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Comparative Study of the Buoyancy and Stability of Two Pelleted and Extruded Rainbow Trout Feeds for to Improve Water Quality

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Abstract

This research evaluates the effect of processing and feed formulation on fish feed properties with the aim of providing information on physical properties of the feed and their impact in water environment. The physical quality of feed fish is important in aquaculture given its susceptibility to pellet degradation and leaching nutrients, the pollution of environment which causes fish stress and the development of pathogenic diseases. The objective of this study was to evaluate the Buoyancy and stability of on the physical properties of of extruded and pelleted rainbow trout feed with different formulations. Feed pellet floatability and stability were recorded every five minutes. Results showed that Highest feed pellet buoyancy was recorded in extruded diet and least in pelleted diet that the difference is significant. Feed processing (pelleting or extrusion) significantly affected feed buoyancy (P<0.05), the highest water buoyancy was noted with respectively 72,57 ± 3,31 for the extruded diet and 48,04 ± 1,42 for pelleted diet after 30 minutes in water. There was also a difference in the water stability of the extruded diet and pelleted diet, had the highest water stability (77,56 ± 1,19 and 17,43 ± 1,78b respectively) after 60 minutes of exposure to water. The effect of extrusion had an effect on the buoyancy and stability of the feed, and the fat content had a major impact on the buoyancy of the fat-rich extruded feed. With salmonid aquaculture developing, so have concerns regarding the environmental impacts caused by the rainbow trout's feed, in particular, the buoyancy and stability of fish feed and the possibility of environmental damage. The improving of these physical qualities at production levels, contributes more to food efficiency, and feed quality of aquafeeds could reduce waste and consequent environmental impacts, for better water quality for rainbow trout.

Keywords: *Aquafeed, Buoyancy, Stability, Extrusion, Pelleting, Quality, Water.*

INTRODUCTION

According to FAO, (2024) [1], aquaculture is considered to be one of the fastest growing food sectors worldwide, due to the steady increase in demand for fish products, associated with the growing population and knowledge of the nutritional characteristics and health benefits of these products [2] (Heller and Keoleian, 2015). With growing consumer demand, Increased production of high-value aquatic species and intensification of existing culture practices to produce more fish, and shrimp, has contributed significantly to the large production and utilization of industrial aquafeeds in the world [3], these aquafeeds accounts for 50-70% of the cost of fish production, which has a direct impact on the economy of the fish farmer, who is in constant search of economically viable production [4], [5], so, fish feed production is an important factor to be considered in both subsistence and commercial fish farming as it has consequences on both growth efficiency and feed wastage [6], [7], and the intensive use of natural resources and high production of nutrients can make the fish and shrimp farming a significant source of eutrophication [8], hence, fish diet production is a compromise between the nutritional quality and physical quality of fish feed and not affecting the tanks water quality negatively [9], [10], [11].The method used to produce fish feed pellets can have a direct impact on physicals and chemical properties, which can affect pellet durability, water stability, floatability and resulting water quality [12], [13], [14].

Pelleting and extrusion are two main methods of feed granulating [15],[16],[17].In aquacultural sector, Feed processing technology mainly includes grinding, mixture, preconditioning, granulating and drying [18]. The main barrier to the use of extrusion in small-scale aquaculture operations is the cost of extruder equipment, which is not compensated for when the available production volumes are low. However, the production of fish feed is faced by a number

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of factors, including the physical quality of feed which is easily broken and dissolved in water so that it can quickly reduce water quality; and feed that is easily drowned before consumption by fish [19], for optimal health, fast growth and sustainable production of farmed fish, a balanced feed with a good physical characteristic is required to ensure good aquaculture production [20].

