EFFECT OF STEAM CONDITIONING ON PHYSICAL PROPERTIES OF PELLETS AND ENERGY CONSUMPTION IN PELLETTING PROCESS

UTICAJ KONDICIONIRANJA PAROM NA FIZIČKA KARAKTERISTIKE PELETA I POTROŠNJU ENERGIJE U PROCESU PELETIRANJA

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ABSTRACT

In this paper, effect of moisture addition during steam conditioning of feed on pellet quality and electrical energy consumption in pelleting process was investigated. Complete mixture for pigs II (from 15 to 25 kg) was conditioned up to moisture content of 15.97 %, 19.40 %, and 21.88 %. Physical properties examined in course of pellet quality determination were hardness and durability of pellets. Pellets, produced from conditioned material with higher content of moisture, were more stable and less hard. Higher moisture content of conditioned material resulted in decreasing of energy consumption during pelleting process. Electrical energy consumption in pelleting process, along with achieving targeted pellet quality, could be significantly lower by choosing proper conditioning process parameters.

Key words: pelleting process, steam conditioning, moisture content, energy consumption, pellet quality.

REZIME

Proces kondicioniranja u proizvodnji hrane za životinje podrazumeva prevođenje praškaste mešavine u fizičko stanje pogodnije za sabijanje smešte delovanjem toplote, vlage i pritiska sa određenom vremenskom periodom. Kondicioniranjem se povećava proizvodni kapacitet i istovremeno podiže kvalitet hrane sa fizičkog, nutritivnog i higijenskog aspekta. Primena vodene pare u proizvodnji hrane za životinje već dugo niz godina se smatra dobrim načinom za postizanje visokog kvaliteta peleta. Dodatak pare u procesu kondicioniranja utiče na porast sadržaja vlage i temperature smešte. Iz pomenutih razloga, u ovom radu ispitivani su efekti povećanja vlage, pri kondicioniranju vodenum parom i vodom, na potrošnju električne energije i kvalitet peleta u procesu peletiranja kondicionirane hrane za životinje. Kompletan smer za svinje II (od 15 do 25 kg) kondicionirana je do temperature od 80 °C i sadržaja vlage od 15,97 %, 19,40 % i 21,88 %. Kondicionirani materijal je zatim peletiran na presi za peletiranje sa ravnom matricom, AMANDUS KAHL GmbH & Co. KG, Nemačka. Fizičke karakteristike, koje su ispitivane u cilju definisanja kvaliteta peleta, bile su tvrdoće i otičanje peleta. Za statističku obradu podataka korišćen je softver Statistical Analysis System (Statistical, Tulsa, Oklahoma, USA). Pelenke proizvedene od kondicioniranog materijala sa većim sadržajem vlage bile su značajno (p < 0,05) stabilnije (sniženje procenta abrazije), ali manje tvrdoće. Potrošnja električne energije u procesu peletiranja je očuvana sa displeja prese za peletiranje. Primećeno je da je za peletiranje materijala sa povećanom količinom vlage (19,40 % i 21,88 %) potreban značajno (p < 0,05) manji utrošak energije u poredenju sa materijalom sa 15,97 % vlage. U ovom radu pokazano je da se odabirom odgovarajućih procesnih parametara može značajno smanjiti potrošnja električne energije, uz istovremeno postizanje željenog kvaliteta peleta.

Ključne reči: peletiranje, kondicioniranje vodenum parom, sadržaj vlage, potrošnja energije, kvalitet peleta.

INTRODUCTION

Conditioning in animal feed production is process of converting mixed mash with use of heat, water, pressure and time, to a physical state which is more suitable for compaction of feed mash. Conditioning increases production capacity and, in the same time, affects physical, nutritional, and hygienic quality of produced feed (Sredanović and Lević, 2000). Addition of heat and water leads to changes of components, such as starch and protein, in a way that binding property comes into effect. Production output, energy consumption and pellet quality are closely related, depending on applied combination of process variables. Applying too much heat or water has negative effect on production capacity and pellet quality and may lead to plugging of pellet press die. Properly conditioned feed mash will give pellets with good durability, hardness and hygienic quality, together with improved nutritional value of feed (Thomas et al., 1997; Winoviski, 1985).

Final choice of conditioning equipment depends on several different factors. On the first place, it depends on type of processed feed; cattle feed requires different method of processing than pig feed. Significant attention should be paid on necessary range of processing conditions and on system variables.

