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Faculty of Biosciences
Department of Animal and Aquacultural Sciences

Influence of Nanocellulose, Peanut Fiber, and Fibersol to Physical Characteristics of the Extruded Dog Food kibbles.

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Abstract

This thesis investigates the impact of screw speed and fiber composition on the physical quality of pet food kibbles. The study focuses on understanding how variations in screw speed (475 rpm and 650 rpm) and different fiber sources (peanut, Fibersol, and Nano-cellulose) influence parameters such as water activity, bulk density, hardness, moisture content, and durability of the pet food kibbles. The experimental results indicate that the physical quality of the pet food kibbles is not only dependent on the nature of the fiber but also significantly affected by the screw speed of the extruder. At lower screw speeds, more compact kibbles were formed, while higher screw speeds resulted in less dense kibbles. Additionally, the moisture content and water activity of the kibbles were found to be higher at lower screw speeds. The inclusion of different fiber sources had a limited impact on the physical parameter. The study utilized one-way ANOVA with Tukey pairwise comparisons to analyze the data and identify significant differences between the experimental groups. The findings from this thesis contribute to optimizing the production of high-quality pet food and provide insights into the importance of considering both screw speed and fiber composition in pet food formulation.

Keywords: extrusion, Fibers, Peanut fiber, Nano-cellulose, Fibersol, physical quality, moisture content, water activity, hardness, pellet durability index, pet food.

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1. Introduction

1.1 Natural fibers

Plants, animals, and minerals are the origin of natural fibers. While all animal fibers are protein-based, plant fibers are made of cellulose (John & Thomas, 2008). Animal fibers are mostly made of wool, fur, and feathers (Puttegowda et al., 2018). Mineral fibers, on the other hand, are man-made and can be manufactured from glass or rocks. In contrast with plant fibers, mineral fibers, and animal fibers are not classified as fibers that can be added to food or feed (Humans, 1988).

Plant fibers are hydrophilic due to the presence of functional groups such as hydroxyl in their structure. (Parveen et al., 2017). Plant fibers are typically made of cellulose, the most prevalent organic polymer (Klemm et al., 2005).

1.2 Dietary Fibers

Dietary fiber is often known as part of plant foods that cannot be absorbed or utilized. unlike other nutritional components such as lipids, proteins, and carbohydrates, Fiber goes through the stomach, small intestine, and colon largely intact before getting out of the body (Dhingra et al., 2012). Fibers are added to the diets of humans and animals because of their benefits in health. For example, dietary fibers keep the gastrointestinal system running normally and improve intestinal and fecal mass, reducing transit time and preventing constipation. Insoluble fiber lowers blood cholesterol levels, lowering the risk of heart disease. It also reduces the chance of developing colon cancer. (Damodaran et al., 2007).

1.3 Dietary Fiber Molecules

Dietary fibers, including cellulose, hemicellulose, lignin, and pectin are plant components that cannot be digested. Cellulose, a stiff and linear chain of approximately 3000 -d-glucopyranosyl units, forms lengthy junction zones. (Damodaran et al., 2007). For living organisms to be able to produce cellulose, one significant factor is needed, which is the enzyme called cellulose synthase. Genes for this enzyme can be found in many living organisms like bacteria and mostly all trees (Saxena & Brown, 2001).

Hemicellulose is a natural polymer like cellulose which means they are recognized as a substance found in nature or derived from plants or animals. Hemicellulose's structure is more flexible and non-crystalline due to the presence of many side-branch groups. Because of its open structure, hemicellulose draws more water molecules than cellulose (Benaimeche et al., 2020). Moreover, hemicellulose can contain many different sugars and because of that, their structure varies.(Nayak et al., 2021)

After cellulose, lignin is the most abundant natural substance found in the cell wall of plants (Yue & Economy, 2017). Lignin has a complex structure with many elements, including 40 oxygenated phenyl propane and alcohol. It forms a strong bond with carbon, resulting in a rigid and inflexible structure, making it the most difficult dietary fiber to digest. (George et al., 2020).

Pectin is a high-molecular-weight carbohydrate polymer found in almost all plants, where it contributes to cell structure. Compared to other dietary fibers has different properties, they can act like a gelling agent and is soluble(Flutto, 2003). Characteristics of pectin depend on the side chains and branches of the pectin molecules, this side chains commonly are sugars (Damodaran et al., 2007). Pectin sources mostly are fruits and are rich in citrus fruits (Flutto, 2003).

1.4 Fibers used in this thesis

1.4.1 Peanut fiber

Peanut fiber is one of the three fibers used in this project, which is derived from the outer shell of peanuts, and possesses several unique characteristics that make it a valuable and versatile material. Firstly, peanut fiber is rich in dietary fiber, making it an excellent addition to food products aimed at promoting digestive health. (Bobet et al., 2020). Furthermore, peanut fiber contributes to the texture and mouthfeel of food, providing a desired thickness and enhancing the overall sensory experience. (Reddy & Yang, 2005). Being a plant-based fiber, it is renewable and eco-friendly, contributing to a more sustainable approach in various industries (Reddy & Yang, 2005). Finally, its ability to absorb moisture also makes it a useful ingredient in food products that require moisture control, such as the pet food industry (Meng et al., 2020).

14.2 Fibersol

Fibersol, a prominent dietary fiber component, is well-known in the food business for its multiple beneficial characteristics. Fibersol is a soluble fiber derived from maize that provides a variety of functional and health advantages this information has been obtained from their official website.

Fibersol is also extremely stable, which means it can survive a wide range of processing conditions, such as high temperatures or acidic environments, without losing effectiveness(Ye et al., 2015). Furthermore, Fibersol functions as a prebiotic, supporting the beneficial bacteria in the stomach and boosting gut health and digestion. It also helps to control blood sugar levels and may aid with weight loss by boosting satiety (Ye et al., 2015).

1.4.3 Nano-cellulose

Nanocellulose, a remarkable material derived from cellulose fibers, this nanoscale cellulose material offers several intriguing characteristics. For starters, nano cellulose offers remarkable mechanical qualities that provide reinforcement and improve structural integrity in food items. As a result, it is an excellent contender for enhancing the texture and stability of many food compositions (Perumal et al., 2022). Second, because Nanocellulose has a huge surface area, it may interact with other components at the molecular level (Li et al., 2021). Finally, nanocellulose has an excellent water-binding capacity, contributing to moisture retention in food and preventing undesirable texture changes (Perumal et al., 2022).

