products using anchoita

2.5.1 Argentina

Argentina is the leading producer of salt-cured anchoita, whole frozen anchoita, tinned anchoita fillets and more recently, marinated anchoita and anchoita paste.

- ***Salt-cured anchoita processing*** – The 1978 Argentine Food Code characterizes salted or brined anchoita as an edible product treated with salt or brine for at least five months (Bertolotti and Manca, 1986). Salt-cured anchoita is currently the main product manufactured using anchoita as raw material in Argentina (Baima Gahn *et al*., 2005). The processing of salt-cured anchoita (Figure 4) follows two steps: 1) salting with an osmotically balanced saturated brine and fish muscle; and 2) maturation, a process that can take from 8 to 12 months (Zugarramundi and Lupin, 1977). Figure 5 illustrates the salt-cured product in a tin.
- ***Anchoita fillets*** – After salting and curing, the anchoita is gutted manually and washed (three steps) to remove excess salt. It is then skinned and the pieces are centrifuged. The final product is presented as fillets packed in glass jars with sunflower or olive oil (Figure 6). The anchoita fillets are produced and as well as packed by the same companies, using their own brands. They are exported to countries such as Spain, Portugal and France that reprocess the fish and to consumer countries, such as the United States of America, Mexico and Brazil (Figure 7).
- ***Whole frozen anchoita*** –The raw material is frozen whole in a convection forced-air tunnel and delivered to the international market using very little labour.
- ***Anchoita processed as "Argentine sardine"*** – The Argentine Food Code Art. 456/1978 registered Argentine sardine as an anchoita (*E. anchoita*)-based product processed as sardine. The processing is similar to the one used with Brazilian sardinella (*Sardinella janeiro*) and follows the Argentine Food Code Art. 478/1978. Anchoita may be packed in sunflower oil, olive oil or tomato sauce. Argentine sardines usually target low-income consumers and almost the entire production is for the internal market.

FIGURE 4
Barrel filled by hand with anchoita displayed in crown shape

FIGURE 5
Salt-cured anchoita displayed in a tin

FIGURE 6
Anchoitas fillets in oil and packed in a glass jar

Source: INDUPESA (2006)

FIGURE 7
Vacuum-packed anchoita fillets

- ***Marinated anchoita products*** – Products are obtained by adding acetic acid and sodium chloride to retard the action of bacteria and enzymes in the fish. Argentina has been using this method to process different kinds of fish, and anchoita has proven to be the most suitable species (Yeannes and Casale, 1995; Yeannes, 2006). Marinated anchoita fillets are traditionally known as "boquerones" (Figure 8).
- ***Anchoita paste*** – Anchoita paste is a product developed by researchers at Mar del Plata National University and CONICET in Mar de Plata, Argentina, in partnership with Empresa Pesqueira Centauro S.A. The goal was the utilization of fillet trimmings. This product is characterized as a spread similar to paté with reduced salt content (Baima Gahan *et al*., 2005). The final product contains 8.6 percent NaCl, with a shelf life of six months at 8°C. Figure 9 shows anchoita paste in jars and in tins.

2.5.2 Uruguay

There are no manufactured products for human consumption produced in Uruguay.

2.5.3 Brazil

Anchoita is not yet processed in Brazil. A prototype-scale production of some alternatives to traditional products manufactured in neighbouring countries was performed in the laboratory, as described below.

