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# The effect of steam pelleting of a dry dog food on the Maillard reaction

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ABSTRACT

During processing of pet foods, the Maillard reaction (MR) can occur, which reduces the bioavailability of essential amino acids like lysine and results in the formation of advanced Maillard reaction products (MRPs). This study examined the effect of conditioning temperature (65 and 90 °C) and die hole length (ø 5 × 45, 65, and 80 mm) during pelleting processing of a standard dry dog food on selected indicators of the MR (total lysine, reactive lysine, fructoselysine, ε-*N*-carboxymethyllysine, (5-hydroxymethyl)-2-furfural, lysinoalanine), browning development and CIE-Lab color. Steam pelleting variables did not cause a significant loss of lysine or change in color and absorbance values. Analyzing the unprocessed ingredient mix suggests that the choice of the ingredients used in the ingredient mix, rather than the pelleting process applied, is responsible for the RL/TL ratio observed in the dry standard dog food used in this study. MRP content increased during steam pelleting (fructoselysine: 366.2 to 538.8 mg/kg DM; ε-*N*-carboxymethyllysine: 12.6 to 14.8 mg/kg DM; lysinoalanine: 5.7 to 7.7 mg/kg DM; P<0.05). Increasing conditioning temperature from 65 to 90 °C increased fructoselysine (475.9 to 601.6 mg/kg DM; P<0.01) and ε-*N*-carboxymethyllysine (14.3 to 15.1 mg/kg DM; P=0.003). An increased die hole length of 80 mm decreased fructoselysine content compared to 45 and 65 mm (461.3 *vs.* 573.3 and 581.6 mg/kg DM; P<0.01) but increased lysinoalanine content (8.8 *vs.* 7.4 and 6.8 mg/kg DM; P=0.002). Analyzing total and reactive lysine and absorbance values are not accurate enough to predict the MR and formation of MRPs during processing.



## 1. Introduction

Pelleted dog foods are sold by manufacturers as an alternative to dry extruded dog foods. Compared to the extrusion process, the pelleting process is considered to be less severe with lower temperatures (60 to 90 °C *vs.* 80 to 200 °C) and shorter residence times (2 to 20 s *vs.* 10 to 120 s) (Crane et al., 2010). Processing is known to induce the Maillard reaction

*Abbreviations:* AGE, advanced glycation end-products; CML, ε-*N*-carboxymethyllysine; DM, dry matter; FL, fructoselysine; HMF, (5-hydroxymethyl)-2-furfural; LAL, lysinoalanine; MR, Maillard reaction; MRP, Maillard reaction product; aNDFom, neutral detergent fiber; OMIU, O-methylisourea; RL, reactive lysine; TL, total lysine.

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(MR) where a reducing sugar reacts with a free reactive amino group of an amino acid. Lysine is the most reactive amino acid due to its ε-amino group although other amino acids are also knows to be affected (Silvan et al., 2006). As the MR progresses, advanced Maillard reaction products (MRPs) are formed. As the rate of MR depends on temperature, time and pressure during processing, it can be expected that the amount of blocked lysine and formed MRPs would be lower in pellets compared to extrudates. However, it has previously been reported that commercially pelleted dog foods contain, on average, a lower ratio of reactive to total lysine (RL/TL; lysine that contains a reactive ε-amino group/total amount of lysine) compared to commercially extruded dog foods. Reported RL/TL ratios ranged from 0.72 to 0.94 ($n = 14$) in commercial pelleted dog foods, compared to 0.77 to 0.99 ($n = 14$) in commercial extruded dog foods (Tran et al., 2007; Van Rooijen et al., 2014b). The concentration of MRPs was higher in pellets; commercially available pelleted dog foods contained 1.4, 1.7 and 1.5 times more fructoselysine, carboxymethyllysine, and hydroxymethylfurfural, respectively compared to commercially available extruded dog foods (Van Rooijen et al., 2014a).