1.5 Fiber Effects on Animals

Dietary fiber plays a crucial role in animal health by maintaining normal gastrointestinal function. It also increases intestinal and fecal bulk, reducing intestinal transit time and preventing constipation. Moreover, the presence of dietary fiber in foods induces satiety, making animals feel full and satisfied after a meal.(Damodaran et al., 2007). High-fiber diets can improve metabolism by prolonging intestinal transit time, reducing gas and glucose removal, and lowering serum cholesterol levels(Andrade et al., 2015). Fermentable fibers produce acids and residues in the large intestine, whereas insoluble fibers decrease glucose absorption, shorten colon transit time, and increase fecal volume. Improving intestinal function through dietary fiber intake can also reduce the absorption of triglycerides and serum cholesterol. (Andrade et al., 2015).

1.6 Fibers in dog food

Fibers aid in the regulation of digestion in dogs. The effects of fiber on healthy digestion and fecal output vary depending on the kind and amount taken (Koppel et al., 2015). Fermentable fiber added to pet food can aid in weight management and obesity treatment(Chandler, 2002). Expanding volume to the stomach and intestines helps to increase fullness while ingesting fewer calories. Meals with high amounts of both protein and fiber promote satiety more than diets including only protein or fiber (Chandler, 2002)

The texture and quality of dog food kibble have a considerable impact on pet owners' food purchasing decisions(Schleicher et al., 2019). Consumers have become more concerned about what is in their meals, therefore they have begun to pay more attention to the contents and manufacture of their dogs' food. When compared to themselves, most dog owners place an equal or higher emphasis on purchasing nutritious dog food As a result, the quality of the pellets is the aim to have delighted consumers (Anders, 2013)

Dogs like all other living creatures need a balanced diet to be able to thrive and maintain health. Each component in dog food has a role in their body. There are two types of components in dog food, essential and nonessential ingredients. Essential nutrition is the one that needed to be supplemented in dog food and their body can't produce it. Moreover, the energy requirement of the dog which depends on the age and breed also is a factor that determines the nutritional requirements. Other than metabolic energy dogs need six major nutrients, including water, carbohydrates, proteins, fats, minerals, and vitamins (Case et al., 2010).

1.7 Extrusion Process

Extrusion is a heating process that will bring the ingredient to the cooking point which itself will eliminate many contaminants like bacteria, anti-nutritional factors, and toxins (Strahm, 2020). Extruders are essentially screw pumps; the screw(s) spin within a securely fitting stationary barrel. A feeding mechanism is used to inject the premix into the extruder at a steady rate of mass or volume. (Bhattacharya, 2017). Depending on the mixture and the formulation of diets, extrusion can be used in different ways. This machinery has different parts that are gathered to produce the final product. Common parts of extrusion are the feeder, preconditioner, barrels, and knife (Riaz, 2013).

The feeder is the part that delivers the mixture of the ingredients to the extrusion. It has different sizes depending on the mass of the premix and its goal is to store the mix and deliver it to the extruder. In the feeder, it is common that a shaft is rotating to prevent the mixture from making clumps. In addition, some pet food extrusion systems have screws at the end of the feeder that can help to finely separate and homogenize the mixture before it enters the extruder. (Riaz, 2019).

The preconditioning process in pet food production has the aim of adding more moisture to the mixture. This helps to prevent the formation of a thick and sticky dough that could negatively affect the extrusion process. By adding moisture, the preconditioner can help to improve the flowability of the mixture and ensure that the extruder can process the feed more efficiently, resulting in a higher-quality final product. Therefore, preconditioning is a crucial step in pet food manufacturing that can significantly impact the outcome of the extrusion process (Chaabani et al., 2022). The preconditioner is a piece of machinery that typically consists of barrels and paddles. The paddles help to mix the dough and water, and with the addition of heat, they can also assist in the gelatinization of starch. This is a crucial step in the pet food manufacturing process, as it helps to ensure that the starch in the mixture is properly gelatinized before the extrusion stage This can result in better physical quality of the pellets, making them more durable and easier for pets to consume. Therefore, the preconditioner plays an important role in achieving high-quality pet food products.. (Chaabani et al., 2022).

The extrusion barrels are the key components in the pet food manufacturing process. They typically contain screws that work to mix, knead, and transport the mixture through the entire process until it reaches the die. Depending on the specific requirements of the production, the extrusion barrels can have different configurations and numbers of screws. (Yacu, 2020). Depending on the direction of rotation, twin screw extruders can be co-rotating or counter-rotating.

The die and knife are placed at the end of the last barrel, this is where the expansion of the dough happens and gives the pellets the pores (Sozer & Poutanen, 2013).

Dies are in a variety of shapes and diameters; this is the part that shapes the pellets and determines their diameters. Die size will be determined by calculation depending on the expansion of the mixture in the extrusion. After the expansion of the dough knives will cut the dough that comes out of the die with the speed that has been set, this speed determines the length of the pellets (Baird, 2003).

Moreover, some extrusions give fundamental information to the process such as temperature, pressure, speed, flow rates, and power input. In terms of energy input, retention duration, moisture content, and mixing intensity, variable measurement and computations can give useful information on crucial process parameters. Lastly, the raw materials and final extrudate characteristics can be monitored directly or indirectly to give the operator process input and output information (Strahm, 2020).

This thesis focuses on using fiber as an available and inexpensive additive source for dog food. The goal is to find out the benefits of fiber in dog food so that provides higher-quality kibbles in physical parts to help dog owners feed their pets with better-quality meals.

1.8 Parameters of the technical (physical) Quality of Feed

Production of feed like other industries has its factor and parameters to measure the quality of products. These parameters are moisture, water activity, Pellet Durability Index, and hardness. These will help the feed to have a better shelf life and quality(Thomas & van der Poel, 1996).

1.8.1 Moisture content

Water is found in all feed and surrounding particles it can be bound with other ingredients or act as free water, therefore measuring the water content in the feed is one of the common analyses in the feed manufacturing (Mathlouthi, 2001). Moisture and water activity (Aw) in pet food are two different concepts. Moisture refers to the amount of water in the food, while Aw is the water available for microorganisms to react with. In other words, Aw measures the degree of water availability in pet food that can support the growth of bacteria, mold, and other microorganisms(Chen, 2019). Feed moisture is commonly measured by weighing the feed before and after putting it in the oven so that the evaporated part of the feed can be calculated (Thiex & Richardson, 2003).

