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Influence of Particle Size Distribution before and After Grinding on Quality of Pelleting (Oat and Barley) in Chitwan

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Abstract

This experiments was carried out at National Cattle Research Program Rampur chitwan command area feed industry. In this study there were four types feed samples were used to making of pellet feed test quality of the pellet durability, hardness, and moisture content of the oat and barley based feed. Results showed that pellet durability test in Feed 1 shows the better Pellet Durability Index (PDI) 79% with the hammer mill screen size 3 mm compare to other Feed 2, Feed 3 and Feed 4 with 61.83%, 44.16% and 53.5% in screen size 6, 3 and 6mm respectively. This may indicate that Barley beta-glucan increase solubility and thus increase viscosity after pelleting compare to oat based feed. So it would be better for the use of barley based feed in screen size of 3mm. The pellet hardness test results is better in the Feed 1 with 50% of barley and 30 % of oat because the binding capacity of barley is more to compare with oat. Similarly, the Feed sample 4 also showed good hardness as it contained 20% barley, 30 % whole Barley but with only 30% oat. From the experimental results and data, it can be concluded that different screen sizes of Hammer mill affect the Particle size distribution of oat and barley in the pellet quality.

Keywords: *Pellet, Grinding, Durability, Feed conversion ratio*

Introduction

Grinding is a key stage of feed manufacturing. It is additionally the supreme low-cost and modest exercise and effects in a plentiful reduction in particle size and expose of further surface area to rub of compounds as well as to the gastrointestinal juices. Most of the components in poultry nutrition today, with the omission of cereals, are previously ground when reach the feed mill. Hence, the common technique has been to grind the maize, wheat, Oat, millet, etc., to roughly the same particle size as the preground ingredients. The grinding of ingredients generally raises feed digestibility, mixing stuffs, increases the bulk mass of some ingredients, and simplifies further processes such as extrusion and pelleting (Nir, et al 1995, Nir 1996). Particle size reduction improves mix-ability, increases surface area, which can enhance protein Denaturation and gelatinization contributing to pellet quality. Pelleting has become one of the most common processing methods used to shape feeds. Pellets in the context that we use the word can be defined as a cylinder of feed of varying length and width, produced by pressing the feed through a hole in a metal plate with varying thickness. Size reduction is also used to modify the physical characteristics of ingredients resulting in improved mixing, pelleting, and, in some instances, handling or transport. The reduction of whole grain to a smaller particle size will improve feed efficiency. By reducing particle size, the surface area is increased. This allows the particle surface to have greater contact with digestive enzymes in the intestinal tract in poultry studies show that too fine grinds have a negative effect on performance (Kleyn, 2004). The effects of particle size on feed quality and quality of poultry has been researched in a number of settings (Behnke, 1994). Particle size increases the surface area of the grain, thus allowing for greater interaction with digestive enzymes. It also improves the ease of handling and the mixing characteristics. In poultry diets, the effects of feed particle size appear to be confounded with complexity of the diet as well as further processing such as pelleting or crumblizing. The use of larger particle size for the grain component of a diet would result in a significant saving in the energy cost of grinding. A more developed gizzard is associated with increased grinding activity, resulting in increased gut motility and greater digestion of nutrients. Although, grinding to fine particle size is thought to improve pellet quality, it will markedly increase energy consumption during milling. Systematic investigations on the relationships of feed particle size and diet uniformity with bird performance, gut health and pellet quality are warranted if efficiency is to be optimized in respect of the energy expenditure of grinding (Amerah *et al*., 2007). Particle size distribution of barley ground using hammer mill can be affected by screen sizes, number of hammers on a rotating shaft and their size, arrangement and sharpness of hammers, the speed of rotation, wear patterns of hammers, and clearance at the tip relative to the screen or striking plate (Zijlstra, 2005; Hasting *et al*, 1980). Pelleting was introduced into Europe about 1920 and into the U.S. feed industry in the late 1920's (Schoeff, 1994). Its popularity has grown steadily until about 80% of all feed in the U.S. are currently pelleted. Today, the process is widely used because of both the physical and the nutritional benefits it provides. The physical benefits include improved ease of handling, reduced ingredient segregation, less feed wastage, and increased bulk density. Nutritional benefits have been measured through animal feeding trials (Falk, 1985). According to Reimer (1992), pellet quality is proportionally dependent on the following factors: 40 % diet formulation, 20% particle size, 20% conditioning, 15% die specifications, and 5% cooling and drying).

