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Identification of raw materials that can be used in fish farming in feed manufacturing industries in Senegal

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Abstract
This study is part of a process aimed at enhancing the value of local raw materials used in animal feed manufacturing companies in Senegal and likely to be used in fish feed in aquaculture. The study was carried out in four (4) geographical areas of Senegal (North, South, Centre-West, East), specifically among thirteen (13) active companies. The results of the survey show that 100% of the companies source certain raw materials on the local market. However, the percentage of imported raw materials represents 30.8% of the inputs used in the food manufacturing process. Sixty-one point five percent (61.5%) of companies obtain their raw materials at less than 500 FCFA/kg. The purchase prices of these food inputs and the food production of the companies vary respectively on average between 501 and 750 FCFA/kg, and between 40 and 50 tonnes/year. This food production is intended for livestock, poultry and farmed fish.

Keywords: Food, raw materials, enterprises, feed, fish farming

1. Introduction
In Senegal, agriculture is a key driver of the country's socio-economic development. It will contribute 15% of GDP by 2022, and the majority of the Senegalese population depends on it to meet their social needs [1]. At the start of the twenty-first century, given its strategic importance for food security, agriculture remains an inescapable challenge, despite technological innovations in the agronomic sciences. These include all agricultural activities and practices relating to plant cultivation and production, animal husbandry, as well as capture fisheries and aquaculture [1]. Fish products are an important source of protein and essential micronutrients for optimal growth of individuals and farm animals. Animal protein deficiencies in the human diet are the most widespread in the world [2]. Aquatic food sources are highly diversified and provide the community with quality food. They represent sustainable solutions in the current climate of uncertainty [2]. Human consumption of fish worldwide rose from 9.0 kg/person in 1961 to 20.2 kg/person in 2015 [3]. Aquaculture accounts for over 53% of global fish production most of which is destined for human consumption [3]. Annual fish consumption in Senegal averages 29 kg per capita, and the sector contributes 3.2% of GDP and 12% of value added in the primary sector [4]. In Senegal's economic and social development policy reference document, the Emerging Senegal Plan (ESP), aquaculture is one of 27 flagship projects driving growth and development. It could help to improve the standard of living of the population, particularly in rural areas. It would also provide an alternative to capture fisheries, which are currently struggling to meet national fish requirements due to the over-exploitation of fish products.
However, the results of scientific research on certain fish species have made aquaculture a priority for international decision-makers, in a context of preserving the natural environment and increasing the need for animal protein [5]. In African countries, and Senegal in particular, *Oreochromis niloticus*, *Clarias gariepinus* and many other aquatic species have been the subject of several experimental trials. Their adaptability, rapid production in controlled environments and resistance to disease are just some of the factors that make these fish species of interest in aquaculture.

O. niloticus is planktivorous and omnivorous in artificial omnivorous in artificial environments and is less demanding in terms of nutritional requirements [6]. *C. gariepinus*, on the other hand, is a benthivore with carnivorous tendencies and has higher protein requirements for optimum growth in fish farming [7].

However, in the face of a demographic boom and a drastic reduction in fish stocks, the development of Senegalese aquaculture has not yet progressed beyond the embryonic stage [8]. Added to this is the problem of the lack of high-performance feed available on the local market at low cost. The dietary requirements of the species being tested mean that the feed factor is a challenge to which major measures could be taken to boost aquaculture production [8]. Fish farmers tend to buy imported feed at exorbitant prices, which prevents them from achieving the expected economic profitability. Consequently, the development of the agri-food processing sector would be a real advantage in terms of boosting productivity and business competitiveness and alleviating the constraints associated with fish feed. Furthermore, Senegal's agricultural potential offers a diversity of by-products that can be used as food for humans, but also for farmed fish. In fact, they are the main raw materials used in the manufacture of feed for terrestrial and aquatic animals. Agricultural and agri-food by-products include bran and meal (maize, wheat, cotton, millet, cowpea, etc.), groundnut cake, soya and fish meal [9]. These are crucial in fish farming, as they are rich in energy and protein components, which are responsible for the growth rate and resistance of fish. Apart from their nutritional value, which is essential for optimum fish growth, availability and accessibility make these inputs a priority choice for Senegalese manufacturers.