1.8.2 Water activity

Water activity (Aw) is the difference between the water vapor pressure created by free or unbound water in meals and the water vapor pressure generated by pure water (Belitz et al., 2008). The water content in the feed is different from the moisture, moisture is a vague description that can include other factors other than the water (Mathlouthi, 2001). Water activity (Aw) plays an important role in preventing or restricting microbial development. Aw is the major characteristic responsible for food stability, influencing microbial reaction, and defining the type of microorganisms encountered in food in certain circumstances (Tapia et al., 2020). Feed manufacturers aim for the ideal Aw less than 0.6 because microbial developments are very much prohibited (Belitz et al., 2008).

1.8.3 Pellet Durability Index

PDI is a factor in measuring the durability of the pellets, measuring the durability can be done with different machinery; Holmen tests and Doris is commonly used in feed manufacturing. The durability test aims to show how much pallets can maintain their shape after going through the transportation and storage (Aarseth, 2004). Durability is measuring the dust compared to the unbroken pellets with a unit of percentage.

1.8.4 Hardness

The hardness has a different approach to the pellet's quality measurements than PDI. Hardness is more focused on individual pellets and their point of break. This quality parameter helps determine the pressure the animal needs to chew or bite on the pellets(Thomas & van der Poel, 1996). To determine the hardness of the pellets many types of machinery can be used, it can be manual (Kahl)or work with very sensitive sensors to detect very small breakage of the pellet. The unit for this parameter will be the pressure (N).

2. Aim and objectives of the thesis

Fiber as an additive to dog food kibbles has been subject to discussion in feed manufacturing. Even though it can be a very available source but there is limited research on the topic. Therefore, this thesis aims to fill the gap in research about how these three fibers, peanut fiber, fibers, and nano-cellulose fiber can affect the physical quality of extruded dog food kibbles. The same formulation in all diets can give us the opportunity to compare the fibers' characters in different quality parameters. This will give us an understanding of which fiber can have beneficial effects and change the property of the kibbles. Moreover, in this thesis, the effect of screw speed on the characteristics of the dog food kibbles also have been examined. The objectives of this thesis are:

1. Investigate the effect of different fibers on the physical quality of the extruded pet food kibbles.

2. Compare the three different fiber performances in the dog food and how each fiber characteristic affected the quality control parameters.

3. Compare different percentages of fibers and how it affects the physical quality of the kibbles.

4. Investigate the effect of different screw speeds in extrusion for each diet and compare the kibble's physical quality parameters.

To achieve the 1. objective, the experiment was conducted in which one of the diets did not contain fibers, and the kibbles produced out of it are called the control diet so by comparing the physical quality of this diet to the ones with the fiber we can see the effect of fibers.

To achieve the 2. Objective, the experiment was designed to use three different fibers, peanut fiber, Fibersols, and nano-cellulose fiber in the diet. pellets produce fed from these diets were subjected to physical quality analyses. The result will illustrate the effects of each one on the physical quality of pet food at different parameters.

Objective 3 is achieved by formulating dies with 2 different percentages of each fiber and adding them to the premix to make the final diet. the percentage is 0.7 % and 1.4%., the produced kibble from each parentage is subjected to the physical quality of pet food at different parameters.

Objective 4 is achieved by experimenting with the two different screw speeds in the extrusion the speed is 650 RPM and 475 RPM. The feed produced in each screw speed was subjected to physical quality analyses.

The results of the experiment were discussed in detail further to illustrate more insight into the effect of the fibers and different screw speeds on the physical characteristics of the dog food kibbles.

3. Material and Methods

3.1. Ingredient and formulation

Six different diets were formulated for this experiment, these six diets were each produced with 2 different screw speeds (475 RPM, and 650 RPM). These samples were produced in the Center for Feed Technology (Fôrtek) in the animal science faculty at the Norwegian University of Life Sciences.

The diets in the experiment are categorized based on their fiber content, which is expressed as a percentage. The two fiber percentages used in the experiment are 0.7% and 1.4%, except for the nano-cellulose fiber which was only tested at the 1.4% level due to insufficient ingredients. The goal was to produce 20 kg of the final product (kibbles) for each diet. The pre-mix, which serves as the diet control, has the largest batch size as it is necessary for achieving the optimal temperature during the extrusion process. Table 1 provides the formulation details for each diet, with each ingredient being present in the same percentage across diets to enable an analysis of the effects of different components and factors. Despite not being required for the other diets, water had to be added to all diets to facilitate the incorporation of the nano-cellulose fiber, which needed to be mixed with water beforehand.

In addition, it is worth noting that chicken fat and fish oil are not included in the pre-mix formulation. These ingredients are utilized for vacuum coating purposes after the pellets have been dried. The percentage values presented in the table indicate the composition of various ingredients in the diets.

Table 2 Formulation of all diets and their compositions

Ingredient(kg)	**Diet 1(control)**	**Diet2 peanut fiber0.7 %**	**Diet3 peanut fiber1.4%**	**Diet4 Nanocellulose-fiber 1.4%**	**Diet5 Fibersol® 0.7%**	**Diet6 Fibersol® 1.4%**	**Percentage**
Fish Meal	8	2.4	2.4	1.2	2.8	2.8	4.00
Poultry Meal	50	15	15	7.5	17.5	17.5	25.00
Hordafôr	10	3	3	1.5	3.5	3.5	5.00
Pea Starch	30	9	9	4.5	10.5	10.5	15.00
Wheat	42	12.6	12.6	6.3	14.7	14.7	21.00
Maize	40	12	12	6	14	14	20.00
Guar gum	1	0.3	0.3	0.15	0.35	0.35	0.50
Beet Pulp	2.4	0.72	0.72	0.36	0.84	0.84	1.20
Chicken fat	9.2	2.76	2.76	1.38	3.22	3.22	4.60
Fish Oil	3	0.9	0.9	0.45	1.05	1.05	1.50
Limestone	2.572	0.7716	0.7716	0.386	0.9	0.9	1.29
MCP	1.086	0.3258	0.3258	0.163	0.38	0.38	0.54
Salt	0.788	0.2364	0.2364	0.118	0.276	0.276	0.39
Nanocellulose-fiber	0	0	0	0.42	0	0	1.40
Peanut fiber	0	0.42	0.84	0	0	0	0.70-1.40
Fibersol	0	0	0	0	0.49	0.98	0.70-1.40
water	40	12	12	6	14	14	20.00

3.2 Feed production process

The project for this thesis was conducted at Fôrtek and involved the entire process from ingredient preparation to the main production phase. The pre-mix was produced simultaneously for all the different diets under identical conditions. The extrusion process did not involve pre-conditioning, and there were no changes made to the screw configuration. The flowchart below illustrates the sequential steps of the production process.