Fish feeds unlike livestock feeds face major threats to its stability and floatability before reaching the target in aquatic medium [21],[22]. Water stability is an important physical property of feed for aquatic species is its , defined as the retention of the pellet physical integrity with minimal disintegration and nutrient leaching while it is immersed in the water and until it is consumed by aquatic animals [23]. In order to minimize disintegration and loss of nutrients upon exposure to water, quality aqua feeds should be highly stable in water [24], [25], therefore, the water stability of aquatic animal feeds must be considered by the aquaculturist as fish feeds are composed of macronutrients such as proteins, fats and carbohydrates, as well as micronutrients such as vitamins and minerals, and losses of these valuable nutrients to water must be minimised [26], in order to avoid disintegration and fragmentation of the pellet - adequate physical characteristics that are necessary to ensure a good feeding system [27]. Feeding rainbow trout (Oncorhynchus mykiss) feeds with either high or low water stability resulted in more than 20% difference in feed intake, being the highest in trout fed the feed with low water stability [28], [29].

However, floating feed fish enables fish farmers to observe how active the fish are and their consumption rate [30], moreover, this type of fish feed will enable the farmer to to avoid food waste and minimise water pollution [31]. Floating feed with improved is very suitable for pelagic or surface feeders as rainbow trout because these fish quickly get access to the feed and do not expend much energy in swimming to the bottom to source for food [32]. Floating feed also exhibit superior characters such as greater digestibility, water protection, zero water pollution and zero wastage of r aw materials [33].

The physical quality of feed fish is strongly influenced by the type of material used, the amount of water, the pressure, the method after processing and the use of adhesive material to produce fish feed with a strong, compact and robust structure so that it does not break easily [34]. In the feeding of salmonids, physicochimical properties of ingredients is an important factor, as well as production conditions affect the physical quality of fish feeds for good nutrition [35], [36].

Feed ingredients and process parameters during feed production influence the physical properties and quality of fish feed [37], [38], fish feed water floatability and stability, are an important qualities parameters in the manufacture of aquaculture diets [39]. Use of stable and floating feed will help in complete utilization by the fish and minimum wastage which will help in a more profitable and sustainable aquaculture production [40], [41].

The rainbow trout (*Onchorhynchus mykiss*) is one of the most important aquaculture species in Morocco, due to their excellent flesh quality rich in unsaturated fatty acids and by its good acclimatization to Moroccan aquatic environments. The rainbow trout farming has known in Morocco, the only country in North Africa, an important development since the beginning of the last century, both in recreational fishing and in the commercial aquaculture sector [42].

Improving the floatability stability of pellets in water is not only a physical issue but also a nutritional issue of great importance, which also affects feed conversion rates and of course the cost of the feed, In the feeding of salmonids (e.g. trout), the physical structure of the pellets is an important factor for good nutrition. Therefore, the pellet must have certain characteristics that allow it to maintain its structure for a certain period of time in order to be consumed, especially since rainbow trout are fast eaters. In this context, the objective of the present work is to compare the preservation of the physical integrity of the extruded and pelleted feeds for stability and floatability in water for rainbow trout feeds, with different formulations, for optimization the feeding of this fish and preservation of aquatic environment.

MATERIALS AND METHODS

Study Area

The study was carried out in Laboratory of the National Center for Fish Farming and Hydrobiology, reporting to the High Commission for Water and Forests and the Fight Against Desertification, Azrou Morocco.

Proximate Composition of the Experimental Diets

Table 1. Proximate composition (% dwb) of the key raw materials used for the formulation of the pelleted experimental diets.

Ingredients	Pelleted Diet
Fish meal	41,5%
Fish Oil	11,5%
Corn Gluten	15%
Wheat Flour	30%
Vitamin complex	02%

Table 2. Proximate composition of the key raw materials used for the formulation of the extruded experimental diet.

Ingredients	Extruded Diet
Fish meal	30 %
Soybean meal	15 %
Rapeseed oil	12 %
Fish oil	08 %
Soy concentrate	06 %
Wheat	06 %
Rapeseed meal	06 %
Krill meal	05 %
Vitamin A (UI/kg)	5000
Vitamin D3 (UI/kg)	1000
Vitamin E (mg/kg)	180
Vitamin C (mg/kg)	100

Table 3. Proximate composition of experimental diets (%)

Composition	Extruded Diet	Pelleted Diet
Proteins	42%	44,7%
Lipids	28%	15%
Carbohydrates	17%	28,6%
Fiber	2%	2%
Ash	6%	6,1%
Moisture	4%	6,8%
Gross Energy (Mj/kg)	24,28%	21,58
Digestible Energy (Mj/kg)	20,9%	16,48%