The main objective of the study is to identify locally available and low-cost raw materials that can be used in food manufacturing companies in Senegal.

1.1 Specifically, the aim will be to:

- Identify the raw materials used in companies, their availability and origin.
- Analyse the companies' annual raw material requirements.
- Analyse the costs and accessibility of these raw materials in Senegal.
- Carry out a bromatological analysis of the most commonly used raw materials.

2. Methodology

In this study, the inventory of local raw materials likely to be used in aquaculture feed was carried out following surveys of Senegalese feed manufacturing companies. These companies are spread from north to south, from east to west, including the central-west of the country. The agronomic sciences, aquaculture and food technologies (S2ATA) training and research unit (UFR) issued mission orders and requests for access to these companies. Interviews on raw materials were therefore scheduled. The interviews were conducted using a questionnaire previously drawn up in the Sphinx software, in which all the necessary questions were listed. These companies were selected on the basis of their functionality and use of local raw materials at the time of the surveys. The questionnaire was administered on site to resource persons (Director, Technician, Store Manager, Manager, etc.) from the food manufacturing units. Exceptionally, for reasons of accessibility and availability of certain managers, questionnaires were administered by telephone interviews or by electronic mailings to the companies' professional accounts. Following these interviews, a bromatological analysis was carried out at the Ecole Supérieure Polytechnique (ESP) in Dakar to determine the nutritional quality of foodstuffs that could be used in aquaculture.

3. Results

The results of the data collected in these five geographical areas of Senegal show a diverse range of agricultural and agri-food by-products. These raw materials can be used in the manufacture of feed for terrestrial and aquatic animals. Local cereals and animal meal are essential in the manufacture of feed in all the companies surveyed.

3.1 Legal status of feed manufacturing companies in Senegal: In Senegal, agri-food businesses are governed by a variety of legal statutes. In fact, out of a total of 13 functional enterprises, 30.8% are public limited companies (S.A), 23.1% are economic interest groups (G.I.E) and are followed by public structures, sports and cultural associations (ASC) and finally, limited liability companies (SARL), each of which occupies 15.4% of the total percentage of enterprises surveyed (Figure 1).