Figure 1 Steps in the process of the feed production

3.2.1 Preparation

The initial step in the production process involves the preparation of the premix for all the diets. It commences by grinding the poultry meal and fish meal to achieve uniform particle sizes and create a more homogeneous mixture. A hammer mill grinder with a screen size of 2mm was utilized for grinding all the components. However, Hordafôr, due to its liquid form, was added to the mixer after the grinding process and sprayed onto the mixture. Following the grinding stage, the remaining ingredients were added to the two-shaft mixer in batches and mixed for approximately 2 minutes (refer to Figure 2 for reference).

Figure 2 Two shaft mixer located in Fôrtek

In addition to grinding the premix, the peanut shells were also ground using a 0.5 mm screen size. The accompanying pictures below provide a visual depiction of the process involved in producing peanut fiber.

Figure 3 Peanut shells, Small Batch Grinder, Peanut Fiber

3.2.2 Mixing

The primary objective of the mixing process is to create a homogeneous mixture. In this project, small batches of the mixture were utilized at Fôrtek to combine various percentages of fibers with the premix, along with the addition of water. Each batch consisted of 30 kg of premix, along with the specified amount of the chosen fiber (as indicated in Table 1). The mixture was mixed for approximately 1 minute (as shown in Figure 4), following which water was sprayed into the mixture. It is important to note that Diet 1, the control diet, did not contain any fibers.

Figure 4 Small Mixer in Fôrtek

3.2.3 Extrusion

The extrusion process at Fôrtek utilizes a twin-screw Bühler extruder. The production of kibbles begins by adding the first batch of the prepared mixture, following the specified formulation. The batches are manually added to the feeder, which is positioned at the top of the extrusion entry. The feeder plays a crucial role in maintaining the material flow into the extruder. The capacity of the feeder can be adjusted by controlling the speed of the screws located at the bottom of the feeder. Additionally, the feeder helps to remove any lumps present in the mixture, ensuring a smooth and consistent material flow during extrusion.

The screw configuration that has been designed for this project is demonstrated in Figure 5. This design has been maintained and did not change during the process. Implementation and sketching of the configuration were done by Fôrtek to attain ideal performance.

Table 3 screw configuration used in the project

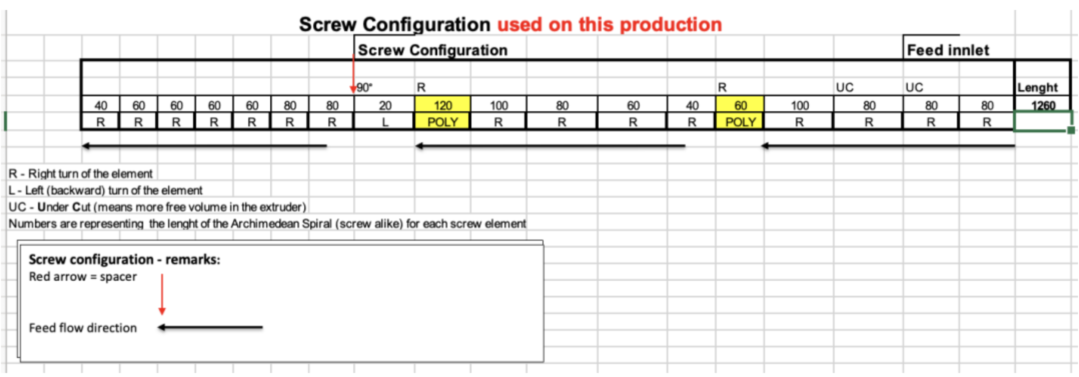

Figure 5 screw configuration used in the project

During the production process, the temperature consistently increased as anticipated, which was necessary for heating up the extrusion. There were no challenges or unexpected issues encountered in maintaining the temperature and flow of the mash within the extruder. Initially, a few batches from the diet control were added solely to reach the optimal temperature of 100°C. Once this temperature was achieved, the production of kibbles commenced. Table 3 provides an overview of the temperature variations for different diets throughout the process. The highest temperature recorded in the extrusion reached approximately 118°C.

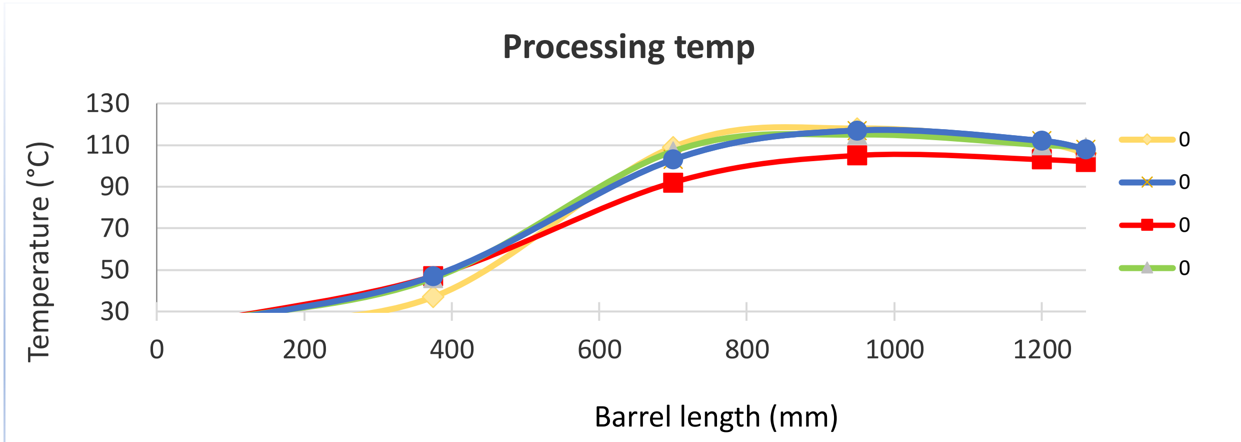

Figure 6 Temperature of barrels during the production

Figure 6 depicts the main temperature locations (represented by dots) as indicated in Figure 5. The mash is added to the extruder according to the configuration displayed in the figure. The lowest temperature is consistently observed in the first barrel (T1), while the highest temperature is typically registered in T3, primarily due to the kneading element within the screw configuration.