Feed Fish Floatbility Test

The floatability test was conducted using triplicate samples. Accorrding to Orire et al., [43], the extruded and pelleted feeds were subjected to floatability test by dropping 20 pieces of pellets into a 500 ml beaker half filled with water using a digital stop watch to record the numbers of pellets that sank every five minutes for 60 minutes. At the end of every observation, the number of the pellets that are afloat were recorded accordingly. The mean numbers of the floating pellets were expressed as percentage of the initial number. The floatability test was calculated using the following

$$\text{Floatability Test \%} = \frac{\text{Final Number of feeds afloat}}{\text{Initial number of fedds afloat}} \text{ x } 100$$

Feed Fish Water Stability Test

The water stability of the fish feed was determined in glass beakers, which contained 1000 ml of spring water from the fish breeding facility of the National Fish farming Centre. The water stability test is determined over a period of 6 hours according Keri et al, [39] by wet durability test with considerable modification to suit the present situation. Triplicate 5 grams samples of pellet of each diet were dropped into 15 immersion times examined were 15 minutes, 30 minutes, 1h, 2h, 4h and 6h water were filtered through filter paper and were dried in the oven (105°C for 30 min), followed by further drying at 65°C to a constant weight, then cooled in a desiccators. The mean differences in weights of beakers containing the feed before immersion and after drying were used to calculate. The percentage dry matter loss, which is a measure of the water stability of the pellets for the corresponding time intervals.

$$\textbf{Leaching rate} = \frac{A \times (1 - r) - R}{A \times (1 - r)} \times 100$$

Where,

A = Weight of pellets before immersion;

r = Moisture content of pellets; and

R = Dry weight of the remaining solid.

Statistical Analyses

Data are presented as means ± standard deviations (SD). All data were subjected to one-way analysis of variance (ANOVA) and differences between the treatment means compared by the Tukey multiple comparison test. Differences were considered significant at $p < 0.05$.

RESULTS

Table 4. Mean percentage water Buoyancy of extruded and pelleted feeds after each observation time

Time	Extruded Diet	Pelleted Diet
05 Minutes	100.00a ± 0.00[a]	91,13 ± 2,21[b]
15 Minutes	89, 67± 0,17[a]	72.67 ± 0,13[b]
30 Minutes	78,57 ± 3,31[a]	48,04 ± 1,42[b]
1 Hour	62,01 ± 2,17[a]	25,71 ± 1, 12[b]
2 Hours	43,31 ± 2,34[a]	12,34 ± 1,89[b]
4 Hours	21,54 ± 1,67[a]	0.00±0.00[b]
6 Hours	16,43 ± 1,78[a]	0.00±0.00[b]

Values in rows with different superscripts are significantly different at p < .05. (Mean ± S.E)

Table 4 shows the percentage of pellets afloat after each time of observation. At the first five minutes, all the extruded pellets floated at proportions 100%, while the least percentage floatation was observed on pelleted diet with 91,13%. The percentage buoyancy of extruded diets was significantly higher (P<0.05) than pressed diets. Within the second time 15 minutes, only extruded Diets floated at 89, 67%, and significantly higher than pelleted diets with 72.67%. Water buoyancy was highest in extruded Diet 1 for 30 minutes and 60 minutes; 78,57 ± 3,31 and 62,01 ± 2,17 respectively, and was lowest in pelleted Diet for both experimental durations, with 48,04 ± 1,42 and 25,71 ± 1, 12 respectively. There was significant difference between 2 the pellets (P<0.05). None of the pelleted diets floated for longer than 120 minutes, while extruded Diet had 21,54 ±1,67% floatation for 4 hours and 16,43 ± 1,78 for 6 hours.

