Michael Gibson & Dr. Sajid Alavi

Department of Grain Science and Industry, Kansas State University, Manhattan, KS 66506

# Starch gelatinization and amylose-lipid complexation during processing of baked and extruded pet foods

## BACKGROUND

In 2011, $19.85 billion worth of pet food products were sold in the U.S. The pet food market, where 60% of all products are extruded, is predicted to continue growing in the future. Dry pet food is typically extruded or baked; however, the effect of baking versus extrusion has not been researched much.

Pet foods are typically complete diets having all major and minor nutritional components, which makes these complex products a challenge with regard to processing, bioavailability and shelf-life. Starch is an important part of a typical dry pet food formulation, and undergoes several important changes during processing that impact the digestibility, palatability and physical attributes of the final product. One such transformation commonly occurring in pet food and other processed foods is the formation of amylose-lipid complexes. The amount of complexation is dependent on the type and amount of both starch and lipid sources in the food, the heat of processing, as well as the degree of starch gelatinization. There is limited, but suggestive evidence that amylose-lipid complexes slow digestion of the product.

This study focuses on starch gelatinization and amylose-lipid complexation during processing of baked and extruded pet foods.

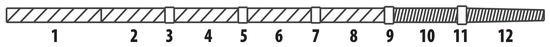
## EXPERIMENTAL METHODS

Three formulations based on a maintenance dog food diet were used in the experiments (Table 1). The three were iso-nutritional with regard to carbohydrate, lipid, protein, and sodium content. The formulations differed from each other with respect to addition of fresh meat (0%, 10% and 20% mechanically deboned chicken), chicken-by product meal and chicken fat. Each diet was extruded using a pilot-scale single screw extruder (Wenger X-20) at two screw speeds (353 and 453 rpm). A typical screw configuration for producing dry expanded kibbles was used (Figure 1). A 30-foot experimental baking oven at 425˚ F was also used for producing dry kibbles from the same three formulations. Proximate analysis confirmed kibbles obtained after baking or extrusion were iso-nutritional at various meat inclusion levels. Two AOAC fat analysis methods (ether extraction and acid hydrolysis) were used for estimation of crude fat in the products. For degree of starch gelatinization (G), both baked and extruded products were analyzed using differential scanning calorimetry (DSC). Degree of gelatinization was evaluated using the gluco-amylase method as well. During DSC testing, amylose-lipid complexation (ALC) was also observed and quantified.

**Table 1: Experimental formulations (0-20% fresh meat).**

| | 0% FM | 10% FM | 20% FM |
|---|---|---|---|
| MD Frozen Chicken | 0.00 | 10.00 | 20.00 |
| Chicken Fat | 5.32 | 4.04 | 2.34 |
| Chicken By-Product Meal | 20.94 | 14.42 | 10.91 |
| Major Ingredients (Brewers rice, Corn, etc.) | 70.63 | 68.23 | 63.52 |
| Minor Ingredients (Vitamins, Minerals, ets.) | 3.11 | 3.32 | 3.25 |

**Figure 1: Extruder Screw Profile**



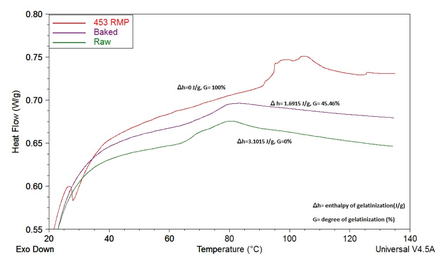

| Number | Screw Element & Description | Length, mm |
|---|---|---|
| 1 | Inlet Screw Single Flight | 145.5 |
| 2 | Single Pitch, Single Flight, Uncut | 98.5 |
| 3 | Small Shear Lock | 14 |
| 4 | Single Pitch, Single Flight, Uncut | 98.5 |
| 5 | Small Shear Lock | 14 |
| 6 | Single Pitch, Single Flight, Uncut | 98.5 |
| 7 | Small Shear Lock | 14 |
| 8 | Single Pitch, Single Flight, Uncut | 98.5 |
| 9 | Medium Shear Lock | 14 |
| 10 | Half Pitch, Double Flight, Uncut | 98.5 |
| 11 | Large Shear Lock | 14 |
| 12 | Half Pitch Cone, Double Flight, Uncut | 119.5 |
| | **Total Screw Length** | **827.5** |

## PROJECT FINDINGS

DSC (Differential Scanning Calorimeter) thermograms indicated complete starch gelatinization (100% G) for extruded kibbles, while baked kibbles had lower G (32 - 45%) (Figure 2). Such a trend was also observed for degree of gelatinization estimated via the gluco-amylose test (data not shown). Baking did not lead to any amylose-lipid complexation that could be detected using DSC. This was attributed to the relatively lower energy intensive nature of the baking process, and involvement of negligible mechanical energy input.

