THE POTENTIAL OF USING PANEL SOLAR COOKERS TO PROCESS FULL-FAT SOYBEANS (*Glycine max*) FOR UREASE ACTIVITY

Mr Owen Nyoni
National Foods Ltd
Foundry Road, Aspindale, P.O. Box 269
Harare, 263 Zimbabwe
owenny@natfood.co.zw

Dr Irvin Mpofu
University of Zimbabwe
Department of Animal Science, P.O. Box MP167, Mount Pleasant
Harare, 263 Zimbabwe
impofu@agric.uz.ac.zw

Professor Stan Makuza
University of Zimbabwe
Department of Animal Science, P.O. Box MP167, Mount Pleasant
Harare 263 Zimbabwe
makuza@agric.uz.ac.zw

ABSTRACT

This study was conducted in order to investigate the efficacy of panel solar cookers in reducing urease activity in full-fat soybeans (*Glycine max*). Changes in urease activity of soaked (SM), coarse-milled (CM) and whole dry (WM) full fat soybeans were investigated by roasting for 0, 30, 60, 90, 120, 150 and 180 minutes in multiple reflector panel solar cookers, in a 3 x 3 factorial experiment. After 180 minutes of solar roasting, urease activity levels had declined by 81 %, 67 % and 23 % in soaked, milled and whole dry soybeans respectively. Full fat soybean urease activity can be reduced more efficiently in soaked than in dry soybeans. Findings suggest that there is potential in using multiple reflector panel solar cookers to reduce urease activity in full fat soybeans.

Keywords: Soybeans, Urease activity, Roasting, Panel solar cookers

1. INTRODUCTION

Solar cooker micro-enterprises in developing countries have been reported to address the main problems associated with using fuel wood by using panel solar cookers (Blum, 1998). A simple panel solar cooker has an aluminized surface and consists of multiple reflecting surfaces, which increase solar radiation input onto the cooking surface. Cooking efficiency is improved by positioning the reflecting surfaces in such a way that they face the sun. In developing countries, the use of low cost solar cookers has largely been confined to preparing household meals and water pasteurization (SCI, 2002; SCP, 2002). A panel solar cooker can heat materials up to 125ºC when the ambient temperature is over 20ºC (TFL, 1997). This study aimed at diversifying the use of panel solar cookers to include heat processing of full-fat soyabeans meant for feeding livestock.

2. BACKGROUND

Soybean meal is an important protein supplement that can alleviate nutritional deficiencies in smallholder livestock feed resources. However, raw soybeans contain some anti-nutritional factors, which can adversely affect digestion and absorption of nutrients, resulting in poor animal performance (McNaughton et al., 1981). The most important anti-nutritional factors in soybeans are trypsin inhibitors and the urease enzyme. For example, urease enzyme in raw soyabeans can be a problem in ruminants if raw soybeans are included in the diet in large amounts, especially in diets containing urea. Urease degrades the urea to ammonia, which can be toxic in the rumen.

Most anti-nutritional factors found in soybeans are heat-labile. McNaughton and Reece (1980) observed a decline in urease and trypsin inhibitor activity in soybean meal roasted at 50ºC. In the same study, it was also observed that heat-moisture-time conditions of processing inactivate urease at approximately the same rate as trypsin inhibitors. Thus, trypsin and urease activity test methods can be used to determine residual activity of either digestibility inhibitor after heat processing of soybeans (McNaughton et al., 1981). Nutritionists prefer to use the urease activity test because it is less expensive and is easier to conduct. One of the common laboratory methods used to determine urease enzyme level involves the measurement of the amount of ammonia produced after incubating urea with a sample of soybean using a Kjeldahl method (Analytichem, 1999).

Heat processing of soybean for livestock feeding in smallholder farming systems in developing countries requires extensive use of wood resources as fuel. Over one-third of the world population depends on wood as a source of energy (Lampinen, 1994). Most of these people live in the tropics, which are the most favourable areas for solar energy utilization. Studies in four rural districts in Zimbabwe established that 100 % of the households used wood as fuel (Mupanda, 2000). In addition to reduction in biodiversity and related ecological values, diminishing wood supplies require longer hours to gather. In some communal areas in Zimbabwe, firewood has to be purchased, straining farmers' limited financial resources (Rodgers, 1994). To address the problems associated with utilizing wood and other sources as fuel, the use of solar energy as an alternative fuel has long been encouraged in most developing countries.

3. THIS PROJECT

This experimental study was conducted over three months at the University of Zimbabwe campus in Harare (17^o 50' S and 31^o 03' E), Zimbabwe between September and November in 2002. The Project received some technical back-up from the Development Technology Centre at the University of Zimbabwe. All laboratory analyses were carried out in the Department of Animal Science of the same university.

3.1 Procedure

Samples of a common source of full fat soybeans were randomly allocated to three pre-treatments before they were roasted using solar kits. The pre-treatments were: soaking (SM); dry coarse-milling (CM); and a whole dry soybean grain (WM). Preparation of SM was completed by soaking raw full fat soybeans in water in a ratio of 1 to 2 (w/v), at room temperature for 14 hours. The CM was prepared by crushing dry full-fat soybeans using a pestle and mortar to pass a 3 mm mesh.

