EFFECTS OF CHEMICAL CHANGES OF STARCH AND PROTEINS ON PHYSICAL PELLET QUALITY IN RESPECT TO EXTRUSION TECHNOLOGY

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EFEKTI HEMIJSKIH PROMENA SKROBA I PROTEINA NA FIZICKE OSOBINE PELETA U ODNOSU NA TEHNOLOGIJU EKSTRUDIRANJA

Abstrakt

Termalna obrada stočne hrane utiče i pozitivno i negativno na dostupnost glavnih nutrijenata hrane, a od posebnog je značaja u slučaju skroba i proteina. Prilikom obrade stočne hrane skrob i proteini su izloženi jedinstvenim i nepovratnim hemijskim modifikacijama. Ove modifikacije uključuju promene u molekularnoj strukturi kroz procese želatinizacije skroba, odnosno denaturacije proteina i mogu da rezultuju u povoljnim funkcionalnim osobinama odnosno nutritivnim vrednostima pomenutih komponenti. Međutim, pregrevanje stočne hrane prilikom termalne obrade vodi do degradacije skroba i proteina praćeno formiranjem novih kompleksa među komponentama hrane, što na kraju rezultuje negativnim nutritivnim vrednostima. Namera iznetog rada je ustanovljenje generalnih međusobnih odnosa između proizvodnih faktora koji karakterističu termalnu obradu stočne hrane i hemijskih modifikacija skroba i proteina, kao i njihovog pratećeg uticaja na fizički kvalitet peleta.

Kljucne reči: *želatinizacija skroba, denaturacija proteina, fizički kvalitet peleta*

INTRODUCTION

A majority of the 600 million tons of compound feed produced annually are pelleted (G i l l, 2003). By the agglomeration of the various feed particles into pellets, challenges of the mash feeding such as selective eating and/or segregation of the ingredients could be solved. Supplementary benefits of pelleting includes: reduced dust problems, decreased feed wastage, destruction of pathogenic organisms, less energy spent for prehension, and eventually improved animal performance. The physical quality of the pellets is instrumental in achieving these goals. If the durability and hardness is insufficient, pellets may break during storage and transport resulting in dust problems and feed loss. Although a lot still remains to be elucidated on the causes for varying physical pellet quality, composition of the diet and processing conditions have been shown to be major factors.

Extruders are assembled as either single- or twin-screw machines. Screws are designed as changeable segments that enable mixing, conveying of the feed mash (forward and backward), kneading and developing of shear forces, with an ultimate generation of temperature and pressure. Although a huge variety of screw elements and consequent configurations exists, generally three different regions/zones along the extruder barrel can be identified; feeding zone (moistening and preheating of feed mash), kneading zone (transition of the feed mash to a plasticized dough-like mass) and final a cooking zone. Shaping of the extruded material is achieved at the outlet die by the action of rotating knifes (mounted at the die outlet) and by the shape of the die. Interrelations among screw configurations associated with application of the either thermal (steam) or electrical energy, facilitate great flexibility in control of production conditions such as temperature (90 to over 140ºC), total moisture content (about 30 %), residence time (up to 60 seconds), and subsequent pressure generation (up to 40 bars). The advantage of extrusion process compared to conventional pelleting is a greater flexibility in product applications, better sterilization of the feed and an improved pellet quality.

Generally, processing of the feeds comprises physical, chemical and thermal treatments of feed previous to animal utilization (M a i e r and B a k k e r – A r k e m a, 1992). Processing treatments of the feed can vary from the simple process such as blending in the form of mash, over conventional pelleting to more complex processes when expander or extruder is used (P i p a and F r a n k, 1989). Often, they are applied in order to achieve certain specific goals such as gelatinisation of starch, denaturation of proteins, inactivation of anti-nutritional factors (endogenous enzymes, trypsin inhibitors, etc.), drying/cooling and product shaping (V o r a g e n et al. (1995). These changes have influence and/or overall beneficial effect on physical characteristics, digestibility and nutritional value of the feeds.

STARCH: GELATINISATION AND PHYSICAL PELLET QUALITY

When subjected to thermo-mechanical treatments of the feed, starch can be modified by mechanisms such as swelling, gelatinisation and retrogradation. Swelling commences along more accessible and amorphous regions, while crystalline regions mainly remain intact. As the temperature rises above the characteristic temperature known as the gelatinisation temperature, disruption of intermolecular hydrogen bonds between amylose in amorphous regions and amylopectin in crystalline regions increases. At a certain point, when a sufficient amount of heat is present, the crystalline regions are rapidly and irreversibly broken down, indicating gelatinisation. At excess water, gelatinisation temperature for most cereal starches ranges between 50 and 70°C. Aside from swelling and disruption of the molecular and granular structures of the starch during gelatinisation, the viscosity of the media also increases. Under processing conditions where water and/or other solvents are present in limited amounts (<30 %), differences in gelatinisation behaviour can be expected (E l i a s s o n and G u d m u n d s s o n, 1996).