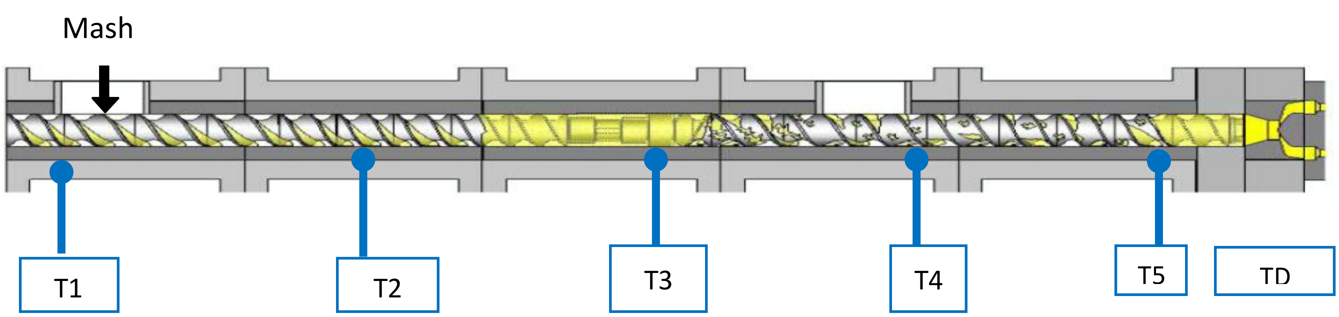

Figure 7 Points of the Extrusion Barrel's Temperature

The extrusion parameters utilized in the project are outlined in Table 3. It should be noted that certain elements of the extrusion remained consistent throughout the project, including the die size, number of dies, speed of the knives, and number of knives. During the feed production process, particular attention was given to keeping the torque below 50% to ensure optimal operation of the extrusion. The table demonstrates that the drive power for diets with lower screw speeds (475rpm) is notably lower, as less power is required to rotate the screws under these conditions. Importantly, no challenges or issues were encountered during the feed production process that required addressing.

Table 3 Extrusion parameter during the project

	Control (650rpm)	Control (475rpm)	Diet Peanut 0.7% (475 rpm)	Diet Peanut 0.7% (650 rpm)	Diet Peanut 1.4% (650 rpm)	Diet Peanut 1.4% (475 rpm)	Diet Fibersol 0.7% (650 rpm)	Diet Fibersol 0.7% (475 rpm)	Diet Fibersol 1.4% (650 rpm)	Diet Fibersol 1.4% (475pm)	Diet Nanocell 1.4% (650rpm)	Diet Nanocellulose 1.4% (475 rpm
Die size(mm)	7	7	7	7	7	7	7	7	7	7	7	7
Number of dies	1	1	1	1	1	1	1	1	1	1	1	1
Screw speed(rpm)	650	475	475	650	650	475	650	475	650	475	650	475
Knife speed(rpm)	300	300	300	300	300	300	300	300	300	300	300	300
Number of knives	6	6	6	6	6	6	6	6	6	6	6	6
Drive power (kW)	12.6	9.7	6.1	11.4	11.9	8.1	10.5	7.7	10.9	5.9	10.4	7.7
Torque%	43	45	28	38	40	38	35	37	37	27	36	35

3.2.4 Drying

Following the extrusion process, the kibbles were dried in small batches for a duration of 20 minutes. After this drying period, the moisture content in the kibbles was assessed using instant moisture content measuring techniques (as depicted in figure 8). If the moisture content was found to be less than 12%, the process could proceed with the coating of the pellets. Maintaining a low moisture content is crucial due to adding water during the production process. This ensures the desired quality and stability of the final product.

Figure 8 OHAUS instant moisture analyzer in Fôrtek

3.2.5 vacuum coating

Following the drying process and verifying the moisture content, batches weighing 10 kg for each diet were introduced into the vacuum coater. At this stage, the predetermined quantities of calculated fish oil (1.5 kg) and chicken fat (4.6 kg) were added on top of the pellets. The vacuum coater operates on the principle of removing air from the pores of the pellets by creating a vacuum inside the sealed chamber. Subsequently, upon releasing the vacuum, the kibbles absorb the oil, thereby minimizing oil leakage. This process ensures effective oil coating and enhances the overall quality of the final product.

Figure 9 Vacuum Coater in Fôrtek

4. Pellet analysis

4.1 Durability

4.1.1 New Holmen Durability Tester

To evaluate the physical quality and durability of the kibbles, a new Holmen tester was employed, which measures the Pellet Durability Index (PDI) as a percentage based on a specific kibble size, in this case, 7mm. The PDI value indicates the proportion of pellets that remain intact out of the total number of pellets tested. It serves as an indicator of the amount of fine powder present in a given diet or feed.

Figure 10 HOLMEN TESTER

Higher PDI percentages correspond to greater durability and improved physical quality of the kibbles. This implies that a higher percentage of pellets retain their structural integrity during handling and feeding. Consequently, a lower amount of fine powder is generated, which may otherwise go uneaten by animals consuming the feed.

For each diet, three PDI % values were recorded, providing a comprehensive assessment of the pellet durability and the presence of fine/powder content in the respective diets. These measurements serve as crucial indicators of the overall quality and suitability of the kibbles for animal consumption.

4.1.2 Doris Tester

To assess the durability of the coated kibbles, the DORIS tester was employed. The coated kibbles were fed into the DORIS tester instrument, which subjected them to controlled mechanical forces. The resulting sample was collected in a container, and a subsequent dry-sieving process was conducted.

Figure 11 DORIS TESTER

Prior to sieving, each sieve used in the process was pre-weighed to establish a baseline weight. The sample collected from the DORIS tester was then sieved, and the weight of the sample and the cumulative percentage of broken pellets were determined. The sum percentage of broken pellets is indicative of the durability of the coated kibbles.

A higher sum percentage of broken pellets indicates lower durability, as it suggests that a greater proportion of the coated kibbles have suffered breakage or damage during the testing process. Conversely, a lower sum percentage of broken pellets implies higher durability, as it indicates that a larger proportion of the coated kibbles have withstood the mechanical forces without significant damage.

This method provides valuable insights into the structural integrity and resistance of the coated kibbles, allowing for an assessment of their durability and suitability for consumption.

