Journal of Fisheries Science
https://ojs.bilpublishing.com/index.php/jfs

ARTICLE

Physical Characteristics of Functional Indigenous Farm-made Feeds Using Crude or Gelatinized Tapioca Starch as Sources of Energy

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ARTICLE INFO

Article history
Received: 20 January 2022
Accepted: 18 February 2022
Published Online: 25 February 2022

Keywords:
Physical properties
Tapioca
Indigenous
Farm-made

ABSTRACT

The experiment compared the physical characteristics of aqua feed with crude or gelatinized tapioca starch as sources of energy. The bulk density (BD), water absorption index (WAI), water solubility index (WSI), pellet durability index (PDI) and water stability (WS) were measured in both experimental diets. The results showed significant variations ($p<0.05$) in BD and WAI in diet with crude tapioca starch while non-significant variations ($p>0.05$) were recorded for WSI and WS in both diets. The higher BD of a diet, the better its ability in resisting external forces that can cause disintegration. A high BD also reduces ability to the feed material shrinking, thereby preventing loss to feed dust and fines. The results of WSI, WS and PDI of diets denotes that both pellets were water stable and could spend about same time in water but diet with gelatinized starch had a better water absorption index and pellet durability index. Furthermore, proximate composition of diets showed that diets with gelatinized starch had low moisture (9.04%), low fibre (5.24%), and higher ash (13.61%) and lipid (9.64%) contents. It can be concluded from this experiment that diets with gelatinized starch stands the chance of being a better functional feed for small-scale fish farmers in Sub-Saharan Africa.

1. Introduction

Fish is an essential source of animal protein and other nutrients in human diets, especially in the sub-Saharan Africa [1]. With the geometric rise in world population and consciousness about healthy living, people prefer fish-based protein diets, hence, an increase in fish farming either at subsistence or commercial levels. Aquaculture has continued to be the fastest-growing animal-food-producing sector, from a production of 61.8 million tons in 2011 to 80 million tons in 2016 [2]. In an attempt to provide good quality feeds for farmed fish species, farmers combine various feedstuffs to cater for the chemical and nutritional compositions of aqua feeds with an unintentional oversight into the physical characteristics of such feeds. The introduction of functional farm-made

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DOI: https://doi.org/10.30564/jfs.v4i1.4369

feeds epitomizes a progressing concept in farmed animals' diets. The use of these feeds is beyond satisfying the basic nutritional requirements of species but to also reduce the effect of stress on the animal to the barest minimum by providing a conducive aquatic environment [3,4]. Feeding cost accounts for the lump sum of expenses in any viable aquaculture venture, hence, the need to give it special attention. Farm-made aqua feeds depend on a "basket" of conventional ingredients such as soybean, maize, fish oil, rice bran and wheat for which it competes in the marketplace with other feed production sectors - man and livestock. Most of the major feedstuffs used in the production of both farm-made and commercial feeds are also subjected to global market shocks and volatility as other edible feed ingredients [1].

Nutritional requirement (protein, lipid, vitamins and minerals) of most fish species are not different from those required by man; protein (amino acids), lipids, energy, vitamins and minerals in meeting physiological needs of growth, reproduction, maintenance and tissue repairs. Dietary nutrient levels for optimum growth performance are dependent on fish species, stage of development, sex, maturation, state, season, locality, environment, management practices and other external factors. The value of supplementary feeds depends on the chemical composition and digestibility of individual feed stuff, therefore, adequate combination of various individual feed components that would improve the digestibility and utilization of compounded feeds [5]. Good quality feeds is a major setback to the development of aquaculture in Sub-Saharan Africa as fish farmers depend largely on importation at a premium price.