Table 5. Mean percentage water stability of extruded and pelleted feeds after each observation time

Duration	Extruded Diet	Pelleted Diet
05 Minutes	99,76 ± 0,21[a]	92,16 ± 0,13[b]
15 Minutes	97, 47 ± 0,13[a]	89, 67± 0,17[b]
30 Minutes	95,04 ± 1,42[a]	62,57 ± 3,31[b]
1 Hour	94,71 ± 1, 12[a]	51,01 ± 3,17[b]
2 Hours	92,34 ± 1,89[a]	37,31 ± 2,34[b]
4 Hours	81,17 ± 1,54[a]	26,54 ± 1,67[b]
6 Hours	77,56 ± 1,19[a]	17,43 ± 1,78[b]

Values in rows with different superscripts are significantly different at p < .05. (Mean ± S.E)

The results of water stability test are presented in Table 5. At the end of 5 minutes, all the feeds were found to be quite stable with 99,76 ± 0,21 and 92,16 ± 0,13 % of for extruded diet and pelleted diet pellet respectively. There was also a statistical difference in the water stability of the diets studied (P<0.05), between 05 minutes and 60 minutes of water exposure. At the end of 15 minutes, the percentage of water stability test in the feeds were 97,47 ± 0,13 and 89, 67± 0,17 % in pellet A, and pellet B respectively. At the end of 30 minutes, there was significant fall in the stability especially in pellet B. At the end of 1 hour, the percentage of water stability was 94,71 ± 0,12 and 51,01 ± 3,17 % respectively. At the end of 2 h, interestingly, remains above 90% stability for pellet A, while was recorded while corresponding value of 40,31 % for the diet B. The water stability of pellet A at the end of 6 h was 77,56 1,19 for the diet A and the lowest (24,43 1,78 %) for the diet B.

DISCUSSION

Water Buoyancy

For fish, floating feed is fundamental for optimum feed intake since fish are fast swimmers and naturally eat at the water column to that Felix *et al.* [20]. The initial superiority of the extruded feed over the other feed source in terms of buoyancy can be attributed to the method of manufacture and composition of fish feed. The fact, that the extruded feed, according to Rolfe et al. [244], Sorensen *et al*. [45] and Kanmani *et al*, [46] this food has undergone a high degree of gelatinization which has reduces apparent bulk density of the pellets, which has a direct impact on the buoyancy of fish feed which is similar to our findings, as reported reported by (Aarseth *et al.* [47], Chevanan *et al.* [48] and Ali *et al.* [49], the extrusion reduce viscosity and increases moisture evaporation which in turn directly influences the expansion and promotes better buoyancy of the extruded pellets. The studies of Falayi [50], as confirmed by our results, the role of extrusion in improving the physical buoyancy quality of extruded feed compared to pressed feed, also, this is in agreement with the report of ABC Machinery (2020) [51], that, decrease in the molecular weight of starch during extrusion causes feed floatability. For pelleted diet, over the process of pelletization, there is partial gelatinization of starch, which facilitates ingredients agglutination, and produces high-density materials, which makes it possible to have a low floatability of the pepelleted diet, and our results are consistent with those of Honorato *et al*. [52].

The composition of diets affect floatability, in fact fish feed density is an important property for aquaculture, it will dictate if the pellet will float or sink according to Zettl *et al*. [53] and Pennells *et al*. [54],it was found that out that the lowest the bulk density, the high the floating time according to Adeparusi, and Famurewa, [55], and the differences in floatability can be attributed to the density of fish feeds, which is consistent with the work of Obi *et al*. [56]. The amounts of fat can influence the quality of pelleted feed, because, addition of fat to the surface of small particle feeds improves allows diet to float thereby giving the fish easier access to the feed, in accordance with the authors Steven [57] and Muramatsu *et al.* [58]. The lipids had positive impact on the buoyancy of the experimental diets as observed in the results of Russo, [59]. However, the floatability rate was directly affected by the lipid inclusion level which can be attributed to the molecular weight of the lipids. This is agreement with the finding of Adekunle *et al*. [60] and Nooraida *et al*. [61] who reported that molecular weight of feedstuffs determine diet buoyancy.