4.2 Water Activity (Aw)

Water activity is indeed a critical factor in determining the shelf life of kibble. A lower water activity value indicates a longer shelf life for the product. In this study, the water activity of coated samples from each diet was measured, and it was found to be approximately 0.6. To determine the water activity, samples of each diet were crushed using a grinder in the nutrition lab. Subsequently, two samples from each diet were simultaneously analyzed in a water activity-determining instrument for a duration of 10 minutes.


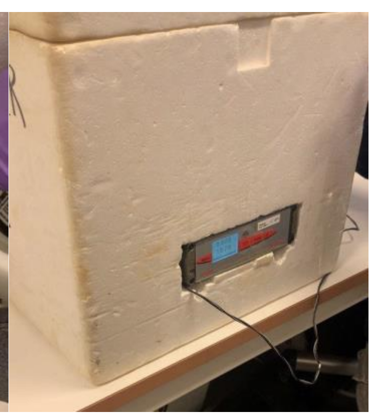

Figure 12 Inside layout of the Aw analyzer.Figure 13 Aw analyzer in Fôrtek

4.3 Hardness

To assess the hardness of the kibbles, a Lloyd hardness tester was utilized. For each diet, 15 kibbles were selected for testing. The length and diameter of each kibble were recorded as part of the analysis.

The Lloyd hardness tester applies controlled pressure to the kibble surface, allowing for the measurement of its resistance to deformation or breakage. By measuring the hardness, valuable insights are gained into the structural integrity and firmness of the kibbles.

The length and diameter measurements of the kibbles provide additional information about their physical dimensions, which can be correlated with the hardness data. These measurements contribute to a comprehensive understanding of the physical characteristics and quality of the kibbles.

Figure 14 Lloyd hardness tester in Nmbu

4.4 Moisture content

Dry matter analysis is a straightforward test used to determine the moisture percentage in feed samples. In this study, a concentration of 100 grams of ground-coated pet food kibbles was measured and placed in a hot air oven set at a temperature of 105 degrees Celsius. The sample was allowed to dry for a period of 24 hours. After the 24-hour drying period, the sample was removed from the oven and allowed to cool. The weight of the sample was then measured again. By comparing the initial weight of the sample to the weight after drying, the moisture percentage can be calculated. The dry matter analysis provides valuable information about the moisture content of the kibbles.

4.5 Data analysis

For the data analyses in this thesis, the One-Way ANOVA test with Tukey pairwise comparisons was employed. The One-Way ANOVA test is a statistical method used to determine whether there are significant differences among the means of three or more groups. In this study, the different screw speeds (475 rpm and 650 rpm) and various diets (control, peanut, Fibersol, and Nano-cellulose) constituted the groups for comparison. By conducting the One-Way ANOVA test, we were able to assess if there were statistically significant variations in the measured parameters, such as water activity, bulk density, hardness, moisture content, and durability, across the different experimental conditions. To further examine the pairwise differences between the groups, Tukey's post hoc test was applied. This test allows for the identification of specific group differences that contribute to the observed significant results in the ANOVA. By utilizing these statistical analyses, we were able to gain insights into the effects of screw speed and diet composition on the physical quality of pet food kibbles and make meaningful comparisons between the experimental groups.

5. Result and Discussion

5.1 parameters in Production

Table 4 provides detailed information on the extrusion parameters used during the manufacturing process, with a specific focus on three important factors: drive power, pressure in barrel 4, and torque. The table allows for a comparative analysis of these parameters across different diets. The results reveal that diet control, which serves as the baseline diet, exhibits the highest values for both drive power and torque when compared to the other diets. This indicates that the control diet requires more power and torque to achieve the desired extrusion process.

In terms of the fiber diets, the one with peanut fiber at a concentration of 1.4% and a screw speed of 650rpm demonstrates the highest values across all three parameters (drive power, pressure in barrel 4, and torque) when compared to the other fiber diets. This suggests that the presence of peanut fiber at this concentration and screw speed places additional demands on the extrusion system.

Conversely, the diets with a screw speed of 475rpm exhibit the lowest values in all three measurements. This implies that a lower screw speed results in reduced requirements for drive power, pressure, and torque during the extrusion process. Notably, the drive power for the Fibersol diet is recorded as the lowest at 5.9kW, while the control diet at 650rpm exhibits the highest drive power at 12.6kW. This highlights the variation in power consumption across different diets and screw speeds.

The findings from Table 4 provide valuable insights into the specific extrusion parameters employed for each diet, allowing for a better understanding of the energy requirements and performance characteristics during the extrusion process. This information aids in optimizing the manufacturing process and ensuring efficient and effective production of the desired kibble products.

Table 4 Extrusion parameter during the project

	Control (650rpm)	Control (475rpm)	Diet Peanut 0,7% (650rpm)	Diet Peanut 0.7%(475 rpm)	Diet Peanut 1.4%(650 rpm)	Diet Peanut 1.4%(475 rpm)	Diet Fibersol 0.7% (650 rpm)	Diet Fibersol 0.7% (475 rpm)	Diet Fibersol 1.4% (650 rpm)	Diet Fibersol 1.4% (475pm)	Diet Nano-cell 1,4% (650rpm)	Diet Nano-cellulose 1.4% (475 rpm
Drive power (kW)	12.6	9.7	11.4	6.1	11.9	8.1	10.5	7.7	10.9	5.9	10.4	7.7
Pressure, barrel 4 (bar)	0.8	0.73	11.4	6.1	11.9	7.7	10.5	8.1	10.9	7.7	10.4	5.9
Torque%	43	45	38	28	40	38	35	37	37	27	36	35

5.2 Physical Quality Results

Table 5 Physical quality parameters results for all diets all based on Tukey comparison