**Figure 2. DSC thermograms for 0% fresh meat inclusion**

*Differential scanning calorimetry (DSC) thermograms for raw, baked and extruded (453 RPM) diets indicated complete starch gelatinization (100% G) for extruded kibbles, while baked kibbles had lower G (32 - 45%).*




Extrusion led to significant amylose-lipid complexation in all treatments, as detected by DSC. In all extruded products, the crude fat estimated by ether extraction method (Figure 3) was consistently lower than that by acid hydrolysis (Figure 4). The crude fat % from the latter method was close to that calculated from fat levels in various components of the experimental diets. This difference in estimated fats from the two methods also indicated formation of ALC corresponding to the portion of fat unextractable with ether but completely recoverable using acid hydrolysis. In the case of baked products, little or no difference was observed in crude fat estimated by the two methods, confirming absence of ALC as observed from DSC thermograms.

**Figure 3. Estimated crude fat using ether extraction method**

*In all extruded products, the crude fat estimated by ether extraction method was consistently lower than that by acid hydrolysis (see Figure 4).*

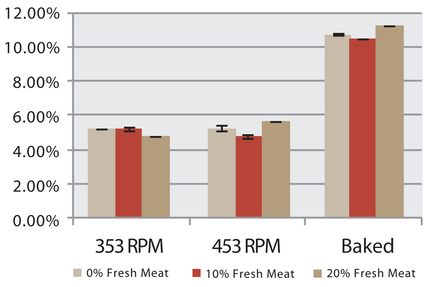
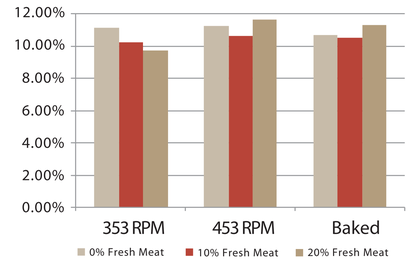



**Figure 4. Estimated crude fat using acid hydrolysis method**

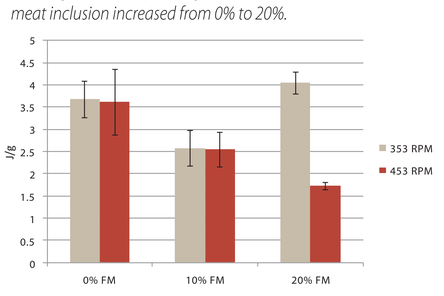
*In all extruded products, the crude fat estimated by acid hydrolysis was consistently higher than by ether extraction method (see Figure 3).*




Higher G and formation of ALC in extruded products was possibly due to the combination of both thermal and mechanical energy involved in the process. Also the area (J/kg) under DSC thermograms corresponding to ALC decreased as level of fresh meat inclusion increased from 0% to 20% (Figure 5). It was hypothesized that level of external lipid (chicken fat) was lower in formulations with higher fresh meat levels, which might have led to reduction in ALC formation. Conversely, internal fat in ingredients such as unrendered fresh meat might be 'protected' from thermal and mechanical conditioning leading to ALC formation. This needs to be verified with further experimentation and analyses.

**Figure 5. Amylose-lipid complex quantified from DSC thermograms**

*The area under differential scanning calorimetry (DSC) thermograms corresponding to ALC decreased as level of fresh meat inclusion increased from 0% to 20%.*




## SUMMARY

- **Baking does not lead to** complete gelatinization or cooking of starch as supported by results from both DSC and glucoamylase tests (data not shown).
- **Mechanical and thermal energy during** extrusion create amylose-lipid complexation.
- **Processing of iso-nutritional diets with** varying fresh meat inclusions might lead to different degree of amylose-lipid complexation due to variation in the proportion of external versus internal lipid.
- **Variation in amylose lipid complexation** between processing methods and formulations point to potential differences in digestibility of starch and lipids and also shelf-life of products

## ACKNOWLEDGMENT

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