Cassava (tapioca) is a multipurpose plant that thrives well in the tropics (Nigeria inclusive) with the extract from the root referred to as 'starch'. Its roots/tubers are cheaper sources of dietary energy compared with grains but the extent of the practical use in aqua feeds is limited [6]. Researchers have indicated that cassava tuber meal can replace conventional energy feedstuffs such as maize, broken rice and sorghum in Africa [7]. Binders are increasingly on the use by feed manufacturers to produce good quality pellets would not crumble upon handling. However, the high cost of conventional synthetic binders makes farm-made aqua feed production difficult for the local small-scale farmer in Sub-Saharan Africa [8]. The high starch content in tapioca root makes it an excellent aqua feed binder which is a promising potential alternative to eliminate expensive artificial binders [9]. This agricultural product will provide an appropriate local substitute to feed manufacturers and low-scale indigenous fish farmers to compound their own feeds [10]. Although, farmers have since embraced the use of cassava tapioca starch as a binder, but an excellent performance can be enhanced by gelatinization. Gelatinization is a process of breaking down the inter-molecular bond present in starch by applying heat and water. Starch has semi-crystalline structure with two components-amylose and amylopectin. The bond between semi-crystalline structures irreversibly breaks down as granules swells and burst with the application of heat and water. This process makes amylose molecules to leach out of the granules giving enzymes access to glycosidic linkage and consequently increase digestion [11]. Gelatinized starch is a readily available source of energy because gelatinization increases starch digestibility, as well as protein and energy retention by catabolizing gelatinized starch for growth and energy instead of protein and energy [12]. When starch is cooked, it is believed to improve the physical quality of the feed by increasing binding properties between particles in the ingredient mix. Tapioca starch is also water stable, hence, its use in this experiment by comparing the physical characteristics in its crude or gelatinized forms.

2. Materials and Methods

The experiment was carried out at the nutrition laboratory of Department of Fisheries and Aquaculture Technology, The Federal University of Technology, Akure, Ondo State, Nigeria. The experiment lasted for 14 days from the preparation of diets to the experimental procedure and analysis of results.

2.1 Preparation of Experimental Diets

Experimental feed ingredients (fish meal, soybean meal, palm and fish oil, tapioca starch, vitamin and mineral premix) were purchased from Animal Feed Concept in Akure, Ondo State, Nigeria, and prepared using the concept of [13]. Two iso-nitrogenous diets containing 40% crude protein of same basal ingredients were prepared and designated as D1 and D2 (Table 1) with diets D1 and D2 containing crude and gelatinized tapioca starch respectively. The tapioca starch was divided into two parts; one part was added to the basal feed mix in its crude form (D 1) while the other was gelatinized by mixing with boiling water and allowed to cook to obtain a sticky and transparent dough (D 2). The gelatinized starch dough was poured as a thin film into a tray and oven-dried at 60 °C for 3 days, after which it was pulverized into powder using a milling machine. The tapioca powder was then added into the basal ingredients to form a homogenized dough which was pelletized through a 2 mm die opening using a Hobart A-120 pelletizer (London, UK). Resultant pellets were sun dried at 30 ^oC for 72 hours, cooled under room temperature for another 24 hours and stored prior to use.

Table 1. Gross composition (%) of experimental diets

Ingredients (g)	D 1 (crude tapioca starch)	D 2 (Gelatinized tapioca starch)
Fish meal	42.30	42.30
Soybean meal	21.15	21.15
Tapioca	22.55	22.55
Fish oil (*g/vol.*)	3.00	3.00
Palm oil (*g/vol.*)	4.00	4.00
Vit. & min. premixes	5.00	5.00
Cellulose	2	2

2.2 Physical Characteristics of Experimental Diets

The experimental diet pellets were subjected to some physical properties tests such as bulk density (g/L), water absorption index (%), water solubility index (%) and water stability (%).