- ***Risotto-type dehydrated product obtained from an anchoita protein base*** – This is a prototype of the risotto-type dehydrated product as previously mentioned (Figure 10), with regional character, targeting a new market and advertising anchoita to the consumer. The purpose was to transform anchoita "meat" into a product similar to beef, which could increase fish consumption, particularly in southern Brazil where beef risotto is a traditional local dish. With that in mind, anchoita was used to obtain a fish protein base, generating a high protein, low fat, deodorized product. Once the washing process was defined, meat flavour concentration, seasoning preparation and formula optimization were studied. The best proportion of rice, protein base and seasoning was defined and the final product was tested by the target population of the local state schools, with the aim of including it in school meal programmes.
- ***Fermented anchoita fillets*** – The fermentation process was developed with a *Lactobacillus sakei* starter culture previously reactivated and categorized according to its metabolic characteristics. The conditions that favoured lactic

bacteria growth formed predominantly by *L. sakei* included pH < 4.2, 2 percent NaCl, 4 percent glucose, and operational temperature between 20 and 21 °C. During the 21-day fermentation period, proteolysis depended not only on the nature of the microbiota but also on the processing parameters, with direct influence on the activity of proteases and peptidases involved in the fermentative process. Following fermentation, anchoitas were packed in 130 g glass jars with corn oil (Figure 11).

FIGURE 8
Marinated anchoita

Source: INFOPESCA (2001)

FIGURE 9
Anchoita paste

Source: INFOPESCA (2001)

- ***Fishmeal*** – A fishmeal production test was carried out during the CNPq project (Brazilian National Council for Scientific and Technological Development, 2007). Fishmeal was produced with anchoita captured in Brazilian waters and processed following three steps: cooking (whole fish), cake pressing and drying. The raw material with 74.5 percent moisture, 4.5 percent lipid and 19.5 percent protein produced fishmeal containing 73 percent protein, 9 percent lipid and 11 percent moisture (Figure 12).
- ***Soup-type dehydrated product with anchoita protein*** – Enzymatic hydrolysis of fish protein and drying technique were used to find technologically feasible alternatives for the utilization of anchoita. Adding enzymes to hydrolyzed protein in foods is an important process that can improve the bioavailability of nutrients and the functional and sensory proprieties of proteins without affecting the nutritional value. The purpose of enzymatic hydrolysis is the solubilization of proteins, adding value to the product. The enzymatically modified muscle of anchoita is a protein concentrate with characteristics different from the unmodified protein base, because functional properties such as solubility, water and oil retention capacity, emulsification and foam formation are improved. Sensory proprieties also improved, making it more attractive. The digestibility is significantly increased, resulting in better nutrient absorption by the consumer. A dehydrated soup (Figure 13) was produced with enzymatically modified anchoita muscle using a spouted bed dryer. The soup is practical and nutritionally appealing, because the protein is highly digestible and easily absorbed. The enzymatically modified muscle can be dehydrated with low-cost drying technology in a small-scale production plant and implemented in cooperatives, generating jobs and income.
- ***Surimi-based sausage*** – This product (Figure 14) was characterized as frankfurter sausage. It is different from conventional fish products in that it is

FIGURE 10
Risotto-type dehydrated product obtained from a fish protein base, using anchoita as raw material

Courtesy of Luciano Gomes Fisher

FIGURE 11
Fermented anchoita fillets in corn oil in a jar

produced from surimi of anchoita and not directly from minced anchoita to avoid possible consumer rejection for the flavour and the strong fish smell. The product was presented as a sausage in collagenous casing, with considerable shelf life due to pasteurization and neutral taste (Prentice and Lempek, 2006). Minced anchoita was treated with diluted solutions, washed and centrifuged. Cryoprotectans to protect the myofibrillar protein against the denaturation caused by cold temperatures were added. The surimi obtained was frozen and reserved for the second phase, when it was thawed at room temperature, mechanically chopped and mixed with ingredients (salt, textured soy protein, seasoning, potato starch and artificial coloring). The mixture was then homogenized and taken to a casing machine where it was fed into sausage casings. The filled casings were divided in segments

FIGURE 12
Fishmeal using anchoita as raw material

Courtesy of Kelly de Moraes

FIGURE 13
Soup-type dehydrated product manufactured with anchoita protein

Courtesy of Kelly de Moraes

of uniform size, washed and pasteurized at 90 °C. Finally, the sausage was cooled in cold water, properly packed and reserved for shelf-life analysis. The heating temperature exerted the greatest influence on the gel strength of the sausage. It is a high-protein product (18 percent) with reduced quantity of lipids (4 percent). It successfully passed sensory acceptance tests, conducted with aim of allowing this product to be included in school meal programmes.