Applications of steam in animal feed manufacturing have long been recognized as a good way to achieve production of high quality pellets (Sredanović et al., 2005). Overall effect of steam addition is an increase in moisture content and heat of feed mash. Because of its gaseous state, steam is more homogeneously dispersed trough mixtures than water. Thin film of water is created around the particles of compounds during condensation of steam, and its main activity is facilitating of bindings between these particles, along with temperature increasing. This effect can be explained through two phenomena’s: water itself builds bonds between particles, and secondly, heat and water induce wide range of physical and chemical change, such as thermal softening of feed, denaturation of proteins, and gelatinization of starch (Maier and Gradecki, 1992; Thomas and van der Poel, 1996).

Pelleting is a process of pressing conditioned material trough die with specific dimensions of openings and thickness. Main objective of this process is to obtain feed pellets quality which is enough to stand rigors of transport and handling with the least possible cost in terms of energy consumption and wear. A majority of pellet presses used in feed industry have ring die design, in which the die rotates around the fixed rollers. Minority is designed as flat-die press, with horizontal static die and vertical
rotated rollers, usually used for small capacities and experimental work (Thomas et al., 1997; Pfost, 1971).

Physical quality of feed pellets is important for numerous reasons. Transportation and handling require pellets of certain integrity without fines produced by attrition stresses. Pellets of high physical quality must have properties which give high nutritional quality, in terms of better feed intake and improved nutritional value. Pellet physical characteristics, which are usually used for determination of pellet quality, are hardness and durability. These quality parameters can also be used to evaluate effects of diet formulation, conditioning, and expander treatment, pellet binders, die selection, etc. (Pfost, 1963). Hardness is defined as force necessary to crush a pellet or a series of them at the same time. It is usually determined by using equipment which measures force needed to fragment the pellet. Test devices for hardness have been developed for both scientific objectives and on-line application in routine animal feed production. Pelleted feeds are exposed to shearing and abrasion during transportation in practical feed manufacturing which induces fines in the feed. Pellets need to have a certain resistance against stresses exerted on them in order to make process of feeding easier. Durability test, which is used for evaluation of shearing and abrasion, is defined as amount of fines returning from pellets after being treated with mechanical or pneumatic agitation (Thomas and van der Poel, 1996; Skoch et al., 1983; Stevens, 1987; Pfost, 1963).

Purpose of this study is to examine effect of steam conditioning process parameters on pellet quality and energy savings in pelleting process.

MATERIAL AND METHOD

Complete mixture for pigs II (from 15 to 25 kg) was conditioned in double-shaft paddle mixer - steam conditioner, Muyang SLHSJ0.2A, China, up to moisture content of 15.97%, 19.40%, and 21.88%, until material reached temperature of 80°C. Batch size was 25 kg. Steam was injected in the conditioner under pressure of 2 bar. In order to achieve final moisture content (19.40% and 21.88%) water is added directly into feed mash.

Conditioned material was pelletized on flat die pellet press 14-175, AMANDUS KAHL GmbH & Co. KG, Germany. Diameter of pellet die openings was 6 mm, with die thickness of 20 mm (channel length 18 mm). Pellets were stored for 24 hours under room conditions in order to achieve stable temperature.

Bulk density was measured with bulk density tester (Tonindustrie, West und Goslar, Germany) and moisture content was determined with moisture analyzer (OHAUS MB 45, Switzerland), both in dry and conditioned material, and, after pelleting, in warm and cold pellets.

Pellet hardness was determined with “Pellet Hardness Tester”, AMANDUS KAHL GmbH & Co. KG, Germany. Pellet is inserted between two bars, and by manually increasing statical pressure, force needed to crack the pellet is determined. The average of 15 measurements is referred to as the “Kahl hardness” (KH) of the pellet.

Durability of pellets was determined with “Pellet Durability Tester”, Bühler, Switzerland. It is determined by inducing fines trough abrasing action of pellets shearing over each other and over the wall of drums (tumbling can device). The procedure is standardised by using a drum with specified dimensions, in which 500 g of sieved pellets are inserted. After tumbling for 10 min at 50 r/min, pellets are subsequently sieved and the amount of fines passing a sieve with a grid size of 0.8 x pellet diameter was determined. Durability is expressed as the ratio of the weight tumbling over the weight before tumbling, multiplied with 10.