2.2.1 Bulk Density (BD)

Bulk densities of experimental diets were carried out in triplicates following the methods of [14]. Pellets was introduced into a 1,000 mL measuring cylinder and the corresponding weight was recorded. BD was calculated as the ratio of the weight of pellets to the volume of the cylinder and expressed as g/L.

$$BD = \frac{Weight\ of\ feed\ (g)}{Vol.\ of\ Cylinder\ (ml)}$$

2.2.2 Water Absorption Index (WAI)

Pellets from each treatment was grinded and sieved through a 200 μm sieve. 2.5 g of the fine powdered pellets (W_{ds}) was suspended in 30 mL distilled water in a 50 mL centrifuge tube at 30 ^oC for 30 minutes and stirred intermittently. The suspended sample was later centrifuged at 3,000 *rpm* for 10 minutes. The supernatant was poured into a known weight of an aluminum disposable dish and oven-dried at 135 ^oC for 2 hours. The weight of gel (W_g) remaining in the centrifuge tube was calculated as WAI from the following equation:

$$\text{WAI} = \frac{Wg}{Wds}$$

2.2.3 Water Solubility Index

The weight of dried solid supernatant (*Wss*) that was recovered after evaporation from the aluminum disposable dish was calculated as WSI following the method of [15].

$$\text{WSI} = \left(\frac{Wss}{Wds}\right) \text{x } 100$$

2.2.4 Water Stability

This parameter was calculated from the ratio of original sample to that of the sample after drying.

$$WS = \frac{\text{Original sample}}{\text{Sample after drying}}\ X\ 100$$

2.2.5 Pellet Durability Index

$$PDI = \frac{\text{weight of sample after fines removal}}{Weight\ of\ original\ sample}\ X\ 100$$

2.3 Proximate Analysis

The proximate analysis of the experimental diets was carried out following standard methods as described by [16]. Crude protein was determined using micro-kjeldahl distillation method, crude lipid extraction was carried out with the aid of Soxhlet's apparatus, moisture content of dry matter was determined using a conventional oven at 105 ^oC, crude ash content was measured by placing dry samples in a furnace at 550 ^oC, crude fibre content was determined using the method by Tecator Fibretec System of 1995.

2.4 Statistical Analysis

All data generated were subjected to one way analysis of variance (ANOVA) using SPSS 22 (Statistical Package for Social Sciences) and means were separated by Duncan's Multiple Range Rest (DMRT) at 5 % confidence level.

3. Results and Discussion

3.1 Proximate Composition of Experimental Feed and Starch

The proximate composition of experimental diets is presented in Table 2. Crude protein of experimental diets ranged between 42.12% and 42.93%, this did not show any significant variation ($p>0.05$) observed in other parameters. The basal feed mix had 40% crude protein, the slight increase recorded in this experiment could be from other feed ingredients in the diet. Crude protein of 40% is adjudged adequate for the supply of nutrients for most farmed tropical fish species especially, the African catfish. Crude protein of 35%-40% in the diets of cultivable tropical fish species was recommended by [17] for optimum growth. Dry matter, crude ash and lipid contents in diets were significantly different ($p<0.05$) as diet with crude tapioca starch was consistently low in the fore-mentioned parameters. The percentage of dry matter in diets signified low moisture content especially in diet with gelatinized starch which is a good parameter to consider in farm made feeds. Low moisture content is important for good storage and also to prolong shelf life of feed ingredients and prepared feeds, therefore, low moisture content recorded in diet D2 points to a longer shelf life and keeping ability. A moisture content of about 10% or less was suggested in fish diets to prevent prepared feeds and feed ingredients from spoilage and optimal [18]. Fish diet with crude tapioca starch had a lower crude ash and lipid contents when compared with the gelatinized diet. Tapioca starch is known to be a good source of minerals (calcium and iron) and gelatinization makes the starch readily available, hence, the probable reason for a higher ash content in the latter diet. Lipids are primarily included in formulated diets to maximize their protein sparing effect being a source of energy. Crude lipid contents recorded in this experiment were within the recommended limits (5%-10%) of inclusion into the diets of fresh water fish species [17]. Lipid of 10%-20% was opined by [19] in diets for most freshwater fish species. Crude fibre and nitrogen free extract (NFE) contents in experimental diets was lower in gelatinized tapioca starch diet but were all within the recommended dietary limits for most freshwater fishes. Fish diets with high fibre content of more than 12% would result in low nutrient quality, as such, not desirable in fish feeds due to low digestibility [20]. Chemical constituents or composition (%) of the starch (crude) used in the experiment are; moisture (7.60±0.18), crude protein (1.71±0.21), crude ash (1.56±0.13), crude fibre (0.68±0.02) and nitrogen free extract - NFE (88.45±0.28).