The lipids had positive impact on the buoyancy of the experimental diets as observed in the results of Russo, [59] and Orire, and Salihu [62] the results of showed , that rate of floatability was directly affected by the lipid inclusion level which can be attributed to the molecular weight of the lipids, and these results are in perfect agreement with those of our work, where the low-fat pressed feed has poor buoyancy while the high-fat extruded feed has the best buoyancy. The pelleted food contains less fat because its physical structure does not allow incorporation of these fats [63];[64], which has a direct impact on the high density and low floatability of the this feed. Furthermore, the work of Sorensen *et al.* [45] on salmonids, revealed that also, the extrusion process allows to control the physical properties of the feed; as it allows to modulate the density in order to generate buoyant pellets by the amounts of lipids that can be added to the pellets, which favours their buoyancy due to their low density [45] and these results are in agreement with our work.

It should also be noted that different carbohydrate sources have also by pelletizing (or extrusion), different contributions to water pellet buoyancy and the various floatability levels could be attributed to this, as highlighted by Momoh *et al*. [65], Fashina *et al*. [66], and our results, and the initial superiority of differents carbohydrates in term of floating ability can be attributed to processus of extrusion.

Water Stability

Pellet water stability is defined as the ability of the pellet to retain both its integrity and nutrients while in water, until consumed by the aquatic animal desscribe by Obaldo *et al*. [23]. The results from this study showed that the pelleted feed to be the least water stable pellet, while the extruded feed has the longer period of water stability employed in this test. During the first 5 minutes, we recorded a stability rate of more than 90% for the pressed feed and our results are in agreement with those of Solomon *et al*. [21], using wheat as a binder.

After the first 15 minutes, water stability remains higher for the extruded pellets, this is probably because this pellets had better adhesion as a result of the gelatinization of starches caused by the relatively high moisture and heat employed during the extrusion, and these results are consistent with those of Misra *et al*. [13]and Abubakar *et al*. [67]. Feed processing conditions affect the nutritional value of diets for carnivorous fish, which may impact of physical quality of the extruded diet, such as starch gelatinization, also improve physical quality of feed due to increased binding between feed particles demonstrated by Sørensen *et al*. [68], our results are also consistent with those of to Hilton *et al*. [12], Jayaram and Shetty [69], and Obaldo *et al*. [70], the degree of pellet water stability is directly related to the degree of gelatinization by the effect of extrusion that increases the stability of fish feed in water. Gelatinization of starch is crucial in fish feed production, maintained that starch gelatinization affects feed digestibility, expansion and contributes to water stability according to Kannadhason *et al*. [71], this is in conformity with the results by Kannadhason *et al*. [72] on effects of ingredients and extrusion parameters on aquafeeds (stability, digestibility and expansion). Moreover our results for water stability are in line with those of Welker *et al*. [73], while Fiordelmondo *et al*. [74], pointed out that, the extrusion technique showed greater stability in water and allowed the food to be available to the trout for a longer period.

Pelleted feeds are exposed to lower temperature and pressure, the conditions are generally less severe providing less complete starch gelatinization described by Prestløkken and Fôrutvikling [75], and therefore, water stability and physical durability are generally lower in steam conditioned-compressed pellets than for extruded feeds demonstrated by Hardy and Barrows [9], welker *et al*. [75] and potentially have a more negative impact on water quality, while the extent of heat treatment and starch transformation by gelatinization are primarily responsible for the durability of extruded feeds reported by Barrows and Hardy [76], Misra *et al*. [13], Brown *et al*. [78]. The same results were observed in the work of Gao *et al*. [18] on gibel carp (*Carassius gibelio*), where the extrusion method of fish feed production improved the stability of the extruded feed compared to the pelleted feed.

In addition, the addition of fat to the surface of pellets may also improve the water stability and reduce the leaching rate of water soluble nutrients as described by Lim and Cuzon, [79]. Increased of the fat levels reduce the extruder viscous heat dissipation due to the lubrication effect of lipids, resulting in best physical pellet quality and water stability and our results are in line with those of Zivic *et al*. [80] for Carp (*Cyprinus carpio L.*) and Samuelsen *et al*. [81] for Atlantic salmon (*Salmo salar*). The lipid content in pressed feeds is low because their structure does not allow for the incorporation of a high fat content, whereas in extruded feeds, the incorporation of lipids is high as demonstrated by Aba *et al*.[82].