Improvement in poultry

(Hussar and Robblee 1962) Studied that regrinding pellets did not disturb early bird performance but matured birds fed whole pellets had better body weight gain and feed conversion. (Hull et al.1968) reported birds fed pelleted diets had a 5% better FCR, but regrinding the pellets resulted in lower feed conversion than the mass feed. (Scheideler 1991) indicated birds fed 75% whole pellets as equaled to 25% whole pellets had better feed conversion ratio. Total of 60% pellet quality is determined before the mash feed processto the conditioner. After conditioning there was increased 80% quality, but before mash has even entered the die chamber of a pellet mill. In this research we investigated the effects of different coarse and fine grinding (particle size) of barley and oat using hammer mill in relation to quality of pellet and grinding.

Materials and methods

Diets and processing

Diets formulation, processing and particle size analysis were conducted at skylark feed and mill chitwan. Four different diets were formulated with oat, barley, whole oat and whole barley. Two feeds with 30% oat, 50% barley, 12% soybean meal, 5% soy oil, 1.5% Mono-calcium P, 1.5% Ground Limestone, concentrated feed were used as control under 3 mm and 6mm sieve size of Hammer Mill (Model: E-22115 TF, Muench - Wuppertal, Germany driving by18.5kW electric motor with speed of 3000 rpm). Similarly, two feed with different concentrations of whole oat and whole barley under Hammer Mill of 3mm and 6mm sieve size were used as the experimental feed which are stated on the table below:

Table 1. Diet Formulation for the experiment.

Feed features		**Feed 1**	**Feed 2**	**Feed 3**	**Feed 4**
		Standard conditioning	Standard conditioning	Standard conditioning	Standard conditioning
Form of Processing		Pelleting	Pelleting	Pelleting	Pelleting
Grinding Hammer Mill	Sieve size (mm)	3	6	3	6
Diet formulation					
Oat	%	30	30	30	30
Barley	%	50	50	20	20
Whole Oat	%	0	0	30	0
Whole Barley	%	0	0	0	30
Soybean meal	%	12	12	12	12
Soy oil	%	5	5	5	5

Mono-calcium P	%	1.5	1.5	1.5	1.5
Ground Limestone	%	1.5	1.5	1.5	1.5
Total	%	100	100	100	100

The milled grains were transported into the mixing section by the aid of air suction fitted with the Hammer Mill filled with a type DFC filter. After mixing, sample was taken for the analysis. Each diet was mixed in a single batch of 200kg using a Dennison twin shaft high-speed mixer then conditioned in a pre-conditioner at 75°C for 30secs. Here, other samples were obtained for moisture content analysis. Feed mixed in conditioner were pelleted under pellet press (model RPM 350.100 Muench - Wupertal, Germany) adjusting the die diameter of 3.5mm and length 50mm with capacity of 600kg/h. Pellets were collected from the pellet press output in an insulation box then the temperature of the pellets was measured. At the same time, pellets coming from the pellet press were collected in a container inside a bin fixed with an electric fan for drying. After cooling inside the dryer for 10 min, another samples were taken to determine the pellet durability index using the Holmen Tester and also for the hardness test.

QualityAnalysis

Each sample of the feed collected after mixing (mash), conditioning and pelleting (final product) were kept in plastic bags until subjected to test. These samples were used to test the pellet durability, hardness, and moisture content of the feed. Dry sieving test was carried out for the particle size distribution from different feed formulation samples. Pellet durability test was done using Holmen Tester and the hardness test was done using Kahl Tester.

Sieving Test

100g of each sample were weighed into series of sieves. For feed with 3mm output, sieves sizes 2.00mm, 1.6mm, 0.8mm and 500µm were used. For feed with 6mm ouput, sieves sizes 5.6mm, 4.00mm, 3.55mm, 2.00mm, 1.6mm, 0.8mm and 500µm were used. The empty weights of the sieve were taken. Then, the weighted samples were vortexed on amplitude 1.5mm for 1min on a Retsch AS 200 (F-kurt Retsch GmbH and Co., Hann, Germany). After which the mean particle sizes based on grains that passed and grains that were left on each sieve were calculated.

