Production of Fish Feed from Soy Residue and Shrimp Waste using Tapioca as Binding Agent

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Abstract. The most used fish feed in cultivation activities is commercial feed that spends most of total cultivation cost. One of the effort to solve this problem is providing homemade fish feed. The pellet based on local waste raw materials can reduce dependency of commercial fish feed. One of the local wastes that can be used is soy residue and shrimp waste. Tapioca is used as a binding agent for fish pellet. The aim of the research was to study the effect of raw material composition and binding agent concentration on proximate value, performance and mechanical strength. The research was conducted in several steps such as raw materials pretreatment, the experiment of raw materials and binding agent formulation, mixing, extrusion, prilling process, drying process, and product analysis (proximate and performance analysis). There are five formulations of raw materials and three different of formulation on binding agents. The drying process was done in 50°C and the product was then analyzed. The result shows that formulation with 30% soy residue, 60% shrimp waste and 10% binding agent resulted in a product with good proximate value (11.23% moisture content, 17.64% ash, 1.33% fat, 25.10% fiber, 29.54% protein). Increasing the percentage of binding agents resulted in higher mechanical strength and higher performance.

Keywords: binding agent; fish feed; soy residue; shrimp waste.

1. Introduction

The cultivation of fish is affected by the fish feed [1]. The total cost for commercial fish feed around 60-70% from total cultivation cost. Producing the homemade fish feed can be option to overcome the problem of higher commercial fish feed cost [2, 3, 4, 5]. The raw materials of homemade fish feed production must be high quality, cheap price and does not compete with human foods needs [6, 7]. Several researcher using potato starch and wheat [8, 9]. Fish feed production from foodstuff is not proper because of compete with human foods needs. Production of fish feed from food waste can be the solution for cheap and easy to get raw materials. Several researcher using foodwaste as the raw materials: tofu waste [10], fish waste [11], food industry waste and soy sauce waste [12] and combination of soy and shrimp waste [13].
Combination of soy residue and shrimp waste can be option since the protein value up to 43.05%. The protein content of soy residue is lower than that combination [13]. Increasing the composition of shrimp waste makes easier to sinking [14]. To increase the stability, the fish feed combination must be added by binding agent. There are two types of binding agents, natural and synthetic. The natural binding agents such as tapioca starch, molasses, and seaweed. Meanwhile, the synthetic binding agents such as CMC (Carboxy Methyl Cellulose) [15]. The natural binding agents is more affordable price than synthetic, easy to get and biodegradable [16, 17]. The tapioca start can be used as the natural binding agents in fish feed production [18]. Based on the literature study, there is not research about the effect of combination of soy residue and shrimp waste) using tapioca starch as the binding agents. The effect of the combination on proximate value and performance.

2. Materials and Methods

2.1. Materials
Soy residue and shrimp waste as the raw materials were obtained from tofu industry and fish auction in Semarang, Indonesia. Tapioca flour was from Rose brand, Indonesia and used as the binding agent. K2SO4, HgO, H2SO4, NaOH, Na2S2O3, H3BO3, and HCl were used for proximate analysis purchased from Sigma, Germany and used for analysis.

2.2. Methods
This research was conducted in several steps that involved raw materials pretreatment (drying and size reduction), experiment of raw materials and binding agent formulation, mixing, extrusion, prilling process, drying process, and product analysis (proximate, mechanical strength and physical analysis). The raw materials and binding agent formulation was used to produce the product with the good proximate value, mechanical strength and physical characteristic.

Materials preparation. Soy residue was dried in environmental condition, ground and sieved. Shrimp waste was fermented as the previous study [19], drying, ground and sieved. The raw materials was 0.177 mm in size. The tapioca flour as the binding agent was gelatinized by adding the hot water (90˚C). The raw materials and binding agent were then analyzed by proximate to evaluate initial value of nutrition (Table 1).

| Composition | Tapioca starch (%) | Soy residue (%) | Shrimp waste (%) |
|-------------|--------------------|----------------|-----------------|
| Moisture    | 15.57              | 13.77          | 8.86            |
| Protein     | 0.54               | 19.19          | 32.26           |
| Lipid       | 0.15               | 3.64           | 0.79            |
| Ash         | 0.8                | 4.73           | 38.34           |
| Fiber       | 2.74               | 16.51          | 12.2            |