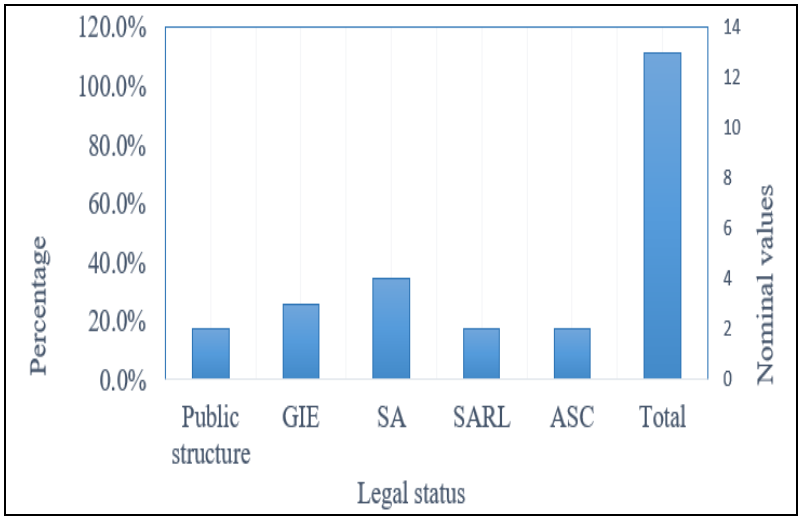

Fig 1: Legal status of food manufacturing companies in Senegal

3.2 Inventory and availability of raw materials in companies in Senegal

Figure 2 shows that the results of surveys carried out in feed manufacturing companies provide a significant illustration of agricultural and animal by-products in feed formulation. They constitute a wide range of raw materials (Table 1) that can be used in feed because of their high nutritional value and their organoleptic characteristics, which are appreciated by livestock. These by-products come from cereals produced locally, but also imported to a lesser extent. The majority of the companies surveyed use raw materials produced at national level (local market). However, four companies, or 30.8% of those surveyed, use both raw materials from the local market and those produced internationally. In terms of the extent to which raw materials are used in the companies visited, groundnut cake is at the top of the list, accounting for 84.5% of cases surveyed, followed by rice bran and fish meal for 69.2% of companies surveyed. Maize (61.5%), vitamins and trace elements (46.2%), wheat bran, fish oil (38.5%) and millet bran (30.8%) also occupy a strategic position in the hierarchy of use of these food inputs. However, palm fronds, shrimp meal and others are the least represented in terms of percentage of use, with 7.7% of cases processed.

There is also a wide disparity in the availability of raw materials used in the manufacture of feed in Senegal. Figure 2 below also shows that palm leaves and other raw materials are fully available for all the companies surveyed. They are followed by wheat bran, which is available in 60% of cases, and wheat flour, molasses and peanut hulls, each of which is available in 50% of cases. However, there are "off-peak" periods during which the availability of raw materials is a major constraint. The results of the survey show that these periods include the months of June, July, August and September, when raw materials are scarce throughout the country. This scarcity leads to an increase in the price of these inputs, which in turn increases the production costs of the manufactured feeds. The high nutritional content of these commodities cannot be replaced in terrestrial and aquatic animal feed.