	Control (650rpm)	Control (475rpm)	Diet Peanut 0,7% (650rpm)	Diet Peanut 0.7%(475 rpm)	Diet Peanut 1.4%(650 rpm)	Diet Peanut 1.4%(475 rpm)	Diet Fibersol 0.7% (650 rpm)	Diet Fibersol 0.7% (475 rpm)	Diet Fibersol 1.4% (650 rpm)	Diet Fibersol 1.4% (475pm)	Diet Nano-cell 1,4% (650rpm)	Diet Nano-cellulose 1.4% (475 rpm
Water activity	**0.57**	**0.66**	**0.62**	**0.79**	**0.62**	**0.69**	**0.67**	**0.68**	**0.58**	**0.71**	**0.64**	**0.66**
Bulk Density (g/l)	**377.6**	**445.0**	**447.6**	**502.3**	**485.6**	**502.3**	**495.3**	**611.3**	**494.0**	**658.6**	**448.0**	**495.6**
Hardness (N)	**76.73**	**76.79**	**65.93**	**81.27**	**74.27**	**63.47**	**66.27**	**74**	**74.00**	**51.47**	**60.67**	**71.60**
Moisture content (%)	**11.9**	**14.10**	**13.30**	**18.70**	**11**	**14**	**12.50**	**13.60**	**10.70**	**17.80**	**12.70**	**14.20**
Durability (%) Doris	**97.03**	**99.43**	**98.86**	**99.88**	**98.84**	**99.74**	**99.49**	**99.01**	**98.47**	**99.78**	**99.38**	**99.61**
Durability (%) Holmen	**96.3**	**98.37**	**99**	**97.93**	**97.33**	**98.63**	**98.4**	**98.93**	**97.17**	**99.03**	**97.93**	**98.57**

The table provides data on various parameters measured for Physical quality analysis, including all different diets. The parameters analyzed include water activity, bulk density, hardness, moisture content, and durability.

5.2.1 Water activity:

Water activity is a crucial parameter that affects the shelf stability and microbial growth in pet food. In this study, it was observed that the water activity values varied across different diets and screw speeds. The control diet at 650 rpm exhibited the lowest water activity (0.57), indicating a relatively dry product. However, the control diet at 475 rpm had a higher water activity (0.66), indicating increased moisture retention. Among the diets with added peanut (0.7% and 1.4%) and Fibersol (0.7% and 1.4%), there were slight variations in water activity. The diet with Nano-cellulose (1.4%) at 650 rpm had the lowest water activity (0.64). These differences in water activity can be attributed to variations in moisture content and the interaction between the ingredients and processing conditions.

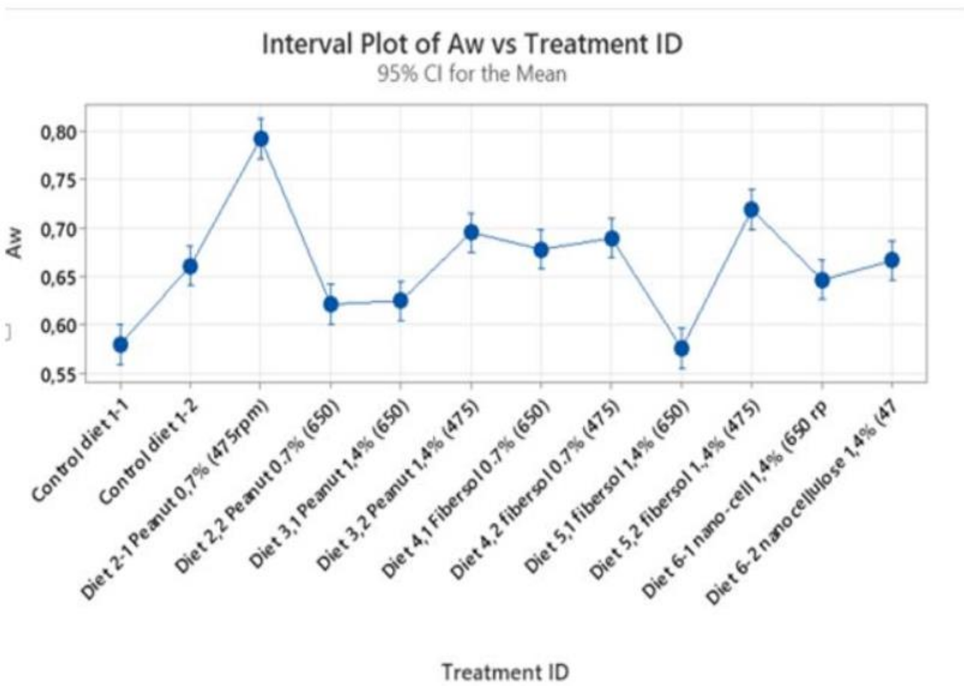

Figure 15 INTERVAL PLOT OF WATER ACTIVITY EACH OF 12 DIETS

5.2.2 Bulk Density:

Bulk density is a measure of how tightly the pet food kibbles are packed together. In this study, the bulk density values showed significant variations based on screw speed and diet composition. The Diet Fibersol 1.4% (475rpm) had a higher bulk density (445.0 g/l) compared to the control diet at 650 rpm (377.6 g/l). This indicates that the lower screw speed resulted in more compact kibbles. Among the diets with added peanut, Fibersol, and Nano-cellulose, different combinations of screw speeds and fiber sources resulted in variations in bulk density. Generally, higher fiber content led to slightly higher bulk density, indicating a denser kibble structure.

