



DINING IN SPACE—Dr. Clinton Rappole, Professor and Eric Hilton Distinguished Chair in the Hilton College of Hotel and Restaurant Management, is dedicated to solving problems of making food for astronauts. A processor has been designed to prepare soy products from hydroponically grown plants, and different methods for producing baked goods are being devised for dining on extended missions in outer space.

Design of a Food Service and Food Processing System for Long-Duration Missions in a Closed Environment

64-ISSO

Abstract—

Soybeans and other baseline crops such as wheat show higher levels of protein when hydroponically grown. The product characteristics of these crops warrant investigation. Also, “waste” products and water usage from tofu manufacture need to be quantified. Minimizing both of these characteristics would assist integration of the food element with the other Advanced Life Support elements for implementation during a long-duration space mission.

The Soy, Tofu, Okara and Whey (STOW) Processor prototype is the first of its kind as well as the first piece of processing equipment to be evaluated for its use on long-duration space missions. Hydroponically grown soybeans will be evaluated using the STOW for their processing characteristics. A preliminary evaluation of the STOW has prompted a redesign of its hardware/software interface as well as the control software.

An ongoing project focuses on bread manufacture using high protein wheat. In regard to crop functionality, inclusion of whole hard red spring wheat into bread has shown that higher protein content formulations result in higher loaf volumes and lower hardness values. This knowledge may prove useful in terms of incorporating byproducts of tofu manufacture into bread formulations. A renewal of a Center Director’s Discretionary Fund (CDDF) for the project entitled: “Prediction of Processing Parameters of Wheat-based Food Products with Varying Compositions” is now in process that will fund some of the activities already in progress as well as an evaluation of bread making equipment and the use of other ingredients such as soy and rice flours.

THE FOOD ELEMENT WITHIN ADVANCED LIFE SUPPORT (ALS) has recently acquired a new facility to support the BIO-Plex project, the Food Processing System Development Facility. This facility is a complement to the Space Food Laboratory. Currently, work is being done concerning use of crops such as wheat and soybean.

Crops such as these need to be investigated in order to ascertain functionality data including quantities of ingredients needed and waste generated. Hydroponically grown wheat and soybeans have shown higher protein contents^{1,2} raising questions regarding the necessary water incorporation in bread and tofu formulations. Also, tofu manufacturing results in byproduct (okara, whey and excess soymilk) generation. To decrease the demand on solid waste systems during long duration space missions, attempts are being made to use these byproducts in other product formulations.

A coinciding project is the evaluation of the Soy, Tofu, Okara, and Whey (STOW) Processor prototype. This is a first generation prototype designed and built by personnel from SpaceHab and Johnson Engineering. The STOW evaluation will include engineering and food science perspectives. This evaluation will be used to decide what modifications can be made to the existing prototype to provide as many capabilities as possible, while at the same time reducing weight, space and energy requirements as well as the amount of waste generated. This evaluation will also assist in determining necessary steps to take in future food processing equipment development.

Bread Project

Methods and Materials

Bread loaves were made using a Zojirushi model BBCC-V20 breadmaker. The following ingredients were added in a prescribed order: water, oil, flour, gluten, sugar, salt and yeast. Formulas were based on 100 percent flour (baker's formulation) and adjusted to alter protein and moisture contents. Protein levels and combined moisture levels tested were 15, 18, and 22 percent and 67, 70, and 73 percent, respectively. After weighing ingredients on an Ohaus Adventurer scale, they were placed into a bread pan and processed through a "Quick Wheat" cycle. Once complete, the loaves were allowed to cool for 20-30 minutes before analysis.

To compare processing methodologies (use of warm cycle and comparison of bread makers) a 15 percent protein level was used combined with a 67 percent moisture level.

Loaves were tested for weight, volume, texture, and moisture content. For texture analysis, a TA-XT2i texture analyzer was used. This instrument simulates two bites taken on slices taken from the loaf. These mechanical bites were analyzed using Texture Expert software to give values on hardness, springiness, and cohesiveness.

Results

Moisture contents for all loaves made ranged from 40-44 percent, increasing as formula water content increased. Weights were similar with all loaves falling within three percent of the average.

It is quite clear from Fig. 1 that differences in hardness arise from use of one breadmaker or another and whether a warming cycle is included in the baking process. There was almost a two-fold increase in hardness if a warm cycle was allowed and a one-third difference in values from one breadmaker to another.