Table 2. Proximate composition (%) of experimental diets

PARAMETER (%)	D 1	D 2
Dry matter	87.94 ±0.07^{a}	90.96±0.03^{b}
Crude ash	6.26±0.03^{a}	13.61±0.0b^{b}
Crude lipid	4.19±0.00^{a}	9.64±0.23^{b}
Crude fibre	6.24±0.07^{b}	5.24±0.07^{b}
Crude protein	42.93±0.26^{a}	42.12±0.09^{a}
NFE	28.31±0.29^{b}	20.36±0.37^{a}

Values with the same superscripts on the same row are not significantly different

3.2 Physical Properties of Experimental Diets

The result of physical properties of the experimental feed is illustrated in Table 3. There were significant variations ($p<0.05$) in bulk densities (BD) and water absorption indices (WAI) of both diets. On the other hand water solubility indices (WSI) and water stability (WS) did not indicate any significant ($p>0.05$) variation. Physical characteristics of feeds such as the above mentioned play important roles in the overall feed efficiency to obtain optimum result. The diet with gelatinized tapioca starch had a lower BD (0.48%) compared with the crude tapioca starch diet. Low BD observed in the microstructure of feed was linked to pore formation by [21]. BD is an important factor that determines inter particulate bond that facilitates closer better performance during preparation. Extruded diets having higher BD require less space which facilitates transportation of more products in smaller containers thereby reducing the total cost of shipment [22].

The WAI and WSI explain the interaction between extruded diets and water which involves the conversion of starch granules to a homogenous lump [23]. The result showed that there were significant variations ($p<0.05$) in the WAI of experimental diets, with the gelatinized tapioca starch having a higher numerical value of 4.65%. This corroborates the study of [24] that increased WAI values indicated that the pellets underwent a high degree of gelatinization while a decrease on the other hand connotes starch degradation [25]. Water absorption and solubility indices are parameters that measure swollen gelled particles which maintain their integrity in aqueous diffusion and the degradation of molecular components [26,27]. The WSI depends largely on the volume of soluble matter which increases due to the breaking down of starch molecules [28,29]. Although, there was no significant variation ($p>0.05$) in the WSI of both diets, however, the diet with crude tapioca starch had a slightly higher numerical value. At high die temperatures, extruded pellets were able to maximize the degree of starch gelatinization leading to a reduction in starch degradation [22]. This result showed that there was no significant variation ($p>0.05$) in water stability of experimental diets. Water stability between 15.65%-16.12% was attributed to the presence of starch [29] and its duration in water. The degree of a diet's stability is directly related to the degree of gelatinization during steam condition [30,31]. Diets with good water stability might be due to the presence of gelatinized binder in the feed [31]. Pellet durability index (PDI) is used to determine the amount of fines that will exist in pellets at feeding time. Pellet durability indicates the ability of the pellet to resist attrition during storage and transport [32]. This was developed as a predictor of pellet fines produced during mechanical handling. PDI of diet with gelatinized starch was higher, corroborating the assertion of [31]. Also, [33] reported that pellet durability is an effective means of reducing fines which can be improved by steam pelleting and the use of raw materials with good binding ability.

Table 3. Physical properties of experimental diets

PARAMETER	D 1	D 2
Bulk density (BD)	0.57±0.01[b]	0.48±0.01[a]
Water absorption index (WAI)	2.62±0.26[a]	4.65±1.85[b]
Water solubility index (WSI)	2.77±0.45[a]	2.63±0.81[a]
Water stability (WS)	18.81±0.55[a]	18.76±0.59[a]
Pellet durability index (PDI)	60.04±0.25[a]	68.71±0.16[b]

Values on the same row with same superscripts are not significantly different ($p>0.05$)