Formulation of raw material and binding agent. The material formulations can be seen in the Table 2. All of the material was mix with domestic mixing equipment. Water was added to form the uniform material. As the comparison, the tapioca flour concentration was variated, range from 0 until 10%. Then the effect of raw material formulation and binding agent was analyzed.
Table 2. Formulation of materials

| Run | Tapioca flour (%) | Soy residue (%) | Shrimp waste (%) |
|-----|------------------|----------------|-----------------|
| 1   | 10 %             | 45 %           | 45 %            |
| 2   | 10 %             | 0 %            | 90 %            |
| 3   | 10 %             | 30 %           | 60 %            |
| 4   | 10 %             | 60 %           | 30 %            |
| 5   | 10 %             | 90 %           | 0 %             |

Fish pellet production. The production of fish pellet was performed in a laboratory scale extrusion machine (Figure 1). Amount 100 gram of mixed materials (Table 2) is entered into hopper of the extrusion machine and fell down into pelletizing chamber by gravitational force. The motor is used to rotate the screw in chamber. The force on the screw pushed the feed in to the die and impacts the feed into solid. The blade cut of the pellet and causes the pellet uniform size and shape. The cylindrical fish pellet was then dried using oven to produce the dry feed, the moisture content less than 10% moisture [20]. The drying process was conducted at drying temperature 50˚C until the constant weight.

![Figure 1. Schematic of laboratory extrusion machine: (1) hopper, (2) handle/motor, (3) screw/auger, (4) die](image)

Proximate analysis. The material and fish pellet formulation were analyzed using standard procedures for proximate analysis [21]. The moisture was determined by drying the samples at drying temperatures 105˚C until the constant weight. The ash content was obtained by burning the sample organic compound in muffle furnace (temperature 450˚C) for 24 hours. Protein content was obtained using Kjeldahl method. Lipid content by extraction using N-Hexane. All the nutrient was determined from 100, the Nitrogen-Free-Extract was calculated by subtracting the sum of percentages of all the nutrients.

Performance analysis. There was four types of performance analysis, % floatation and Water Absorption Rate (WAR) and mechanical strength. The analysis was triplicate and the average value was used. The floatation test was conducted by the method in the previous study [22]. Ten pellets was placed in 2 liters bowls that contain 75% water. Every 5 minutes, the remaining pellet was calculated until 30 minutes. The percentage of floatation was determined using Equation 1:

\[
\text{Percentage of floatation} = \frac{\text{Number of floated pellets}}{\text{Number of pellets in sample}} \times 100\% \quad (1)
\]

The mechanical strength of fish pellet was analyzed using texture analyzer model TA-PLUS (Lloyd Instruments, Fareham, UK). The equipment was equipped with ball probes (5 mm in diameter, depression rate of 60 mm per minute).
3. Results and Discussion

3.1 Effect of raw material formulation on proximate composition and perfomance

The criteria in selecting fish feed must be cheap enough and good nutritional value for fish growth, contain a necessary component to attract the fish, suitable in size that can be easily consumed, fish feed should not to be disintegrate and sinking before the feed is consumed by the fish, it can be manufactured, have a good shelf-life during during storage [23]. A good nutritional value must be contain protein (20-35 %); fats (2-10 %); ash (<12%) and moisture content (<12%) [24]. Protein is used for fish growth, if the energy is obtained from of fats and carbohydrates and vise versa. Lipids have two times energy than protein [25]. According to the Table 3, several run fulfil that standard. All the run gives the results that carbohidrat and fat fullfill the standard [24]. Meanwhile the highest protein contain was resulted on run two and three. When the composition of carbohidrat and fat are enough, the protein will used for fish growth. The compotition of run two with 90% shrimp waste content makes it easier to sinking because of it’s heavier density [26]. So, the run three with 60% of shrimp waste and 30% soy residue were selected as the option of fish pellet composition. Moreover, the proximate value of run number three almost similar the proximate value of commercial fish feed pellets. Adding soy residue can can improve carbohydrate content and makes higher calories. Run five have higher calories value, but protein content has the lowest value and moisture content doesn’t meet the standard [24].