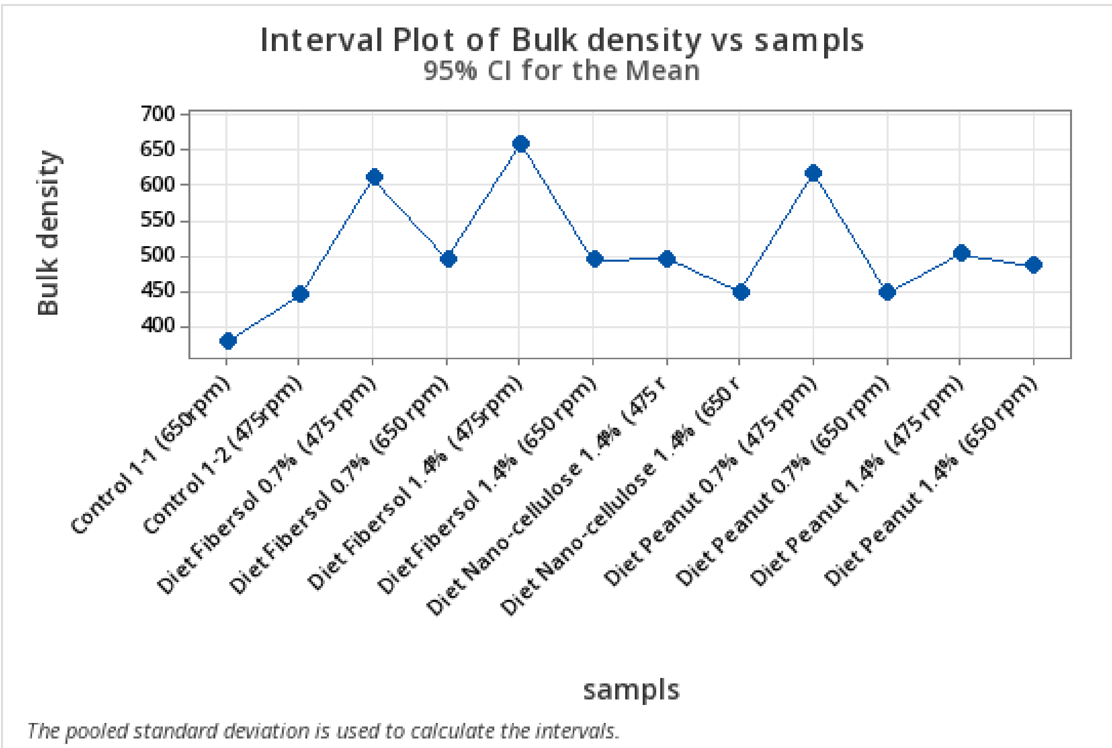

Figure 16 INTERVAL PLOT of bulk density of all diets

5.2.3 Hardness:

Hardness is a measure of the force required to break the pet food kibbles. The hardness values showed some variability across the different diets and screw speeds. The control diets at both screw speeds had comparable hardness values, with no significant difference observed. However, diets with added peanut fiber and Nano-cellulose showed variations in hardness. The diet with peanut (0.7%) at 475 rpm exhibited the highest hardness (81.27 N), while the diet with Fibersol (1.4%) at 475 rpm had the lowest hardness (51.47 N). These differences can be attributed to the interaction between fiber sources and processing conditions, which affect the kibble structure and texture.

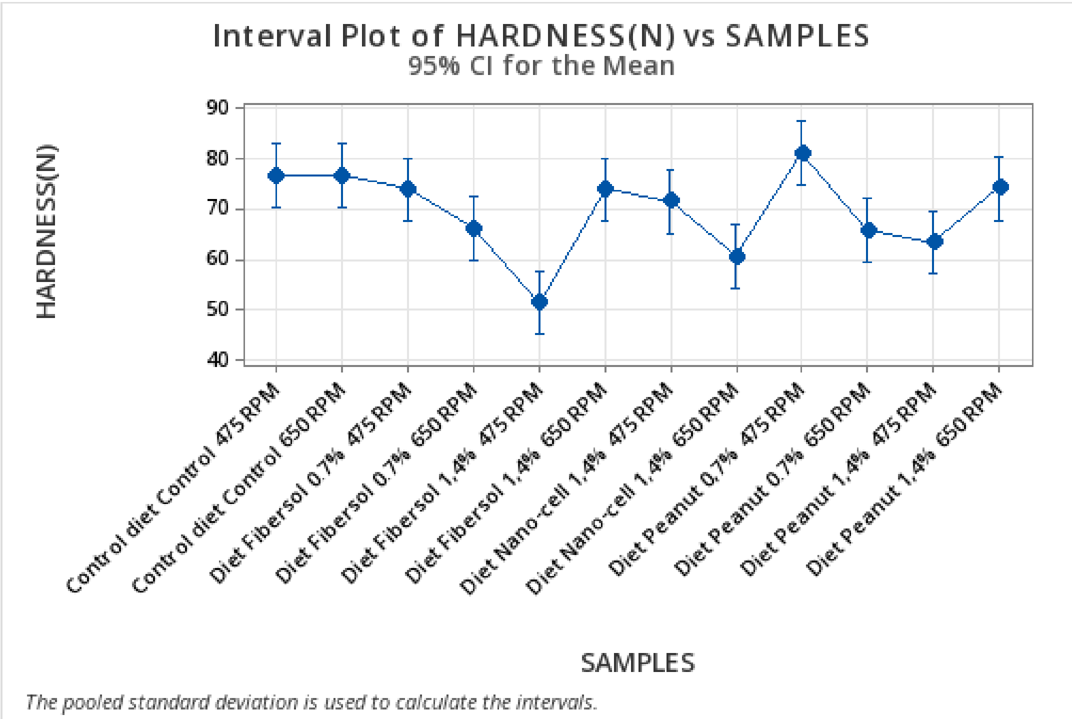

Figure 17 INTERVAL PLOT OF hardness all diets

5.2.4 Moisture Content:

Moisture content is a crucial parameter that affects the stability, texture, and palatability of pet food. In this study, the moisture content values varied across different diets and screw speeds. The Diet Peanut 0.7% (475 rpm) had the highest moisture content (18.70%), indicating increased water retention during processing. The Diet Peanut 1.4% (650 rpm) had a lower moisture content (11%). Among the diets with added peanut, Fibersol, and Nano-cellulose, variations in moisture content were observed. Diets with higher fiber content generally exhibited slightly higher moisture content, indicating increased water retention due to the hydrophilic nature of fibers.

5.2.5 Durability:

Durability represents the resistance of the pet food kibbles to breakage during handling and consumption. Durability was measured using two different methods: Doris and Holmen. The results indicated that the diets and screw speeds had a limited impact on durability, as the differences observed were not significant. Both Doris and Holmen's durability values were consistently high across all diets and screw speeds, ranging from 96.3% to 99.88%. moreover, Diet Fibersol 1.4% (475pm) has the highest durability after coating the kibbles, and Diet Peanut 0.7% (475 rpm) has the highest durability without coating This indicates that the pet food kibbles produced in this study were generally robust and able to withstand normal handling and chewing.

6. Conclusion

In conclusion, the experimental results demonstrate that the physical quality of pet food kibbles is influenced by various factors, including the screw speed of the extruder and the composition of the diets. The lower screw speed of 475 rpm resulted in more compact kibbles with higher moisture content and water activity, indicating increased water retention during processing. Different fiber sources, such as peanut, Fibersol, and Nano-cellulose, had subtle effects on the physical parameters of the pet food kibbles, but these differences were not consistently significant. Furthermore, the diets and screw speeds showed limited impact on the hardness and durability of the kibbles, as they exhibited high values across the experimental conditions. These findings highlight the importance of considering both processing parameters, such as screw speed, and dietary composition, including fiber sources, to optimize the physical quality of pet food kibbles. Further studies should explore additional screw speeds, higher fiber content, and alternative fiber sources to gain a more comprehensive understanding of their effects on pet food quality. By enhancing our knowledge in this area, the pet food industry can continue to improve the nutritional value and overall appeal of pet food products.

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