4. Conclusions

The aqua feed technology is a moving tandem with aquaculture growth through production of feeds for improved digestibility. One goal the industry tends to achieve is compounding functional feeds that would enhance digestibility. Gelatinized starch improves physical quality of feed by increasing binding between particles in the ingredient mix. Physical characteristics such as bulk densities, water absorption and water solubility index are good parameters for evaluating the efficiency of feeds. From this experiment, there were significant variations in some physical characteristics such as BD and WAI. The crude tapioca starch had a higher BD which is a measure of the packing characteristics of the diet's particulate solids. The higher the BD of a diet, the better its ability to resist external forces that can disintegrate it, hence, a higher durability which reduces shrinkage that gives way to dustiness. It is a known fact that gelatinized starches improves pellet quality and have better water stability as shown in this experiment. Starch concentration also gives the feed more compactness, decrease water deterioration and helps in effective monitoring of feeding. Furthermore, chemical compositions of both experimental feeds were within recommended ranges for successful culture of tropical fish species. This study provides some facts that the local or small-scale farmer may be unaware of, since the essence of research is to proffer solution to farmers' immediate challenges and bridge the gap between research and stake-holders. Feed ingredients used are indigenous and also conventional, hence, the fish farmers can easily lay hands on them. Also, method used in gelatinizing starch is not complicated as such, does not require any form of expertise prepared diets can be replicated in any part of the world using same method.

References

[1] FAO, 2013. Food and Agriculture Organization of the United Nations, Rome. pp. 114.

[2] FAO, 2018. State of world fisheries and Aquaculture. Meeting the sustainable development goals. Food and Agriculture Organizations of the United Nations, Rome. pp. 227.

[3] US Grains Council, 2008. Use of DDGS in aquaculture diets. DDGS User Handbook. Available online at %20DDGS%20in%20Aquaculture%20Diets.pdf.

[4] ECOCROP, 2011. Ecocrop database. FAO, Rome. www.feedipedia.org/node/5368

[5] Kuiper, L., Ekmecki, B., Hamelink, C., et al., 2007. Bio-ethanol from cassava. Utrecht, The Netherlands. pp. 1-44.

[6] Lebot, V., 2009. Tropical root and tuber crops: cassava, sweet potato, yams and aroids. Crop Production Science in Horticulture (17), CAB books. Wallingford, UK. pp. 413.

[7] Oresegun, A., Alegbeleye, W.O., 2002. Serum and tissue thiocyanate concentration in Tilapia (*Oreochromis niloticus*) fed cassava peel based diets supplemented with DL-Methionine. J. Aqua. Trop. 17(2), 93-100.

[8] Nwoke, F.I., Lynam, J.K., Spencer, D.S.C., 2002. The cassava transformation: Africa's best kept secret. Michigan State University Press, USA. pp. 7-206.

[9] Montagnac, J.A., Davis, C.R., Tanumihardjo, S.A., 2009. Nutritional value of cassava for use as a staple food and recent advances for improvement. Comp. Rev. Food Sci. & Food Safety. (8), 181-194.

[10] Dafour, D., O'Brien, G.M., Best, R., 2002. Cassava flour and Starch: Progress in Research and Development. International Centre for Tropical Agriculture (CIAT), Colombia. pp. 133-142.

[11] Svihus, B., 2014. Nutritive and digestive effects of starch and fibre in whole wheat, wheat and rice in disease prevention and health: Benefits, risks and mechanisms of whole grains in health promotion. pp. 81.

[12] Peres, H., Oliva-Teles, A., 2002. Utilization of raw and gelatinized starch by European sea bass (*Dicentrarchus labrax*) juveniles. Aqua. 205(3), 287-299.

[13] United States-Canadian Tables of Feed Composition, 1982. Nutritional Data for United States and Canadian Feeds, third revision. The National Academies Press, Washington, DC. pp. 148.

[14] Aas, T., Krutzimanig, H.I., Austreng, E., 2011. Fish silage for salmonids: a cheap way of utilizing waste as feed. Feedstuffs. 53, 22-24.