Holmen Tester

Durability test were done using Holmen pellet tester (Holmen chemical ltd., Borregaard group, UK). 100g of sample were weighed and placed into a closed circuit Holmen tester. It was run for 60secs and the feed material was sieved on a 3mm opening. Then the weight of the pellet on the Holmen collector was measured. Durability is then known to be equal to percentage of material not passing through the sieve.

Hardness Test

Hardness test were performed on 20 pieces of pellets taking from diet to determine the fragmentation strength using a Kahl tester (AMANDUS KAHL GmbH & Co. Hamburg, Germany). The pellets were each placed between two steel parts; pressure was applied in form of spring and the force when the pellet cracked was measured.

Moisture content

Moisture test was done to determine the moisture content. It was done in a machine Sartorius; Skylark feed. The chamber containing the measuring section was opened and Aluminum plate was placed on it and tare. Then the feed sample was placed on it with a spoon. 3gm weight was taken and spread through the plate. Start button was pressed and the calculation was done automatically with the machine. After the calculation, moisture content was recorded in percentage. Same process was repeated for the rest of the sample.

Table 2. Standard conditioning pelleting parameters for the feed formulated.

		Feed 1	Feed 2	Feed 3	Feed 4
Processing Parameters		Standard Conditioning	Standard Conditioning	Standard Conditioning	Standard Conditioning
		Pelleting	Pelleting	Pelleting	Pelleting
Grinding					
Hammer Mill	mm	3	6	3	6
Pelleting					
PT 100	ºC	75	75	75	75
Die diameter	mm	3.5	3.5	3.5	3.5
Die length	mm	50	50	50	50
Capacity	kg/h	600	600	600	600
Feeder	%	33	33	33	33
Motor load	%	33	26	33	29
Amperes Motor 1	amp	15.5	15.5	15.5	15.5
Amperes Motor 2	amp	14	14	14	14
Ampers motor (SUM)	amp	29.5	29.5	29.5	29.5
Energy Consumption	kw	18.1429	18.1429	18.1429	18.1429
Specific Energy Cons.	kWh/kg	0.0302	0.0302	0.0302	0.0302
Steam Temperature	ºC	56	49.5	51	50
Temperature					
Temperature at the pellet die outlet	set/ºC				
Measured / Lasser	ºC				
Measured / ISO - Box	ºC	83	82.1	83.5	82.7
Sample Collection					
Grinding (Mash)	Kg	2	2	2	2
Conditioning	Kg	2	2	2	2
Final Product (Pelleting)	Kg	2	2	2	2

Results

Particle size distribution

Particle size distribution of dry sieved Oat and Barley through Hammer mill of 3mm and 6mm screen size is shown in figure 1.

