CREATING HEALTHY SNACK FROM MILLET AND SPENT GRAINS USING EXTRUSION TECHNOLOGY

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RESEARCH PROPOSAL

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A proposal submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Agricultural and Biosystems Engineering
at the University of Kentucky

By

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Abstract

Food security is a major challenge for humanity, and the world's population growth continues to put pressure on global food production. Research is being done to make undervalued food sources more useful to industry and consumer alike. Spent grains (SG) from the brewing, brewers spent grain (BSG), and distilling industry, distillers spent grain (DSG), are rich in protein, dietary fiber, and essential amino acids, while offering a cheap source of the essential macro nutrients as well. Millets hardy nature and high nutrient qualities make them a suitable alternative crop for farmers when conditions are not favorable for more lucrative cereals, such as wheat, rice and corn. Millets are low in lysine, an essential amino acid found in SGs. This research intends to develop a puffed snack food from SGs and millet flour with the purpose of adding value to these grains. Feedstock particle size (250 and 1000μm), moisture contents (15-25%), type of SG (DSG vs BSG), and blend ratio (10 and 20% SG) are the parameters that will be studied to test their effect on extrudate's textural analysis, water solubility index (WSI), water absorption index (WAI), piece density, moisture, and radial expansion ratio (RER).

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Chapter One: Introduction

The worlds demand for food is at an all-time high, and will continue to grow, as the world's population is expected to reach 9.7 billion by 2050 (UN, 2015). A research area gaining interest is recycling undervalued spent grains (SG) from the brewing and distilling process into quality foods due to their characteristically high amounts of protein and dietary fiber (Mussatto, Dragone, & Roberto, 2006). Millet grains also show promise in their ability to have an effect on the world's food security problems due to their hardy nature, low moisture requirements, and quality proximate composition (Gulati, Weier, Santra, Subbiah, & Rose, 2016). Extrusion processing is widely utilized in food industry because of its low energy requirements, short processing time, and ability to accomplish a number of unit operations including: mixing, conveying, and shaping, among others.

Kentucky is the world's leading producer of bourbon, with 1.15 million barrels (52.8 gallons/barrel) produced in 2015, and a $2 billion sales value (Kelly, 2017). Distillers spent grain (DSG), the main by-product of the distilling industry is usually given away at no cost to local famers as a feed supplement, which has cost the Kentucky distilling industry an estimated $5 million in potential revenue (Kelly, 2014). While bourbon has been a mainstay, Kentucky's craft beer scene has grown remarkably over the past 5 years. Brewers spent grain (BSG) is the major by-product of the brewing industry and is also given away to local farmers for free. DSG and BSG are high in moisture (70% wb) which leads to a short shelf life of about four days, however once dried (10-12% wb) the shelf life becomes exponentially longer.

Millet, the 6th most produced cereal in the world, has yet to be embraced as ingredient in food processing in the US. It is mostly used as animal feed, but in other parts of the world, millet is a major staple used for making several different types of nutritious foods. Millet consideration as an alternative ingredient stems from its hardy nature, short growing season, and nutrient rich composition. Millet's nutritive composition is comparable to wheat, while also enjoying a higher content of protein, fat, and crude fiber. Millet is superior to the wheat, rice, and corn in terms of its shorter growing season (60-100 days) and water use efficiency. Millet's drought resistance makes its important crop in some developing countries where water scarcity poses an agricultural challenge, and now in the developed countries as water availability issues continue to grow throughout the world.

Lynch et al. (2016) reported that essential amino acids constitute about 30% of SG protein content. Lysine, which is deficient in millet varieties, makes up 14% of the amino acids content in SG (Lynch, Steffen, & Arendt, 2016), which increases its attractiveness as a composite into millet-based snacks.

Extrusion is a technique used in the food industry to develop a variety of different products. It is applicable to the snack food industry due to its ability to create a puffed, ready to eat snack from different grains. Extrusion technology has been used in food processing since the 1900's for sausage production (Riaz, 2000). Today, the application of extrusion has grown to include snacks, pastas, cereals, candies etc. Extrusion processing is versatile operation combining many units of operation including mixing, shearing, cooking, puffing, and drying. Extrusion is a high temperature short time (HTST) process, making it an energy efficient process with a range of food applications. Extrusion processing of grains results in a number of chemical and physical changes, namely: gelatinization of starch, denaturation of proteins, and inactivation of enzymes, microbial reductions, and reduction of anti-nutritional factors (Pathania, Singh, Sharma, Sharma, & Singla, 2013).

In conclusion, millet is a sustainable, nutritious, hardy alternative to major crops. Underutilized spent brewer's grain is another alternative food source for snack development. Extrusion processing could be a tool used for creating functional snacks from these grains.

Chapter 2: Objectives

Having millet developed into a desirable snack would add to its value; therefore, aiding farmers who rely on its economic impact. Millet is also a hardy, nutritious grain, ideal for areas where water is scarce and climate is often unforgiving, allowing it to be a used as a situation crop when weather patterns are unfavorable for more common grains.

The objective of this research is to develop a nutritious extruded snack food from a combination of spent grains and millet, specifically:

1. Determine the effect of SG particle size on extruded snack quality characteristics.
2. Determine the effect of feedstock moisture content on extruded snack quality characteristics.
3. Determine if the type of spent grain has an effect on extruded snack quality characteristics.
4. Determine if the ratio of SG and millet has an effect on extruded snack quality characteristics.

Chapter 3: Materials and Methods

Material Preparation

Proso millet flour will be purchased from Bob's Red, and stored in a dry place until use. Water will be added to millet samples to alter moisture content to specified value. Brewers spent grain will be collected from Alltech's Inc. Lexington Brewery Division. Spent grains will be dried in an oven at 45°C. Spent grains will be milled to 250-1000µm particle size.

