Effects of Soya Bean Meal Feed Properties on Extrusion Failures and Implementing a Solution

P. Muredzi; M. Nyahada; B. W. Mashawa

Abstract — This research was a contribution on the optimization of extrusion process by determining the effects of feed properties on extrusion failures and implementing a solution. The objectives of the research were to increase the set soy meal to chunk conversion standard from 65% to 80%; to determine the effects of feed properties on extrusion failures; to determine the best conditions of the feed properties that promote an effective extrusion cooking process; and to determine a solution of optimizing these feed properties for successful extrusion. The research was company based and it followed the failures of extrusion experienced at Monmouth Path Investment (Pvt) Ltd in Waterfall, Harare. This research was limited to feed properties such as fat content, moisture content and particle size as the factors that cause extrusion failures. The determination of moisture content was done by using a moisture analyzer, fat content was determined through the Soxhlet method and the particle size of the feed was determined through sieve analysis. The results revealed that extrusion process was most successful when the soy meals fat content was greater than 6.0%, with a moisture content less than 6.0% and particle size range of 0.95-1.0mm. The process of optimization of extrusion process was solved by designing an extrusion calculator and blending ratio factors. The objective of determining the effects of feed properties on extrusion failures was achieved as well as that of implementing a solution. The objective of increasing Monmouth Path’s standard soy meal/chunk conversion was partially achieved since the implemented solution is not yet measurable.

Keywords — Extrusion, Feed Material, Feed Rate, Soy Meal Size, , Correlation .

I. Introduction

ExTRUSION is a process of central importance and widespread application in the food industry in Zimbabwe. The extensive development of extrusion technology represents one of the most significant achievements in food process engineering in the last fifty years. Extrusion is done in the production of such products as expanded snacks, ready-to-eat cereals, pellets and texturized proteins products for example, soy chunks (which is the main focus of this research).

This research was focused on the evaluation of the factors that cause extrusion failures and the implementation of a solution.

The research was industrial based for a company called Monmouth Path Investment (Pvt) Ltd located in Waterfall. The company’s prime raw material is soybeans and it is processed into soy based products (cooking oil, soy chunks and oil). One of the main problems this company was facing was that of failures in chunk extrusion. They believed it was caused by the feed properties and according to literature extrusion failures are caused by feed properties and extrusion parameters (www.extrusionfactors.edu). Monmouth’s source of income is mainly boosted by soy chunks and their set standard soy meal conversion to chunks per each production batch is 65%. Considering the fact that soybeans cannot be grown all year round in Zimbabwe therefore any failures on chunk production will result in a depreciation of funds throughout the phases of the end season. The company’s probability of sustenance went down as 0.30 in November and in December and considering the fact that the company has experienced losses of approximately 60% due to extrusion failures since it was founded. If such operation losses continue the company is likely to collapse in the long run.

The aim of the research was to investigate on the effect of feed properties on extrusion failures and implementing a solution. The objectives of the research were to increase the set soy meal to chunk conversion standard from 65% to 80%; to determine the effects of feed properties on extrusion cooking process; to determine the best conditions of the feed properties that promote an effective extrusion cooking process; and to design a device that will help to optimize these feed properties for successful extrusion process. The research was done in the favour of Monmouth as way of increasing its extrusion success operations.

This research was limited to fat, moisture content tests and size of feed particles, physical extrusion operation parameter (feed rate) and not on soybean varieties and the chemistry behind.

Extrusion

The verb "to extrude" derives from Latin word ex (out) and trudere (to thrust), and means to force, as through a small opening or to shape a material under pressure by forcing it through a specially designed opening. [4]
or extrusion cooking is a high-temperature, short-time process in which moistened, expansive, starchy and/or proteanous food materials are plasticized and cooked in a tube by a combination of moisture, pressure, temperature and mechanical shear, resulting in molecular transformation and chemical reactions (Havck & Huber, 1989; Castells et al., 2005).

Extrusion is done by an extruder which is a machine which shapes materials or a thermostatically controlled cylinder or conical body which contains a polished, rotating screw with a gradually decreasing pitch. According to Harper (1979), a food extruder consists of a flighted Archimedes screw, which rotates in a tightly fitting cylindrical barrel. Raw ingredients are pre-ground and blended before being placed in the feeding system of the extrusion screw. The action of the flights on the screw push the food products forward and in so doing, work and mix the constituents into viscous dough-like mass.

There are two main types of extruders namely single screw extruders and twin-screw extruders (co-rotating and counter rotating). At Monmouth Path they use single screw extruders and these extruders they only have one parameter of control and that is feed rate. The screw seed remains constant and the temperature that is friction generated.

Extrusion cooking is a continuous process by which food biopolymers and ingredients are mixed, plasticized, cooked and formed by combination of moisture, temperature, pressure, and mechanical shear. The extrusion-cooking process combines the effect of heat with the action of extrusion (Westwood, K.T, 1994). All combinations that promote the occurrence of extrusion can however affect the rate of extrusion if they are not attained, for example, because of the temperature and moisture conditions in this extrusion process a post die expansion of extrudate takes place resulting in a light and crispy product (Harper, 1979).

Extrusion cooking process is affected by two classified groups of factors which are:

- Feed properties
- Moisture Content

Moisture is one of the key factors that affect extrusion cooking, lowering water content of the feed material (soy meal) results in higher viscosity, which causes throughput rate to decrease, pressure drop to increase, and power consumption to increase. However, in extrusion of starch, gelatinization occurs more readily at higher moisture contents. Soybeans are harvested at 11 to 13% moisture content and can be placed directly into ordinary storage bins equipped with simple aeration systems (www.soybeans.umn.edu). A modern way of obtaining moisture content is by using a moisture content analyzer.