The MR can affect the nutritional quality of pet foods in different ways. Firstly, a loss of essential amino acids, especially lysine, can occur when the reactive amino group of an amino acid is the substrate of the reaction. Modified lysine derivatives like fructoselysine (FL, also referred to as Amadori compound) are formed that may be partially absorbed but cannot be utilized by the body, thereby, reducing the bioavailable lysine content (Hurrell and Carpenter, 1981; Moughan, 2003; Finot, 2005). Secondly, during the MR crosslinking of peptides can occur, for example the formation of lysinoalanine (LAL). These compounds will decrease the digestibility of the protein and, therefore, utilization and uptake of all amino acids. Finally, several pathways lead to the formation of advanced MRPs as the MR progresses, such as ε-*N*-carboxymethyllysine (CML) and (5-hydroxymethyl)-2-furfural (HMF). Their endogenous analogues, advanced glycation end-products (AGE), as well as dietary MRPs have been associated with the etiology of age-related diseases in humans, such as diabetes mellitus and impaired renal function (Singh et al., 2001). In dogs, elevated levels of AGEs in tissue proteins were observed in a number of diseases with increasing age (Bras et al., 2007; Comazzi et al., 2008; Shapiro et al., 2008; Chiers et al., 2010) and it is possible that bioavailable dietary MRPs contribute to the endogenous AGE levels in dogs as has been reported for humans (Koschinsky et al., 1997; Uribarri et al., 2005).

During pelleting, processing parameters like steam conditioning, residence time and pressure can influence the MR, resulting in a decrease in RL and an increase in the formation of MRPs. Pelleting is a processing technique in which mash conditioning, agglomeration (pelleting) and subsequent cooling take place. Mash conditioning includes heat, water and pressure, often combined in the form of steam, to induce softening of the food, denaturation of proteins and gelatinization of starch before the product enters the pellet press (Abdollahi et al., 2013). After conditioning, the mash is compacted and pressed through a die using rollers in the pellet press. The rollers continuously press layers of mash inside the die hole, by which the pellet is actually built up. The application of mechanical energy by rollers on a die results in pressure and friction in the die. The extent of compression depends on the height of the layer and the gap distance between the die and the roller. Die holes can differ in their length to diameter ratio, influencing the amount of shear which the feed mash receives. After leaving the die, pellets are usually cooled by air flow or using a conveyer belt (Thomas et al., 1997).

Studies that report the effect of the pelleting process (unprocessed meal *vs.* pellets) on RL contain contrasting results. Fluorodinitrobenzene-reactive lysine significantly increased with 0.8, 0.9 and 1.1% by pelleting an unprocessed starter, grower, and finisher pig diet meal (80 °C using a 4 mm die), respectively (Vande Ginste and De Schrijver, 1998). Pelleting a complex nursery pig diet (steam conditioned at 60 °C for 45 s through a 5 × 38 mm die) had no effect on lysine bioavailability as measured using a standard-curve bioassay with 8-d-old chicks (Mavromichalis and Baker, 2000). However, pelleting a pre-starter diet for suckling piglets (steam-conditioned at 40 °C for 30 s; pelleted at 60 to 65 °C through a 1.7 × 40 mm die) resulted in an increase of furosine (a hydrolysis product and indicator of FL) from 11.7 to 35.2 mg/kg (Delgado-Andrade et al., 2010a). The same study reported an increase in HMF from 12.6 to 16.7 mg/kg, while Shipe et al. (2012) found no effect of change in furfural concentration due to the pelleting process (steam conditioned at 82 °C, using 38.1 or 44.5 mm die hole length). All these studies aimed to elucidate the effect of the total pelleting process rather than focusing on the difference in conditioning temperature and shear forces/pressure induced by the die dimensions during pelleting. In addition, studies investigating the effect of the pelleting process for pet food manufacture are lacking.

The objective of this study was to examine the effect of steam conditioning temperature and die hole length applied during the pelleting process of a standard dry dog food on the progression of the MR as measured using selected indicators as well as browning index and color development.

## 2. Materials and methods

### 2.1. Experimental food

The ingredient mixture of a standard dry dog food, hammer milled over a 1.5 mm sieve and thoroughly mixed, was provided by a pet food manufacturer. Ingredient composition and analyzed chemical composition of the food is shown in Table 1.