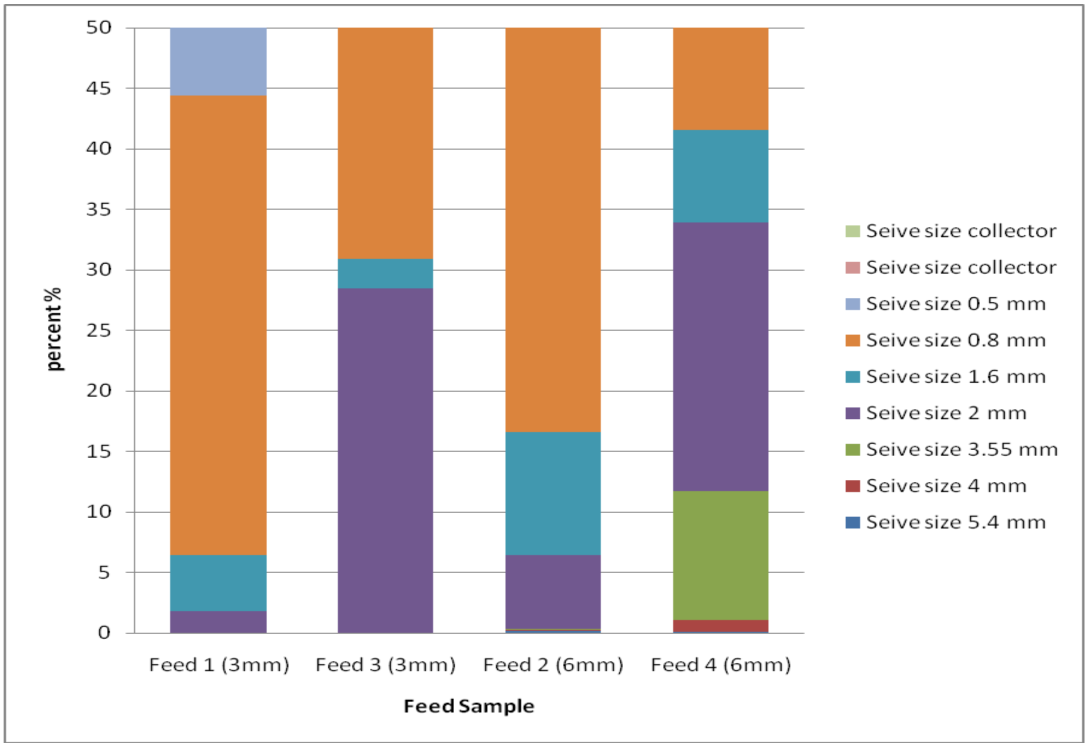

Fig. 1. Particle distribution of Oat and Barley grounded in a Hammer mill (HM) fitted with 3 and 6mm screens.

Holmen Pellet Tester

Holmen Pellet tester was used to determine the durability of the pellet.

S.N.	Feed sample	PDI (%)
1	Feed 1 (3mm)	79.33
2	Feed 2 (6mm)	61.83
3	Feed 3 (3mm)	44.16
4	Feed 4 (6mm)	53.5

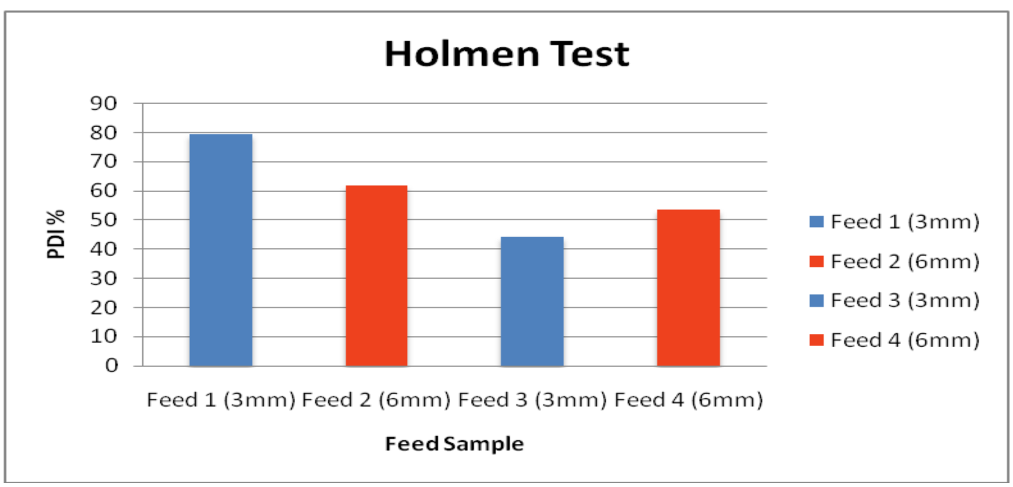

Figure 2. Pellet Durability Index (PDI) as a function of diet composition and sieve size.

Hardness Test

The hardness of the pellets was tested. The maximum hardness of the pellet was determined in feed1 with 3mm pellets and minimum hardness was determined in feed3 with 3mm pellets. From the data comparing with 3mm sieve size materials, the pellets formed was determined to have maximum hardness with 30 % Oat and 50 % Barley but the materials from the same sieve size with 30% oat, 20% barley and 30 % whole oat was determined to have minimum hardness. The reason for this may be due to less binding of the materials with whole oat. The feed with same amount of oat and barley but 30% whole barley was determined to have good hardness. From this it can be noted that the feed with 30% oat and 50 % barley with 3mm sieve size and 30% oat, 20% barley and 30 % whole oat have good hardness than feed with other composition.