Extrusion

A co-rotating twin screw 40:1 L/D laboratory scale extruder (EuroLab 1600, Thermo Scientific, Karlsruhe, Germany) will be used for producing the expanded snacks. A screw volumetric feeder will be used to deliver the feedstock at a rate to be determined based on preliminary trials. The extrusion barrel temperature will range between 50 – 130°C. Other extrusion conditions namely, screw speed and moisture inject rate will be determined based on the experimental design. The exit die has an internal diameter of 3 mm.

Product Analysis

Proximate composition data will be measured, including: crude protein, crude fiber, ash and moisture. Physical characteristics of the product will also be measured, including: radial expansion ratio (RER), texture analysis, piece density, moisture, water absorption index (WAI), and water solubility index (WSI).

Radial Expansion Ratio Specific mechanical energy (SME) will be calculated using the following standard equation used by Kirjoranta et al. (2016):

$$SME\left(\frac{Wh}{kg}\right) = \frac{Screw\ speed(rps) \cdot Torque\ (Nm)}{Mass\ flow\ \left(\frac{kg}{h}\right)}$$

Moisture Content Moisture content for feedstock and extrudates will be determined using the hot air oven method (AOAC 1984).

Water solubility and Absorption Indices (WSI and WAI): WSI and WAI will be measured following the method by (Anderson, Conway, & Peplinski, 1970). The average of three replicates will be used for analysis.

Degree of gelatinization: *Pasting properties:* Extrudate will be ground to 250 microns, and the method of Singh and Adedeji (2017) will be followed.(Singh & Adedeji, 2017).

Texture Measurement: The textural characteristics (hardness and crispiness) of the extrudates will be determined using Texture analyzer TA.XT Plus (Texture Technologies Corporation) fitted with a Kramer shear cell, according to the method of (Meng, Threinen, Hansen, & Driedger, 2010).

Microstructural Characterization (3D rendition, Porosity and Pore Size Distribution): An X-ray MicroCT scanner (SkyScan 1173 system, Bruker, Kontick, Belgium) will be used to obtain 3D images of the extrudate, determine the porosity, and pore size distribution according to the method of (Adedeji & Ngadi, 2011).

Experimental Design and Statistical Analysis: A full factorial design will be ran at 3 levels of SG (10 – 20%) to millet flour, 3 moisture contents (15 – 25%, wet basis (wb)), SG particle size (250 vs 1000 mm), and two levels of spent grain source (BSG and DSG). Analysis of variance will be performed to determine the effect of model and where significant, mean separation will be done at 5% probability. All statistical analyses will be done using SAS (version 9.3).

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Appendix: Budget

1. Direct Costs	Year 1	Year 2	Total
A. Salaries and Wages			
(1) Joseph Woomer	$16,000	$16,000	$32,000
(2) Advisor	$8,600	$9,202	$17,802
Total Salaries and Wages	**$24,600**	**$25,202**	**$49,802**
B. Fringe Benefits			
(1) Joseph Woomer	$1,416.00	$1,416.00	$2,832.00
(2) Advisor	$1,840.25	$1,840.25	$3,680.50
Total Fringe Benefits	**$3,256.25**	**$3,256.25**	**$6,512.50**
C. Travel			
(1) ASABE meeting	$1,280.00	$1,280.00	$2,560.00
Total Travel	**$1,280.00**	**$1,280.00**	**$2,560.00**
D. Materials and Supplies			
(1) Millet	$200.00		$200.00
(2) Other foods	$500.00		$500.00
Total Materials and Supplies	**$700.00**		**$700.00**
F. Other Direct Costs			
(1) Publication costs	$1,000.00	$1,000.00	$2,000.00
(2) Tuition and fees	$12,236	$12,236	$24,472
(5) Institutional Review Board	$3,810.00	$3,810.00	$7,620.00
Total Other Direct Costs	**$17,046**	**$17,046**	**$34,092**
G. Modified Total Direct Costs	**$46,882**	**$46,784**	**$93,666**
2. Indirect Costs	**$23,675**	**$23,626**	**$47,301**
3. Total Costs	**$70,557**	**$70,410**	**$140,968**

1. Direct Costs
   A. Salaries and Wages
      (1) Based on current departmental stipend of $16000/year for a first-year MS Research Assistant.
   B. Fringe Benefits

(1) Current University of Kentucky fringe benefit rate for graduate students is 8.85%

C. Travel
   (1) Attendance at 2017 International Meeting of ASABE. Air fare estimated as $500, three days' lodging and per diem at $100 per day meeting registration of $480.

D. Materials and Supplies
   (1) 200 lbs of Millet at $1/lb.
   (2) Various food supplies, such as coating oils, cheese powders, etc.

E. Other Direct Costs
   (1) Estimated 10-page article to be published in *Journal of Food Science* at $120/page.

F. Modified Total Direct Costs. As per University of Kentucky guidance, calculated as Total Direct Cost less graduate tuition and equipment.

2. Indirect Costs. Calculated as 50.5% of Modified Total Direct Costs as per University of Kentucky Office of Sponsored Projects Administration.

Future Years: Salaries and wages are increased by 1.7%/year based on the 2015 Consumer Price Index.

Appendix: Research Plan

MILESTONES

4/20/2017: Finish training on micro CT, pycnometer, texture analyzer

6/16/2017: Comfortable creating variety of millet based snacks

8/20/2017: Completed snack recipes

10/1/2017: Paperwork in to IRB for review

10/29/2017: Proximate analysis completed

12/6/2017: Sensory Analysis Completed

12/26/2017: Statistical Analysis Completed

03/05/18: Send in Manuscript for approval