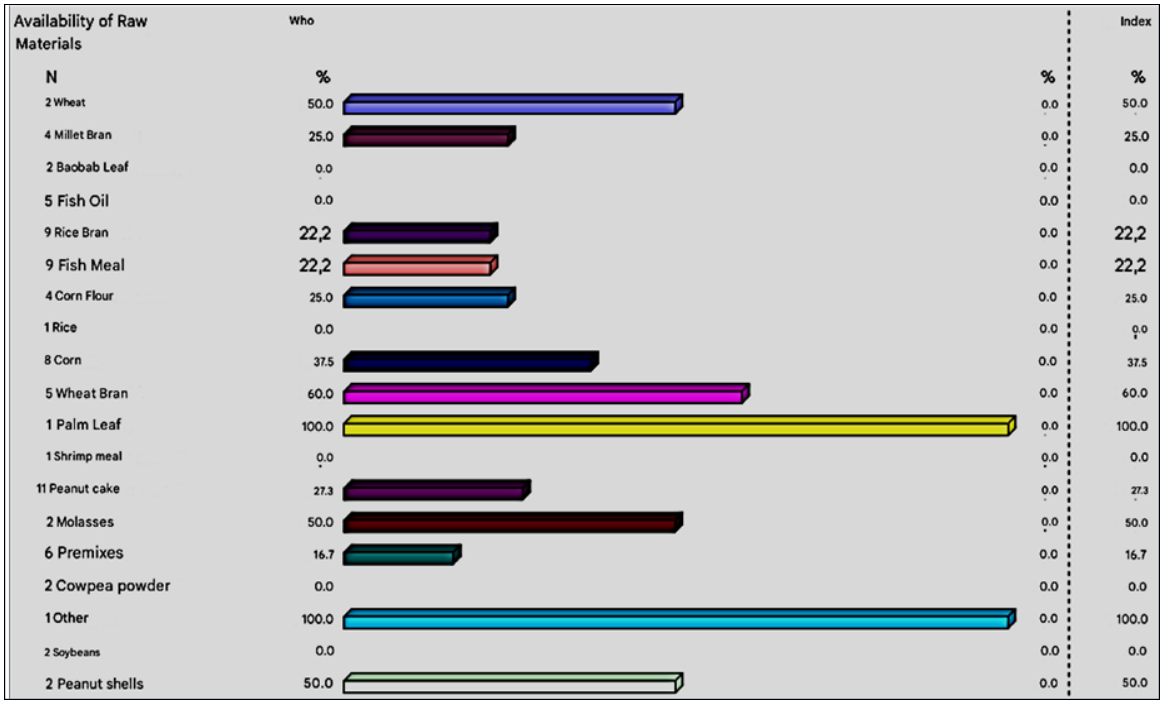

Fig 2: Availability of raw materials in feed manufacturing companies

Table 1: Inventory of raw materials available in Senegal

Raw Materials	Number of Companies	Observation (%)
Wheat Flour	3	23.1%
Millet Bran	4	30.8%
Baobab Leaf	2	15.4%
Fish Oil	5	38.5%
Rice Bran	8	61.5%
Fish Meal	9	69.2%
Corn Flour	4	30.8%
Rice Flour	1	7.7%
Corn Bran	5	61.5%
Wheat Bran	3	38.5%
Palm Leaf	1	7.7%
Shrimp Meal	1	7.7%
Peanut Cake	11	84.6%
Molasses	2	15.4%
Premixes	6	46.2%
Cowpea Flour	2	15.4%
Others	1	7.7%
Peanut Shell	2	15.4%
Total	13	100%

3.3 Location and analysis of companies' annual raw material requirements

Most of the raw materials used by Senegalese food manufacturers are produced locally. Figure 3 shows that 100% of the businesses surveyed obtain their raw materials locally. However, in addition to the local market, 30.8% of the companies surveyed also source their raw materials from the international market. In addition, only one of the 13 companies surveyed manufactures its own production inputs for the feed formulation process in Senegal.

However, half of the companies visited use between 5 and 10 tonnes of raw materials, and some of them (41.7%) use less than one tonne of raw materials per year. Only one company procures between 10 and 15 tonnes of these food inputs. On the other hand, the quantities of raw materials used in these companies are different from the actual production capacity per year. The survey results show that, on average, food input requirements vary between 10 and 20 tonnes per year. Some companies, 36.4% of those surveyed, also needed less than one tonne to reach their maximum production. For others, however, a tonnage of one to 10 tonnes of by-products could enable them to reach their overall production level. The diversity of the production capacities of these feed manufacturing companies showed a disparity in annual raw material requirements. For example, the annual raw material requirements of only three companies exceeded 50 tonnes per year.

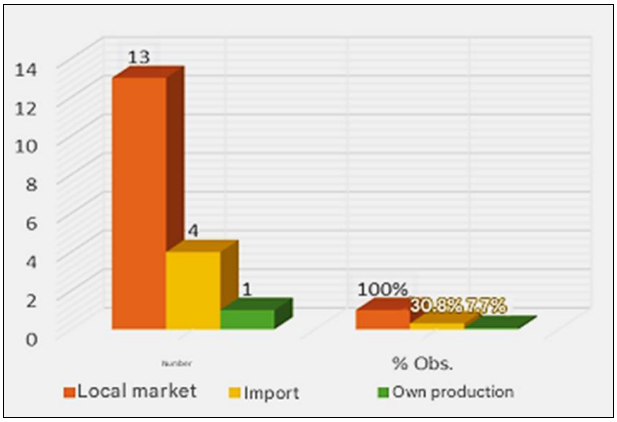

Fig 3: Origin of raw materials used by food manufacturers

Table 2: Raw material requirements of food manufacturers

Quantity supplied in raw materials		
Average = 1.91 '1 and 10 tonnes/year'		
Quantity	**Nb**	**% Cit.**
Less than 1 tonne/year	4	36.4
1 and 10 tonnes/year	4	36.4
More than 50 tonnes/year	3	27.3
Total	11	100

3.4 The cost and accessibility of raw materials

The results obtained on the cost and accessibility of raw materials give an overall idea of price trends over an annual period. Eight of the 13 companies surveyed buy their raw materials at less than 500 FCFA/Kg, while the remaining five obtain foodstuffs at between 501 and 1000 FCFA/Kg (Table 4). Regardless of the time of year, 76.9% of the companies surveyed consider the raw materials used in feed formulation to be very accessible (Table 5). However, these results also confirm a variation in feed input prices for 84.6% of the total number of businesses surveyed (Table 6).