[15] Okaka, J.E., Potter, N.N., 1979. Physicochemical and functional properties of soyabean powders processed to reduce flavour. J. Food Sci. 44, 1235-1240.

[16] AOAC, 2010. Association of Official Analytical Chemists, Official Method of Analysis of AOAC, W. Horwitz Editor 18th edition, Washington. pp. 322.

[17] Yasutoyo, N., 1990. Fish Feed Technology. UNDP/ FAO Project THA/89/003. pp. 22.

[18] Daramola, E.O., Osayinlusi, J.A., 2006. Nutritional potentials of cassava tuber wastes: A case study of a cassava starch processing factory in south-western Nigeria. Livestock Res. for Rural Dev. 22, 213.

[19] Ross, L.G., 1985. Environmental physiology and energetic, pp. 89-128, In: M.C.M. Beveridge, B.J. Ihekoronye, Ngoddy P.O. Integrated Food Science and Technology for the Tropics. 1st edn. Macmillan Publishers Ltd., London and Basingstaoke. pp. 302.

[20] Jauncey, K., 2000. Nutritional requirements. In: Beveridge, M.C.M. and Mc Andrew, B.J. (eds), Tilapias: Biology and exploitation. Fish and Fisheries Series 25, Kluwer Academic Publishers, London, UK. pp. 327-376.

[21] Colonna, P., Tayeb, J., Mercier, C., 1989. Extrusion cooking of starch and starchy products, In: Mercier C. Linko P. Harper J. (Eds.), Extrusion cooking, American Association of Cereal Chemists, St. Paul, Minnesota. pp. 247-319.

[22] Umar, S., Kamarudin, M.S., Ramezani-Fard, E., 2013. Physical properties of extruded aquafeed with a combination of sago and tapioca starches at different moisture contents. Animal feed Sci. & Tech. 183, 51-55.

[23] Sriburi, S.H., Dong, F.M., Rathebone, C.K., et al., 1999. Apparent protein digestibility and mineral availability in various feed ingredients for salmonid feeds. Aqua. 159, 177-202.

[24] Badrie, N., Mellows, W.A., 1991. Effect of extrusion variables on cassava extrudates. J. Food Sci. 56, 1334-1337.

[25] Mason, W.R., Hoseney, R.C. 1986. Factors affecting the viscosity of extrusion cooked wheat starch. Cereal Chem. 63, 436-441.

[26] Kirby, A.R., Ollett, A.L., Parker, R., et al., 1988. An experimental study of screw configuration effects in the twin screw extrusion-cooking of maize grits. J. Food Eng. 8, 247-272.
DOI: https://doi.org/10.1016/0260-8774(88)90016-7.

[27] Solomon, S.G., Ataguba, G.A., Abeje, A., 2011. Water stability and floatation test of fish pellets using local starch sources and yeast (*Saccahromyces cerevisae*). Int. J. Latest Trends in Agric. Food Sci. 1(1), 1-5.

[28] Guha, F.J., Walter, G.G., Danlot, H.Y., 1997. In: Extrusion Cooking: Technologies and Applications. Edited by Guy, R., Woodhead Publishing Ltd., Cambridge, UK, 2001, ISBN 1-85573-559-8.

[29] Ahamad, S.A., Gopal, C., Ramana, J.V., et al., 2005. Effect of different sources of starch and guar gum on aqua stability of shrimp feed pellets. Ind. J. Fish. 52(3), 301-305.

[30] Jayaram, M.G., Shetty, H.P.C., 1981. Formulation, processing and water stability of two new pelleted fish feeds. Aqua. 23, 355-359.

[31] Orire, A.M., Sadiku S.O., Tiamiyu, L.O., 2010. Evaluation of yam starch (*Discorea rotundata*) as aquatic feed binder. Pakistan J. Nut. 9(7), 668-671.

[32] Winowiski, T., 1995. Pellet quality in animal feeds. ASA Technical Bulletin Vol. FT21.

[33] Marcus, K., Rollins, D., 2007. Feed physical quality: Technical information for the Broiler industry. Poultry Nutri. pp. 1-8.