FIGURE 14
Sausages processed with anchoita-based surimi

3. ECONOMIC AND SOCIAL ASPECTS OF CURRENT AND POTENTIAL ALTERNATIVE USES OF ANCHOITA IN ARGENTINA, URUGUAY AND BRAZIL

3.1 Costs of alternative uses for human consumption and for reduction

3.1.1 Human consumption

This section describes the comparative cost analysis of three important manufactured anchoita-based products for human consumption in Argentina: salted anchoita, marinated anchoita and anchoita paste (Table 7). Unfortunately, costs were not available for whole frozen anchoita and anchoita in oil.

Marinated anchoita is sold in 170 g jars, anchoita paste is packed in small 90 g jars and salted anchoita is wrapped in individual 1 kg packs. The most expensive item in the production of salted anchoita and anchoita paste is the raw materials, corresponding to 67 percent and 50 percent of the production costs, respectively. Raw materials include anchoita, salt, margarine, oil, seasoning, etc., depending upon the product. Packaging is an important part of the total production cost of marinated anchoita and anchoita paste, accounting for 31 percent of the cost for each product. Around 81 percent of the total production cost of anchoita paste corresponds to raw material (50 percent) and packaging (31 percent). The production cost of marinated anchoita is more equally distributed: raw material, 26 percent; packaging, 31 percent; labour, 22 percent, accounting for 79 percent of the total production cost. Table 8 shows the variable production costs of the products mentioned above.

The variable cost to produce 1 kg of salted anchoita was US$1.44; 52 percent of the cost was raw material. The total cost to produce 170 g of marinated anchoita was

TABLE 7
Structure of production cost of three anchoita-based products, 2001

Cost items	Salted anchoita (%)	Marinated anchoita (%)	Anchoita paste (%)
Raw material	67	26	50
Packaging	8	31	31
Labour	11	22	5
Services and maintenance	2	1	1
Depreciation, insurance and tax	4	2	3
Supervision, laboratory, administration and direction	6	12	3
Sale cost	1	6	7
Total	**99**	**100**	**100**

Source: Avdalov and Pereira (2001)

TABLE 8

Variable costs of three processed products, 2005 (US$/unit)

Cost items	Salted anchoita (1 kg pack)	Marinated anchoita (170 g jar)	Anchoita paste (90 g jar)
Raw material			
Anchoita	0.75	0.08	0.12
Other raw material	0.37	0.12	0.31
Packaging	0.14	0.24	0.26
Labour	0.18	0.16	0.04
Variable cost (US$/unit)	1.44	0.60	0.73
Variable cost (US$/kg)	1.44	3.53	8.11

Source: Avdalov and Pereira (2001), data were corrected to 2005 prices

US$0.60, packaging being the most expensive item (US$0.24). Anchoita accounts for 39 percent of the raw material used in this product, while other raw materials amount to 61 percent. The production of 90 g of anchoita paste costs US$0.73, the costlier items being raw materials other than anchoita and packaging, respectively 42 percent and 33 percent of the total variable costs. Anchoita provides 28 percent of the raw material used in this product, and other materials (seasoning, salt, etc.) provide 72 percent.

The variable costs presented in Table 8 show that anchoita is the most expensive item in the salted anchoita production. Packaging and labour are the costlier items in marinated anchoita production, while both packaging and raw materials other than anchoita amount to nearly 80 percent of the variable costs presented. The variable cost per kilogram is the lowest for salted anchoita.

Of the prototype products developed in Brazil, only the costs of the risotto production were possible to calculate. Costs for the other products are still being evaluated. The fixed and variable production costs of anchoita risotto were calculated based on laboratory experiments, extrapolating to an industrial scale, keeping the respective proportions of each item used. The estimated total cost of production was US$0.67 per pack of 0.175 g.