II. METHODOLOGY

Data collection of the research was done in two forms classes namely primary and secondary data.

Primary Data

This data was obtained from the field by the use of experiments and brainstorming. Experiments which were conducted included the determination of moisture content and fat content in the soy bean and soy meal, the determination of water intake (rate) using a stop watch and average calculation of extrusion feed rate.

Secondary Data

This type of data that was collected from secondary sources such as records, journals, internet and books, for such a research like this the secondary data concerned techniques used to determine the content of fat and moisture.

The data was analysed both qualitatively and quantitatively. Scientific graphs and statistical techniques of analysis were used to analyse the soy constituencies, process conditions and parameters.

The mapping of this research was done through design models. The research followed two design models in coming up with a hybrid model to use. The two design processes in consideration are according to Hertz (2007) and Norman (1995). These two design processes were selected taking into account the weaknesses and strengths of each model over the other.

Research Brief

The purpose for the research was to evaluate the possible factors causing the failures in extrusion operation and implementing a solution. The research mainly concentrated on the feed properties such as moisture content, fat content and size of particles of the soy-meal as the factors that affect extrusion. Operating factors were not considered highly in this research since the type of extruders operating at Mon-Mouth has constant operation parameters except for the screw feed rate. The solution implemented to the problem was that of an extrusion calculator which was developed from the data analysis on the correlation between feed properties and feed rate.

Research Procedures

The procedures of data collection were done and results were produced experimentally. Corresponding feed rate and sample particle size were frequently collected, averaged and recorded. All the experimental procedures and measured parameters that followed the research design are as follows:

Determination of Moisture Content

The determination of moisture content within the soy meal was done by the use of a Moisture Analyzer. 5g of the soymeal was measured and inserted in a moisture analyzer at a
temperature of 110°C. Results were obtained after 10mins per each sample.

**Determination of Fat/Oil Content**

The determination of the fat content within the soymeal followed the Soxhlet Extraction Method (Soxhlet, F; 1879 and William B, 2007)

**Calculation**

Weight of fat = weight of flask + fat - weight of empty flask.

% content = (weight of fat ×100)/initial sample weight (5)

**Determination of Average Extrusion Feed Rate**

Initial extrusion feed rate and any changes of the feed rate during processing were recorded. After the recording of all the extrusion feed rate values, an average was calculated and recorded on the results sheet.

**Determination of Average Soy-meal Size**

Size determination of the soy-meal was obtained through sieve analysis (ASTM International - Standards Worldwide; 2006)

### III. RESULTS AND RESULTS ANALYSIS

Results were obtained and an evaluation of the trend was done. It was observed that extrusion successes in production of good and excellent chunks were most prominent of those soy meal batches which had fat/oil content of 6.0% and above.

According to the literature, oil is of importance since it helps in the lubrication of the extrusion cooking process and also decreases the amount of viscous heat dissipation. The results trend highlighted a common trend justifying that for extrusion to occur successfully the fat content had to be slightly above the moisture content. According to the literature, one of the factors that affect extrusion cooking process is oil content within the sample. It is usually important for a sample to have at most an average oil content of 6.5-8.5% prior to extrusion (www.soybeans.umn.edu). The results clearly highlighted that since most of the extrusion process was successful when the oil content was above 6.0% through the average range in mentioned above is slightly higher.

Since extrusion cooking occurs in the presence of injected water, the reason of having low moisture content in the soy meal than 6.0% was justified. The available literature only explained that soybeans are harvested at 11 to 13% moisture content which means that this research highlighted that moisture content from the point of soybeans is different to that of soy meal because through every stage of process from crushing till soy meal production moisture content is lost.

**Conceptualization**

The results led the research into design conceptualization. According to Hertz (2007), the third step of design is called conceptualization. At this stage designer considers the alternative concepts to find the best possible design to solution problem. The research was done considering two alternatives to implementing a solution.

### IV. DISCUSSION

The design of the extrusion calculation as an implementation procedure was built on the basis of the data obtained from the results. Because of such analysis of the trends, a formula was formulated to promote maximum extrusion and an error of deviation of ±0.4rev/min was
obtained and it must be accounted for at all cases. The formula which was obtained from the analysis of the results data was used to come up with a program that is currently running on the calculator. The extrusion calculator was designed to meet the needs at Monmouth Path Investments and to eliminate the error of extrusion failure. The application of the extrusion calculator and ratio mixing chart were implemented to increase the general soy meal/chunk conversion from 65% to 80%.

V. CONCLUSION

The research was done and some of its objectives were met. The objective of determining the effects of feed properties on extrusion cooking process was achieved. Following the results, the objective of determining the effects of feed properties on extrusion process, the best conditions of these feed properties to satisfy an effective extrusion process were achieved. These conditions were: the soy meal must have fat content of greater than 6.0%, moisture content of less than 6.0% and the soy meal must have a particle size of 0.8 – 1.0mm. The objective of increasing the soy meal/chunk conversion standard of 65% was met though the extent of increasing the standard up to 80% is not yet measurable. For the best extrusion cooking process, in the case of attaining an optimized-controlled extrusion cooking process, an extrusion calculator and a ratio mixing/bending chart were designed. The extrusion calculator assists in the calculation of the feed rate under the above mentioned conditions and the ratio mixing chart helps in obtaining the standard extrusion fat content of greater than or equal to 6.0%.

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