Different carbohydrate sources have also by pelletizing (or extrusion), different contributions to water pellet stability and the various stability levels could be attributed to this, as highlighted by Momoh *et al*.[65], Fashina *et al*. [66]), and our results, The initial superiority of differents carbohydrates in term of stability ability can be attributed to processus of extrusion of feed fish.

Water Quality and Water Buoyancy, Stability

Aquaculture plays an increasingly important role in the global food system, human health and the environment (Fry *et al*., [66]). However, to ensure the sustainability of this sector, there is a need to develop sustainable production methods that will not endanger the aquatic environment (Dauda *et al*, [84]). Water quality is one of the primary limiting factors to aquaculture production, and this water quality is of primary importance for the welfare of trout as described by Sidoruk and Cymes, [85]. Furthermore, fish feed has been reported to be the major source of waste in aquaculture systems reported by Akinwole, *et al*..[86]; Martins *et al*.[87]. The Waste production from feed depends on so many factors, including its nutrient composition, method of production (extruded vs pelleted) as demonstrated by Miller and Semmens, [88]. Food composition, digestibility, feed conversion rates and manufacturing (Pelletization, Extrusion) largely determine the level of discharges from fish farming according to the work of Ackefors and Enell, [89]; Kaushik, [63]; Cho and Bureau, [90] ; Sindilariu, [91]; Aba *et al*.[92].

For salmonids (eg trout), physical feed fish properties interact with the nutritional response in fish according to Aas et al.[93], [29]; Baeverfjord *et al*.[94]; Glencross, Hawkins, *et al*.[95] and Oehme *et al*.[35], while the feed ingredients and process parameters during feed production influence the physical properties of the feed in accordance to Draganovic *et al*.[97]; Glencross *et al*.[98], 2011; Kraugerud *et al*.[99]; Kraugerud and Svihus, [100]; Samuelsen *et al*.[101], [102]; Sørensen, [103]; Sørensen *et al*.[104], [45]. Feed quality also directly affects water quality, because a proportion of the feed intake by fish, and non-ingested food is returned to the aquatic environments as metabolites or soluble by-products of metabolism, which is an important environmental concern according to Thorpe and Cho, [105] ; Welker *et al*.[106].

In aquaculture, two elements have mostly contributed to improving aspects of change concerning fish feeding, in particular, in rainbow trout: The use of the feed extrusion technique and the adoption of restrictive environmental rules according to Fiordelmondo *et al*. [74].Moreover, many studies have focused on the relationship between physical feed quality and water quality according to the work of Dalsgaard and Pedersen, .[107], Welker *et al*.[106], Fiordelmondo *et al*.[74] and Galezan *et al*. [108], because a proportion of the feed intake by fish is returned to the environment as metabolites or soluble by-products of metabolism in addition to the food not ingested, and that the significant improvement in water quality was due to the adoption of the modern type of feeding based on the extrusion technique.

The deterioration of water quality parameters affects fish physiology, growth rate, and feed efficiency, leading to pathological changes and even mortality under extreme conditions according to MacIntrye *et al*. [109], knowing that the impact of water quality is dependent on the density of fish in the ponds reported by Person-Le Ruyet *et al*. [110]. For all these reasons, the aquaculturist must take into account the physical quality of the feed in order to improve the health and production costs of his fish products and to preserve the aquatic environment.

CONCLUSION

Feed is a very important aspect for fish in intensive farming, therefore, the physical qualities and in particular the buoyancy and water stability of the feed greatly influence fish production and water quality in aquaculture systems. The extruded feed enables high environmental sustainability due to the increase of digestibility, buoyancy and stability in water, with a consequent reduction of suspended solids and nutrients.

Higher floatability and stability are desired in pellets by salmonid's aquaculturists and improved physical qualities of fish feeds help control feed wastage, improve feed conversion and reduce nutrient losses to minimise the environmental impact of feeds on aquatic environments. So, there is potential for improving nutrional efficiency of feed and water quality for farmed salmonids (eg Trout) by optimising the pellet physicals qualities.

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