3.1.2 Reduction fisheries

Neither reduction fisheries nor fishmeal production are well developed in any of the three countries assessed. Anchoita fishing for fishmeal production is forbidden in Argentina (www.cedepesca.org.ar), and Brazil does not have any anchoita processing plants.

Only one plant was identified in Uruguay, processing ca. 54 000 tonnes of anchoita during the nine months of annual capture. The yield obtained was 23 percent, generating 12 420 tonnes of fishmeal. The main importers are Germany, Italy, India, the Russian Federation, Japan, China and Chile. The entire Uruguayan production is exported for use in aquaculture. Consequently, Uruguay does not manufacture any fishmeal by-products or products for human consumption at present.

A structure of the annual costs of fishmeal production based on a FAO study (1986) was prepared in order to discuss the utilization of anchoita in reduction fisheries to produce fishmeal (Table 9). The calculation was based on a plant with capacity to process 150 tonnes of fishmeal per day using two-thirds of its productive capacity. The price of raw material (anchoita) refers to the ex-vessel price of US$60 per tonne.

Given a fishmeal yield of 23 percent, the final cost per tonne is US$483.45. Assuming a fishmeal market FOB price of US$800 (using the anchoveta fishmeal FOB price in Peru), the profitability is US$316.6 or 39.6 percent.

TABLE 9

Structure of daily production costs of fishmeal

Production costs	%	US$
Fixed plant costs	29	3 225
Variable costs		
Raw material	54	6 000
Other variable costs	17	1 895
Total production costs per day	**100**	**11 120**

Source: FAO (1986)

3.2 Potential alternative anchoita uses and their impact on food security and poverty

The potential anchoita annual biomass exploitation in Brazil is estimated at around 135 000 tonnes (see Section 1.7)[2]. At present, Brazil imports around 60 000 tonnes of sardines to supply the domestic market. Based on this figure, some projections for potential alternative uses of anchoita are presented, specifically for risotto and soup, as well as fishmeal. The projections are important for future investments into such products as a basis for food security and poverty reduction in Argentina, Brazil and Uruguay.

The minimum daily protein requirement for a person is 1.25 g protein/kg/day (Sgarbieri, 1987). Thus, the minimum protein intake required by a Brazilian school-aged child[3] waghing 45 kg on average would be ca. 56 g/day or 20.5 kg/year. Every 100 g of anchoita risotto contains 30 g of anchoita protein base, consequently a school-aged child would need to eat ca. 187 g/day of risotto to meet his/her protein requirements, or ca. 68 kg of risotto in a year. This corresponds to ca. 126 kg/year of anchoita, as each kilogram of processed anchoita generates 0.540 kg of risotto (Brazilian National Council for Scientific and Technological Development, Personal Communication, 2007). In this scenario, the anchoita risotto would provide 100 percent of the protein requirements of a school-aged child.

Considering the dehydrated product, 171 kg/year of dehydrated anchoita soup would provide the minimum protein intake of a student. This corresponds to an annual processing of 401 kg of anchoita, because each kilogram of processed anchoita generates 426.5 g of dehydrated soup.

Given a modest capture of 5 000 tonnes of anchoita, the production of risotto and soup could provide the minimum protein requirements of 39 451 or 12 469 school children, respectively, for a year. Based on the same 5 000 tonnes of anchoita, a production of 1 150 tonnes of fishmeal can be obtained (assuming a yield of 23 percent as mentioned by Tacon, Hasan and Subasinghe, 2006).