Variable	Mean	SE Mean	StDev	Variance	Sum
Feed 1(3mm)	4.495	0.263	1.176	1.383	89.900
Feed 2(6mm)	2.945	0.171	0.767	0.588	58.900
Feed 3(3mm)	2.565	0.154	0.690	0.476	51.300
Feed4(6mm)	4.245	0.248	1.111	1.234	84.900

Table: Hardness test compared with the standard deviation and feed with different sieve size

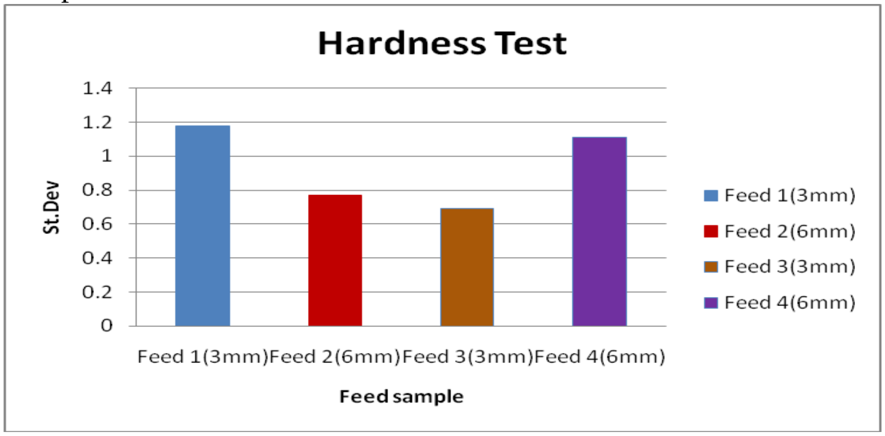

Figure 3. Hardness test compared with the standard deviation and feed with different sieve size

Moisture Content

Moisture content of the feed affects quality of pellets. Required percentage of moisture content in the conditioner is beneficial for swelling and degree of gelatinization of the pellets, which increases the binding capacity within pellets. The moisture content during the conditioning was determined to be higher than in the pelleting. It is obvious because we are adding steam during the conditioning process. The highest percentage of moisture was determined in the feed 2 (6mm). It was the first sample used for the determination of moisture content after collection of all the samples. So, it may be the reason for higher percentage of moisture than others. The samples tested later showed minimum percentage of moisture than first one. The reason for this may be due to the temperature in the lab which helped in drying of the samples.

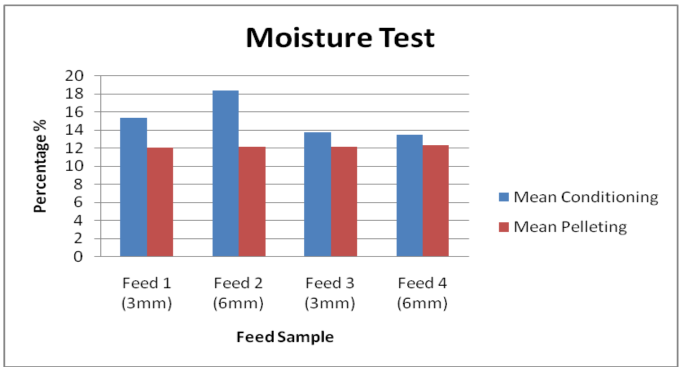

Figure 4. Variation of Moisture content during different stages of feed processing

DISCUSSIONS:

Particle size distribution

Fig 3 shows that the Dry-sieving of the pellets indicates differences in particle size distribution between diets based on oats and barley after pelleting, especially for proportion of coarse particles over 3 mm. Grinding barley resulted in coarser particles in the compared with oats. The barley diet (6mm) consisted of 25.3% of particles over 3 mm compared with 22.6% in the fine oats diet (6mm). That is maybe due to differences in endosperm hardness between these two grain types (Amerah et al., 2008). The amount of particles over 1mm reduced after pelleting compared to conditioning because of the mechanical influence on the materials to some extent. Some experiment before indicated that a variation in particle size showed a better pellet than a homogeneous particle size. It is in agreement with the findings of this experiment. Feed 1(3 mm) with large variation in particle size has the best durability and hardness. In addition, insoluble plant fibers can entangle and fold among different particles or strands of fiber and hence contribute to adhesion between particles in the pellets. The particle size of the fibers however has a large influence on pellet quality. Large fiber strands within the pellet are possible weak spots which facilitate breaking of the pellet, thus decreasing their quality. The increase in the amount of coarse particles may result in more fractures and weak spots in the pellet due to reduced particle surface area. Small particles on the other hand enhance pellet quality due to more inter-contact sites which allow better heat moisture penetration into feed components. (Svihus 2004a) reported that the average particle size tends to be smaller than when whole cereals are used when a standard ground cereals is used. This suggests that in fact the gizzard is a more effective mill than the hammer mill used in the factory.