On average, 2.64% of the businesses visited stated that price variations reached minimum and maximum values of 501 and 750 FCFA/Kg respectively during the year (Table 3), taking into account the welding and harvest periods.

Table 3: Purchase price of raw materials

Raw material purchase price		
Average = 1.38 'Less than 500 FCFA/KG'		
Price	**Nb**	**% Cit.**
Less than 500/KG	8	61.5
501 and 1000/Kg	5	38.5
Total	13	100%

Table 4: Minimum and maximum raw material prices

Minimum and maximum prices		
Average = 2.50 '750 and 1000 FCFA/Kg'		
Price ranges	**Nb**	**% Cit.**
501 and 500 FCFA/Kg	5	50
751 and 1000 FCFA/Kg	5	50
Total	10	100%

Table 5: Accessibility of raw materials

Accessibility		
Average = 1.23 'Very accessible'		
	Nb	**% Cit.**
Very accessible	10	76.9
Not very accessible	3	23.1
Total	13	100%

Table 6: Variation in raw material prices

Price variation		
	Nb	**% Cit.**
Yes	11	84.6
No	2	15.4
Total	13	100%

3.5 Determining the nutritional importance of raw materials

The results of analyses carried out on the raw materials (Table 7) most commonly used in Senegalese food manufacturing companies show that the nutritional character of these foodstuffs differs from one another. Fishmeal tops the list with a protein content of 51.52%, followed by groundnut cake, which has a protein content of 25.54%. Rice bran and maize flour contained the lowest protein percentages, with values of 7.18 and 8.78 respectively.

3.6 Analysis of the production of feed manufacturing companies in Senegal

In Senegal, there is a fairly large number of companies manufacturing feed for both terrestrial and aquatic animals. Surveys of 13 of these companies, spread over four areas of the country, show that two companies specialize in the production of poultry feed (15.4%) and five others manufacture livestock feed (38.5%). However, the number of companies manufacturing fish feed is 10, or 76.9%. Some companies manufacture feed for farmed fish, but also for other land animals (livestock and/or poultry).

Their production capacity averages between 40 and 50 tonnes/year, corresponding to 76.9% of the companies surveyed. One company produces between 1 and 10 tonnes per year, while 10 other companies produce more than 50 tonnes per year. The protein content of the feed formulated in these companies varies between 20 and 30%, or 76.9% of

the cases surveyed. Figures 8 and 9 show, respectively, a correlation between the type of feed and production capacity, but also the type of feed in relation to the protein content obtained after manufacture of the feed in agri-food businesses in Senegal.

Table 7: Composition of raw materials by bromatological analysis

Samples	Protein (%)	Fat (%)	Dry Matter (%)	Mineral Matter (%)	Organic Matter (%)
Corn Flour	8.78	3.88	90.05 / 89.5	1.45 / 1.60	88.6 / 87.9
Fish Meal	51.62	2.04	93.5 / 93.6	18.15 / 27.65	65.35 / 65.95
Peanut Cake	25.54	8.15	95.5 / 95.65	8.60 / 8.35	86.9 / 87.3
Millet Bran	14.36	5.70	93.2 / 97.5	17.2 / 16.80	76.00 / 76.9
Rice Bran	7.18	5.35	94.55 / 94.10	12.00 / 12.20	82.55 / 81.9
Wheat Bran	15.16	4.15	89.4 / 88.7	5.00 / 5.65	83.85 / 83.05
Cowpea Flour	22.34	4.75	93.5 / 92.8	3.55 / 3.85	89.95 / 89.15
Cottonseed Cake	22.34	3.55	93.25 / 94.35	5.00 / 5.10	88.25 / 89.25