C o l o n n a et al. (1992) reported a dramatic increase of gelatinisation temperature from 50-60ºC at excess water to above 100ºC at limited (<35%) moisture systems. L u n d (1984) and J a c o b s and D e l c o u r (1998) reported a minimum ratio of 0.3:1 (water: starch) as a prerequisite to initiate starch gelatinisation during heating process.

Compared to a conventional pelleting, extrusion processing causes more complete gelatinisation and disintegration of the starch granules (Z i m o n j a and S v i h u s, 2008). However, the extent of gelatinisation is a function of the variable production parameters during extrusion. H o n g t r a k u l et al. (1998) showed that extrusion of maize with a barrel temperature of 103ºC resulted in a rate of starch gelatinisation of 38.7 % at moisture content of approximately 30 %. When temperature increased up to 137ºC the rate of the gelatinisation was 89.3 %. C h i a n g and J o h n s o n (1977) showed that lowering screw speed lead to increase of the gelatinisation due to prolonged residence time in the extruder. A similar observation was reported by T h o m a s et al. (1999) when expander-pelleting process was used. In a study by Z i m o n j a and S v i h u s (2008), a doubled input of specific mechanical energy was required to gelatinise wheat starch to the same extent as oat starch. Similar observations were also found by C a s e et al. (1992), where different cereal sources required different extrusion conditions to achieve the same level of gelatinisation.

C a s e et al. (1992) also showed that increase in gelatinisation resulted in increased volume and breaking strength of extrudate, while bulk density decreased. B h a t t a c h a r y a and H a n n a (1987) and C a s e et al. (1992) showed positive correlation between increase in gelatinisation and expansion ratio of the extruded pellets. This clearly indicates beneficial effect of gelatinised starch to a physical pellet quality. However, mechanism that follows starch contribution to binding of feed particles is still to be revealed.

PROTEINS: DENATURATION AND PHYSICAL PELLET QUALITY

When subjected to thermo-mechanical treatments proteins undergo disorganisation of the overall molecular structure, usually as unfolding or uncoiling of a coiled or pleated structures, or as a separation of the protein into subunits, followed by aggregation. If thermo-mechanical treatment ceases before aggregation is initiated, unfolding is a reversible process and protein can retain its native structure. However, if sufficient heat is present, non-covalent interactions (hydrophobic and electrostatic) which maintain protein structure may lead to irreversible alteration of the quaternary, tertiary or secondary orders of the proteins. Under severe and/or prolonged heating, however, protein denaturation may be followed by association and disassociation reactions, which ultimately may result in destruction of primary structure, often referred to as a degradation of the protein (F i n e l y, 1989). Transition from the native state of the protein to denatured and/or more destructed forms is interrelated with the production parameters, source of the protein and subsequent interactions among proteins and other components in solution. The denaturation temperature (T_d) for most protein sources is usually below 100ºC, but is highly dependent on the water content in the solution. A study by K i t a b a t a k e and D o i (1992) showed that at excess water T_d of the main storage proteins in soybean meal, conglycinin (7S) and glycinin (11S), is 76.5 and 93.3ºC, respectively. When moisture content decreased to 29 %, however, T_d of glycinin could not be detected, while T_d of conglycinin shifted to over 180°C. This indicates that proteins such as soy globulins and/or sunflower globulins are relatively heat stabile in low moisture systems. Work by

H o s e n e y (1994), on the other hand, showed that gluten proteins such as those in wheat will unfold at moisture content of 16 % even at room temperature. Beneficial effect of the proteins on physical pellet quality has been shown by W i n o w i s k i (1988) where a dramatic increase in pellet durability was observed by increasing overall protein content through addition of wheat rations from 0 to 600 g kg^{-1} diet. Similar results were also shown by B r i g g s et al. (1999), where a positive correlation between pellet durability and increased protein content in the diets was found. Although a number of investigations suggest that proteins derived from plant sources such as wheat (W i n o w i s k i, 1988; B r i g g s et al., 1999), barley (M o r a n, 1989) and soybean meal (C a v a l c a n t i, 2004) will improve physical pellet quality, a mechanism for binding of the feed particles and role of the proteins is not clear. Results by W o o d (1987), for example, showed a considerably higher physical quality of the diets containing raw soy protein compared to those containing denaturated protein. H a s h i m o t o et al. (2002) examined measures of beneficial functional properties of wheat gluten during extrusion, such as expansion ratio and specific volume, and found that wheat gluten was not as efficient as cassava starch. C a v a l c a n t i (2004) reported that protein derived from maize (e.g. maize gluten) had a negative effect on pellet durability. Considering the conflicting results in regard to denaturation of proteins and physical pellet quality, research is needed to investigate effects of chemical modifications of proteins and/or protein sources on pelletability.

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