Durability

Result from pellet durability matched our hypothesis that the pellets would exhibit higher durability due to smaller particle size based on oat and barley. The results of the experiment figure 4 indicates that durability is significantly improved by reducing particle size, where feed 1 indicated 79.33 % of durability followed by feed 2, feed 3, feed 4 with (61.83, 44.16 and 53.5) screen size of 3mm,6mm,3 mm and 6 mm respectively. Which is also been done by (Angulo et al., 1996). The pellet durability was improved for the 3mm grinding screen sizes compared to the 6mm. This is probably because of larger contact area and greater starch gelatinization for smaller particles as compared to larger particles. For it can be achieved in a shorter time with small particles and a large surface area for absorption of heat and moisture to the core of a particle (Behnke, K.C., 1994).By decreasing particle size from a coarse to a fine particle also increases the surface area for bonding. This is in agreement with the findings of (Amerah et al., 2008) and (Svihus et al., 2004b), in which pellets made from fine particles showed better durability compared with those made from coarsely particles. However, when diets are added with whole oat, the smaller particle size did not show a better durability compared to barley. That is maybe related to the chemical and physical characteristics of these two different grains.

Hardness

The hardness of the pellets was tested. The maximum hardness of the pellet was determined in feed1 with 3mm pellets and minimum hardness was determined in feed3 with 3mm pellets. From the data comparing with 3mm sieve size materials, the pellets formed was determined to have maximum hardness with 30 % Oat and 50 % Barley but the materials from the same sieve size with 30% oat, 20% barley and 30 % whole oat was determined to have minimum hardness. The reason for this may be due to less binding of the materials with whole oat. The feed with same amount of oat and barley but 30% whole barley was determined to have good hardness. From this it can be noted that the feed with 30% oat and 50 % barley with 3mm sieve size and 30% oat, 20% barley and 30 % whole oat have good hardness than feed with other composition. The result of the experiment indicates that hardness is significantly improved by using more barley. The pellets have maximum hardness with 30 % Oat and 50 % Barley with 3mm sieve size from the data. The reason for this may be due to less binding of the materials with whole oat compared to barley. From the data, we found hardness is significant positive correlated with durability. According to (Zimonja et al., 2008) Barley Beta-glucans increase solubility and thus increase viscosity after pelleting. High viscosity of soluble fibers may improve the structural integrity of the feed consequently improving durability and hardness of the pellets. Research by (Thomas et., al 1998) the effect of un-dissolved plant fibers may be twofold. Plant fiber may prove beneficial in the pelleting process since they have the opportunity of entangling and folding between different particles or strands of fiber. On the other hand due to their stiffness and elasticity, they may impair problems to the pellet-press operator since resilience characteristics of the material oppose good contact between particles or fibers. Moreover, when large fibers are present within the pellet, they might induce a weak spot in the pellet. Large particles may serve as in homogeneity at which pellets are most likely to break. Increasing the residence time in the die of the pellet press would diminish the effects due to the resilience of the material.

Moisture content

Moisture content of the feed are expected to affects quality of pellets. Required percentage of moisture content added in the conditioner is beneficial for swelling and degree of gelatinization of the pellets, which increases the binding capacity within pellets. The moisture content during the conditioning was determined to be higher than in the pelleting. It is obvious because we are adding steam during the conditioning process. The highest percentage of moisture was determined in the feed 2 (6mm), however, it did not show the best physical quality. The moisture content of all the samples after pelleting showed no significant difference with different particle size. But it was reported that high moisture pellets for chicken diets produced higher durability compared to low moisture equivalents (*www.poultrypro.com*). However, the moisture content did not have obvious effect on the physical quality of pellets in this experiment. That is maybe the added moisture is not enough to get a significant difference.

CONCLUSION

It is concluded that the strong point of pelleted feed based on cereals is affected by the size of the particles when feed are manufactured under the similar settings of temperature and pressure. The coarser particles produced resulting weakest pellets. These pellets are able to hold out smaller deformations when compared to pellets made of finer particle sizes.

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