4. Discussion

Analysis of the data collected from Senegalese feed manufacturing companies shows a diversity of raw materials that can be used in fish feed. Thus, the results relating to the availability, location and bromatological analyses of these inputs indicate their quantitative and qualitative importance for fish. It emerges that the 13 companies surveyed make extensive use of raw materials from the local market, and that 76.9% of them consider these feed inputs to be very accessible. The results of the study confirm those of Mendez and Bauer [10] and of Presoa [11], which state that the availability and accessibility of agri-food by-products in rural areas could be the reason for their use in food production. The increased availability of these raw materials is generally accompanied by a variability of ingredients that can be used in the manufacturing processes of feed for livestock, poultry and farmed fish. Indeed, this would not constitute real competition, but rather complementarity, insofar as the dietary needs and requirements of the species differ from one another [12]. Despite Senegal's countless potential as a producer of raw materials, there are still challenges to be overcome in terms of availability, location and nutritional qualities, in order to ensure sustainable and competitive animal feed. The results of the study show that increasing the value of raw materials, combined with better organisation of the players involved, could guarantee food safety for terrestrial and aquatic animals. These results would also contribute to the resilience of agricultural sectors in the face of climatic and international market hazards. However, there is a need to harmonise food manufacturing by establishing an appropriate regulatory framework to support the growth of the primary and secondary sectors for quality food production that meets international standards [12]. In other words, the choices made by fish farmers are based on quantity and quality, feed prices and their income from production [13].

In the same vein, this study also shows that the feed production (between 40 and 50 tonnes/year) of most of the companies illustrates the public's interest in developing this sector. The results of the analyses show that fishmeal is the component par excellence of feed for fish farming, as it has a remarkable protein value. Peanut meal, cottonseed meal, maize meal and cowpea meal could be used to produce a combination of feeds containing an optimum protein level for the normal growth of *C. gariepinus* and *O. niloticus*, the main species farmed in Africa and Senegal in particular. In the past, studies on fish farming feeds have also shown that diets based on local by-products have produced acceptable growth results and improved fish flesh quality [14]. In view of the research results on the availability and nutritional importance of raw materials that can be used in the feed manufacturing process, the feed problem could be solved in Africa, and particularly in Senegal.