Nile tilapia (*Oreochromis niloticus*), an intensely farmed species in Brazil with a guaranteed international market, was used in an impact simulation on job generation as a result of the use of anchoita-based feed. Given a 1.56:1 food conversion ratio (FCR) of tilapia feed at US$1.21/kg to the producer, the production cost represents ca. 85 percent of the sale price (Estado de São Paulo, 2007). With the Brazilian monthly minimum wage of US$197.43 (DIEESE, 2007), the production of ca. 737 tonnes of tilapia using 1 150 tonnes of fishmeal feed could generate around 680 monthly minimum wages. These wages would pay around 57 people per year. Considering that each person provides for a family of four, around 228 people would be supported by the production of tilapia fed with 1 150 tonnes of fishmeal produced from 5 000 tonnes of anchoita.

A second analysis considers the farming of carnivorous fish of higher market value, such as Brazilian flounder (*Paralichthys brasiliensis*) priced at US$4.85/kg. As the FCR

[2] It should be noted, however, that to achieve this level of exploitation would require addressing the current lack of infrastructure and tradition of anchoita fishing in Brazil.

[3] School children between 7 and 14 years of age, according to INEP/ME (www.inep.gov.br).

for sole is 2:1, using the same production cost references (85 percent of the sale price) and the minimum wage, approximately 2 121 monthly wages could be generated by the production of 575 tonnes of sole fed with anchoita-based feed. This represents ca. 177 jobs a year supported by sole production and 708 people supported by the production of fishmeal.

As previously mentioned, the scenario with 60 000 tonnes of effective capture in Brazil would allow a wide production margin that could have an effect on food security through school-meal policies. The initial 60 000 tonnes of anchoita per year could supply the protein requirements of 473 412 students. Likewise, the production of tilapia using 60 000 tonnes of anchoita feed would generate 684 jobs a year, supporting 2 736 people. The aquaculture of high-value fish could generate 2 124 jobs, supporting 8 496 people.

Profitability results for risotto and fishmeal were estimated based on yield, costs and revenue information. These products are relevant due to the nutritional capacity of risotto and the global demand for fishmeal for use in aquaculture.

A biomass of 1 tonne of anchoita can generate a profit of US$316.6 or 39.6 percent of the market price (US$800), assuming fishmeal is the target product. In contrast, the same fish biomass would generate 540 kg of risotto at a cost of US$2 067. Considering the final market price of a similar product such as beef risotto sold at US$2 per 0.175 kg in Brazil, a revenue of US$6 171 is estimated if risotto were the target product. This would generate a profitability of 66.5 percent. The same anchoita biomass could provide the protein requirements of 4 881 people with an average weight of 70 kg, if risotto were produced. If used for aquaculture, such biomass would be reduced to 230 kg of fishmeal, which would generate 115 kg of flatfish or 147 kg of tilapia.

The results indicate that the production of protein-rich foods for human consumption would have a significant direct impact on food security and, consequently, on poverty reduction. The revenue generated from anchoita processed as a risotto ingredient is twenty-fold the revenue generated from fishmeal production! Similarly, the absolute numbers of people that could be supplied with the minimum daily protein requirements (based on the consumption of risotto and/or anchoita soup) projected by this report is significant. The production of fishmeal indicates indirect impacts on food security and poverty reduction, and direct social effects through the generation of jobs and income, boosted by the performance of the aquaculture sector.

Pauly (2006) states that we should think of small pelagic fish not as forage fish in the first place, but as a way to augment the current fish supply. This case study has shown that converting raw fish into a risotto-type dehydrated product obtained from anchoita protein base and/or a soup-type dehydrated product formulated with hydrolyzed protein would have much greater impact on food security than reducing the same amount of fish into fishmeal for aquaculture. Further arguments in favour of these products are that they do not need cold storage and hence can be safely and cheaply transported to distant places, reaching the rural poor.

Incentives for the production of anchoita-based products can be provided through relevant public policies, generating significant social benefits. Therefore, besides the sustainable exploitation of fishery resources, the alternative manufacture of anchoita-based products shows positive results for future investment in these products as a basis for food security and poverty reduction in Argentina, Brazil and Uruguay. Importantly, the search for common solutions for the utilization of anchoita should evolve from a strong technical-scientific interaction and mutual collaboration among the governments of the three countries.

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