Table 3. Proximate value at various material competitions

| Variable | Protein (%) | Fat (%) | Carbohydrate (%) | Ash (%) | Moisture Content (%) |
|----------|-------------|---------|------------------|---------|----------------------|
| 1        | 26.07       | 2.71    | 51.22            | 20      | 12.52                |
| 2        | 33.46       | 3.39    | 30.95            | 32.2    | 11.22                |
| 3        | 29.54       | 3.33    | 51.49            | 15.64   | 11.23                |
| 4        | 18.5        | 2.43    | 65.93            | 13.14   | 10.87                |
| 5        | 18.18       | 2.83    | 78.16            | 0.83    | 16.56                |
| Commercial | 33.66     | 4.84    | 51.81            | 9.69    | 8.84                 |

3.2 Effect of binding agent formulation on physical performance

One of the criteria in fish feed selection is fish feed have the good ability, not to be separated and not to be sinking before the feed is consumed by the fish [23]. In this study, the run 3 was selected as the combination to produce the fish feed. But, based on the performance analysis, floating ability of 0 % and 5 % does not meet the requirement (see Figure 2). The percentage of floatation is standardize as the 90% for 2 minutes, the fish feed without binding agents resulted 80% floatation for 2 minutes application. Along fish feed application for 30 minutes, only 20% fish feed remaining.

In fish feed production, addition binding agent is aimed to enhance the stability. The binding agent is divided into three types: protein source binder, carbohydrate source binder and binder with no nutritional value [27]. In this research, the tapioca starch binders from carbohydrate was used. Introduction of water and heat in tapioca starch can change the crystal structure, hydrate and swollen the tapioca starch, the process named gelatinization [14].
In the first two minutes of the test, the fish feed with 5% and 10% binding agent resulted higher % floatation than without binding agent. The standard floating percentage was 90% for the first two minutes [24]. The percentage of floatation in fish feed using 10% of tapioca starch was 4 times higher than without tapioca starch (Figure 2). The existence of gelatinized tapioca starch in fish feed can improve the percentage of the fish feed floatation and enhance the calorific value by giving high amount carbohydrate [28].

In this study the increasing of binding agents concentration can increased the fish pellet hardness (Figure 3). The hardness value of fish feed using 10% binding agents was 2.13 times higher than without binding agents. The addition gelatinized tapioca starch as the binding agents can reduce the porosity of the fish feed because of increasing the contacting point between particle [29]. The fish feed production using whole wheat, potato starch and wheat starch resulted lower hardness, range from 23-26.7 N [8]. While in this study, the hardness result using 10% gelatinized tapioca starch as binding agent was comparable with another study, the hardness value is 32,06 N. While comparing the binding agents with and without gelatinization, the potato starch with gelatinization resulted higher hardness than without gelatinization [8].
Gelatinization process starts from heating starch with excess amount of water. This procedure results in soluble amylose that swell irreversibly [29, 30]. During the swelling, the linear amylose molecules diffuse out from swollen granules and are perfectly solubilized. Cooling of the hot swelling starch, results in a viscoelastic gel [32]. Binding mechanism the gelatinized starch is for holding the integrity and reduced the distances between particles will decrease [32].

The fish feed structure using SEM can be seen in Figure 4. Based on SEM analysis (2500x magnification), absence of tapioca starch (figure 4) makes pellet more porous than adding some variable of starch 5% (figure 5) and 10% (figure 6). Because of that results, hardness test result that most durable and most solid are adding 10% of binding agents and so on. Porousity form in pellet because of temperature in drying process. The absence of water makes the pellet shrinkage and makes little line of fracture [33]. Because of that conditions, the pellets need some gelatinezed starch to fill the emptiness, binding and gap between porous space on pellet. Other than that the addition of gelatine starch can form the stable structure that have the good stability and floatability in water [27].

![Figure 4. SEM analysis of fish pellet 0% binding agent](image1)

![Figure 5. SEM analysis of fish pellet 5% binding agent](image2)
Figure 6. SEM analysis of fish pellet 10% binding agent

4. Conclusions

Increasing the compositions of shrimps waste makes it easier to sink, on the hand the nutritional value gives good results as the standard. The physical performance of fish feed compositions with 30% soy residue and 60% of shrimp waste can be improved using 10% of binding agent. The tapioca starch as the binding agent can enhance the percentage of fish feed floating and hardness. The gelatinized starch can improve the interparticle bonding between particles and reduce the porous and increasing the fish feed hardness.

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