Trends of increased loaf volume and decreased hardness values are seen as protein levels are increased. Figures 2 and 3 illustrate loaf volumes and hardness results. The largest loaf volume was seen at a 22 percent protein level combined with a 67 percent moisture level. This combination also produced one of the softest loaves having a hardness value of 1580 grams.

Springiness and cohesiveness values were all similar with varying ingredient composition. An anomalous reading occurred at the 18 percent protein/67 percent moisture combination; however, this is not presumed to be of any consequence to data interpretation. Figures 4 and 5 illustrate springiness and cohesiveness results.

Discussion

From the results of comparisons of bread processing methodologies, researchers decided that the processing parameters could have a greater effect on final product characteristics than the ingredients used. This has led to the use of protocols for a specific

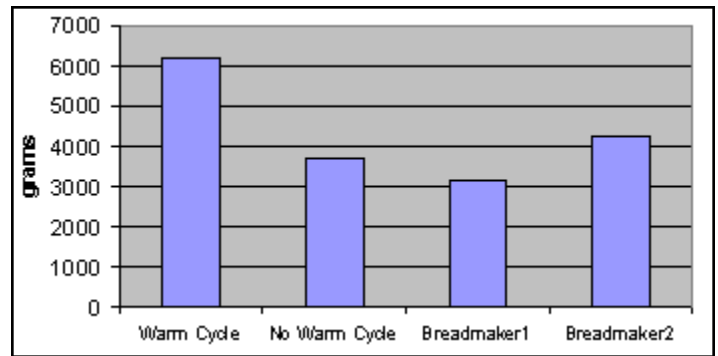


Figure 1. Hardness values for breads made in breadmaker 1 or breadmaker 2 as well as whether loaves were allowed to sit through a warming cycle. Loaves were made at a 15 percent protein level combined with 67 percent moisture incorporation.

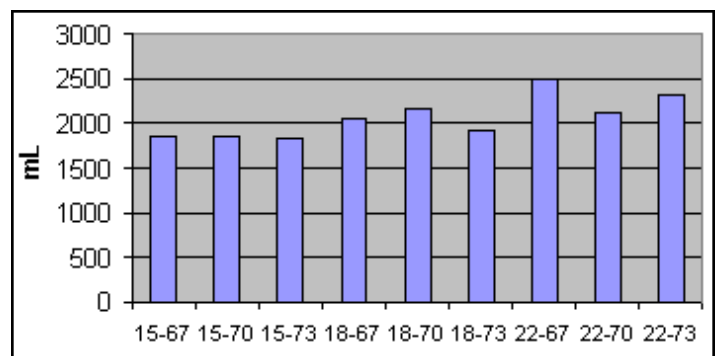


Figure 2. Volumes of loaves using three different protein and moisture levels. Protein levels are identified as 15, 18 or 22 followed by moisture levels of 67, 70 and 73 percent.

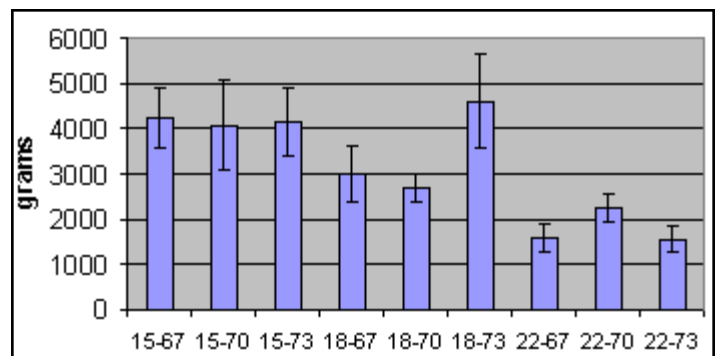


Figure 3. Hardness values of loaves using three different protein and moisture levels. Protein levels are identified as 15, 18 or 22 followed by moisture levels of 67, 70 and 73 percent.

ic processing method. A warm cycle is not to be allowed and loaves using different formulas are to be made in each bread maker so as to negate differences indigenous to the bread maker.

Overall results of this project are encouraging for the use of hydroponically grown wheat varieties. The increased loaf volume is believed to be directly related to the decreased hardness values. This is due to an increased probe-to-crust distance as loaf volume increased. As other textural properties (springiness and cohesiveness) showed similarity, using higher protein wheat should not pose a problem

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in developing an acceptable product.

Future work will focus on using alternative ingredients (okara, whey, soymilk, soy flour and rice flour) in bread formulations. Along with the analytical techniques used thus far there will be a need for sensory analysis and possible microscopic analysis of the ingredients.