RESULTS AND DISCUSSION

After determination of physical properties, raw material was poured in double-shaft paddle mixer - steam conditioner, and mixed for two minutes, in order to achieve fluidization of material, which provides better material-steam contact. The steam and water were subsequently added directly into material. Targeted temperature level for all conditioning treatments was 80°C. Physical properties of raw and conditioned material were determined, and they are listed below (Table 1). It can be seen that bulk density of conditioned material is lower in comparison with unconditioned material.

<table>
<thead>
<tr>
<th></th>
<th>Moisture content (%)</th>
<th>Bulk density (kg/dm³)</th>
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<tbody>
<tr>
<td>Unconditioned material</td>
<td>10.59</td>
<td>0.62</td>
</tr>
<tr>
<td>Conditioned material 1</td>
<td>15.97</td>
<td>0.55</td>
</tr>
<tr>
<td>Conditioned material 2</td>
<td>19.40</td>
<td>0.54</td>
</tr>
<tr>
<td>Conditioned material 3</td>
<td>21.88</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Conditioned material was placed in receiving hopper of pellet press feeder. Feeder was adjusted at dosing speed of 16 kg of conditioned material per hour. Roller speed was set at maximum frequency (63.5 Hz). During pelleting process, temperature of die and pellets was measured. Temperature trend of conditioning and pelleting process is shown at Figure 1. Material with moisture content of 15.97% (conditioned material 1) had higher temperature increase in pellet press die, due to higher friction between material and the die. Increasing of moisture content of material to 19.40% and 21.88% (conditioned material 2 and 3) lowered friction because steam and water had lubricating effect on material.

![Fig. 1. Temperature trend of material during processing](image)

Moisture content of material was determined. The results are shown at Figure 2. During pelleting process, it was noticed that material was losing approximately 1% of moisture at pellet press. After 24 hours, moisture content of pellets continue to decrease, and water loss was in range 3 ÷ 5%, depending of applied conditioning treatment.

Results of pellet quality testing are shown in Table 2. Addition of water and steam in material before pelleting influenced hardness of pellets in terms of softening of material. Pellet hardness of conditioned material 1 was significantly higher than hardness of conditioned material 2 and 3. Also, water and steam added in conditioning process improved binding of particles during pelleting process which had positive effect on pellet durability.
Fig. 2. Moisture content of material

Table 2. Pellet quality

<table>
<thead>
<tr>
<th>Conditioned material</th>
<th>Pellet hardness (KH)</th>
<th>Pellet durability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.62 ± 1.60 a</td>
<td>11.32 ± 0.54 a</td>
</tr>
<tr>
<td>2</td>
<td>6.03 ± 1.72 b</td>
<td>8.96 ± 0.57 b</td>
</tr>
<tr>
<td>3</td>
<td>5.35 ± 2.00 b</td>
<td>6.55 ± 0.18 c</td>
</tr>
</tbody>
</table>

Results are mean ± Standard deviation of 15 measurements for pellet hardness and mean ± Standard deviation of 2 measurements for pellet durability.

*Means with different letters in the same column for each sample are significantly different at the 5% level.

Energy consumption in pelleting process was read out from pellet press display and values are presented in Table 3. It can be seen that, with increase of moisture content of material, energy consumption of pellet press decreased due to lower friction between die hole wall and material.

Table 3. Energy consumption in pelleting process

<table>
<thead>
<tr>
<th>Conditioned material</th>
<th>Energy consumption (kWh/t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>46.25 ± 2.37 a</td>
</tr>
<tr>
<td>2</td>
<td>43.75 ± 2.06 a</td>
</tr>
<tr>
<td>3</td>
<td>42.50 ± 1.75 a</td>
</tr>
</tbody>
</table>

Results are mean ± Standard deviation of 11 measurements.

*Means with different letters in the same column for each sample are significantly different at the 5% level.

CONCLUSION

Conditioning is one of the key unit operations in pellet production. Water and steam addition in material prior to pelleting process affects pellet quality. Improvement in binding of particles during pelleting process can be achieved with addition of water and steam during conditioning process which has positive effect on pellet durability. On the other hand, addition of water and steam lowers the hardness of pellets. Pellets with higher moisture content have higher durability and lower hardness. Also, water and steam addition reduced energy consumption of pellet press. Choosing of proper conditioning process parameters could provide savings of electrical energy consumption in pelleting process, along with achieving targeted pellet quality.

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