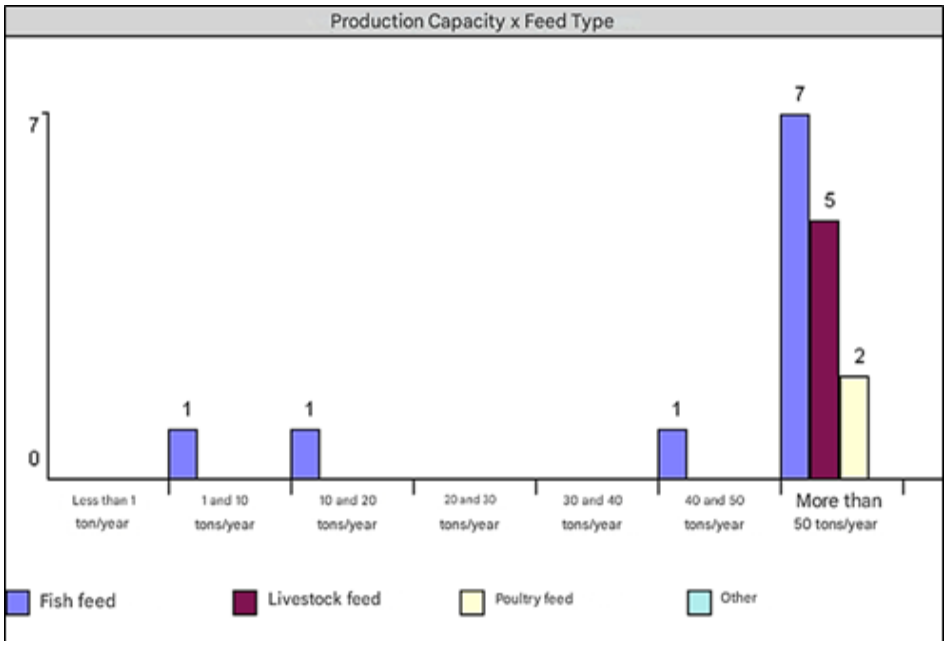

Fig 8: Correlation between feed type and production capacity

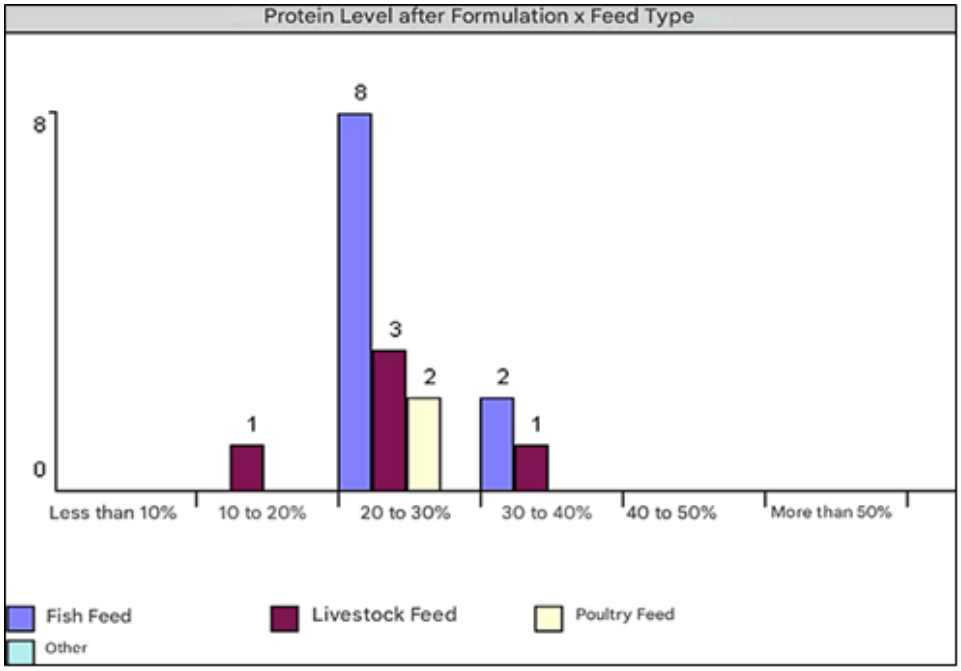

Fig 9: Correlation between type of feed and protein content after manufacture

5. Conclusion

The main objective of this research work was to identify available, low-cost local raw materials that could be used in fish farm feeds from feed manufacturing companies in Senegal. At the end of the study, the raw materials were identified on the basis of their availability and accessibility, as well as the variation in their purchase prices throughout the seasons. The results show that 76.9% of the raw materials used in Senegalese feed manufacturing companies are locally produced agricultural and agri-food by-products. Especially as fish feed is a combination of raw materials with important nutritional qualities, the results of analyses of the raw materials used in these companies are convincing. In fact, these inputs could constitute partial alternatives to fish meal in the feed formulation process. In addition, this study prompts us to make recommendations to private and state actors who are in charge of development projects and programmes:

- Invest in the primary and secondary sectors in order to boost agricultural production and make the most of local raw materials, but also to limit dependence on food imports.
- Facilitate financing for local producers, strengthen technical supervision and the marketing circuit for harvested produce, as well as accessibility to production equipment.
- Improve storage infrastructures to limit post-harvest losses.

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