STOW Project

Work on the STOW Processor prototype began in November 2001. Since that time there have been modifications in design stimulated by safety and control issues. First, upon transport onto JSC, there was a loss in communication between hardware and software. Control could not be initiated until assistance was provided by the original software designer. This has led to a commitment of funds (\$20,000) to the redesign of the hardware/software interface and the control software. These modifications will accomplish multiple goals including:

- A reduction in the space needed for hardware circuitry and communication components.
- A relocation of the hardware circuitry and communication components away from the liquid handling sections of the hardware.
- Use of text-based programming code allowing greater control over hardware components.

Safety issues have also led to a redesign of the fluid handling sections of hardware. A clogged heat exchanger led to rupturing in a transport hose. Since that time, the heat exchanger has been removed as well as resulting superfluous fluid-flow hardware. This redesign has significantly reduced the size and weight of the prototype and is believed to have assisted in the tofu manufacturing process. Minor issues concerning hardware durability have arisen and will be addressed in future evaluations.

Future work with the STOW Processor prototype will address use of hydroponically grown soybeans, microbial growth control mechanisms, integration issues with other ALS elements, and additional design issues that arise.

Classroom Instruction

A class designed for instruction by aerospace fellows has been offered students of the college since 1997 on "Food Service Systems in Space: A Challenge for the 21st Century." Instructors have been Dr. Yale Vodovotz (1997-99), Dr. Elena Vittadini (2000), and Dr. Stephen French (2001).

Dr. Charles Bourland and Dr. Clinton L. Rappole taught a class on "Living, Working, and Playing in Space," scheduled both in 2001 and 2002.

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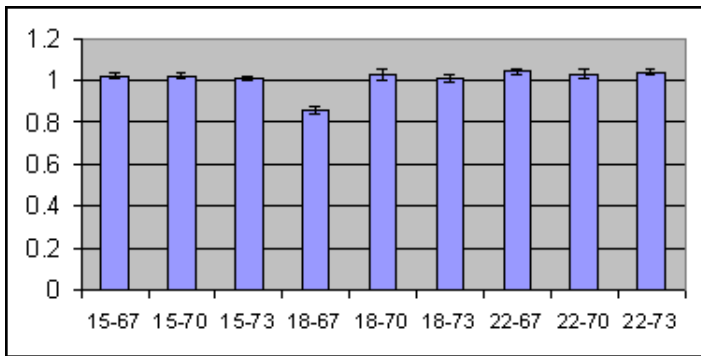


Figure 4. Springiness values of loaves using three different protein and moisture levels. Protein levels are identified as 15, 18, or 22 followed by moisture levels of 67, 70, and 73 percent.

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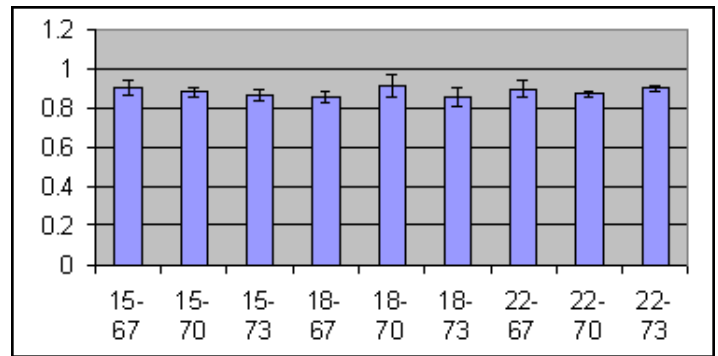


Figure 5. Cohesiveness values of loaves using three different protein and moisture levels. Protein levels are identified as 15, 18, or 22 followed by moisture levels of 67, 70, and 73 percent.

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Post-Doctoral Fellows

- Stephen J. French earned his doctorate degree at the Ohio State University.
- Dr. Yael Vodovotz received her doctorate degree from the University of Massachusetts. Dr. Vodovotz is an Affiliate Faculty Member with the Commercial Space Center in Ames, IA from which she has received funding for research equipment within her laboratory.
- Dr. Ellena Vittadini received her doctorate degree from the University of Massachusetts. She is currently a Visiting Scholar at The Ohio State University Dr. Vittadini has recently left Opta Food Ingredients where she was a Senior Research Scientist. With Opta she developed novel starch-fiber based ingredients for food applications. She also was involved with technical support for production processed improvement and existing starch-fiber based products and their applications.