Roasting of the three pre-treated soybeans was done simultaneously, once a month for three months. Six panel solar cookers and black-coloured (24.5 cm floor diameter and 5 cm deep) steel pans were used. Two-kilogram portions of each of SM, CM and WM were added to the pans before they were sealed in a clear, heat-resistant oven cooking polythene bag. Each sealed pan was placed in a panel solar cooker in such a way that there were two replicates for each of the three types of meals (Fig. 1). Solar roasting started at 1100 h and ended at 1400 h. The roasting kits were placed in an open area with no shading from direct sunlight.

Fig. 1 A photograph showing the arrangement of the panel solar cookers during the study

To ensure a uniform roasting medium, the pans were shaken manually at 10 min intervals. During the same period, a temperature/relative humidity data logger (HOBO H8, Onset Computer, Bourne, Massachusetts) was connected to the kit roasting each of the three soybeans (Fig. 2). The logger recorded the roasting time, ambient temperature, relative humidity and the roasting temperature inside the pan at 10 min intervals. A pyrometer (Einstrahlungs-Messgerät 100, Conrad Electronics, Wels, Austria) was used to measure the amount of solar radiation intensity at 10 min intervals.

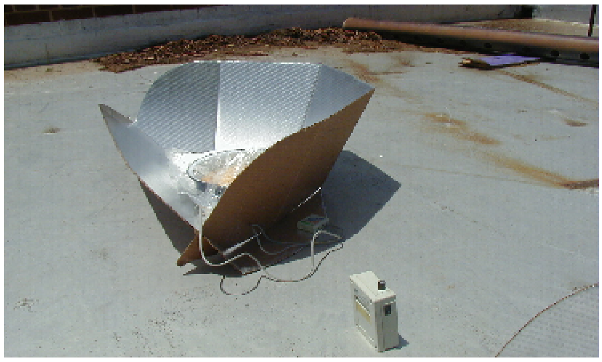


Fig. 2 A panel solar cooking kit showing a sealed pan, a data logger in the shade and a pyrometer in the foreground

Samples were withdrawn from each roasting kit after 30, 60, 90, 120, 150 and 180 minutes of roasting and were cooled before chemical analysis. Samples were hand-milled using a pestle and mortar to pass a 2 mm mesh for chemical analysis. Three replicates of each sample were used to determine residual urease by the Kjeldahl procedure of Analytichem (1999). The urease activity index was expressed as the milliequivalents of ammonia produced from urea by one gram of soybean in 1 h at 30ºC. In this study, the difference between the urease activity of the test sample and the blank was used as the index of urease activity in the sample. Dry matter (DM) was analyzed using the standard procedure of AOAC (1990).

Temperature and relative humidity data from the logger and solar intensity measured from the pyrometer were treated as averages. A one-way analysis of variance (ANOVA) of the Statistical Analysis Systems (SAS, 1996) was then used to determine the fixed effect of month of processing on ambient temperature, relative humidity and solar radiation intensity. A two-way ANOVA was computed to test for the effects of month, soybean pre-treatment and their interaction on roasting temperature.

The effects of pre-treatment, the duration of roasting and the fixed month of processing on DM and urease activity were analyzed using the PROC MIXED procedure of SAS (1996) for repeated measures analysis, as described by Littell et al. (1998). The Least Significant Difference (LSD) was used to compare jeans and significance was declared at $p<0.05$.

3.2 Results and discussion

Ambient temperatures during all the three experimental months were well above 20ºC (Table 1), the minimum threshold likely to create cooking temperatures above 50ºC in a panel solar cooker (TFL, 1997). Roasting temperatures were affected by an interaction between soybean pre-treatment and month of roasting, but the highest ($p<0.05$) mean roasting temperatures were recorded in October (Table 2). Thus, the highest ambient temperature measured in October translated into highest average roasting temperatures in the pans. Since McNaughton and Reece (1980) observed a decline in urease and trypsin inhibitor activity in soybean meal roasted at 50ºC, ambient temperature measurements in this study suggest that the late dry season in Zimbabwe, and elsewhere in the tropics, has the potential to support use of panel solar cookers in inactivation of anti-nutritional factors in soybeans.

TABLE 1. AVERAGE AMBIENT TEMPERATURE, RELATIVE HUMIDITY AND SOLAR RADIATION INTENSITY DURING THE ROASTING DAYS

	September	October	November
Ambient temperature (ºC)	34.7^{a}	36.7^{b}	30.1^{c}
Relative humidity (%)	23.0^{a}	22.5^{b}	22.8^{c}
Solar radiation intensity (W/m^2)	595.5^{a}	596.8^{a}	571.2^{b}

^{a,b,c}Values with different superscripts within a row differ ($p<0.05$).

TABLE 2. EFFECT OF MONTH ON ROASTING TEMPERATURE (ºC) FOR WHOLE DRY, MILLED DRY AND SOAKED FULL FAT SOYBEANS

Month	WM	CM	SM	Mean (± se)
September	76.2^{1a}	89.0^{1b}	84.0^{1b}	$83.0 \pm 1.3^{*}$
October	82.5^{1a}	105.3^{2b}	98.9^{2c}	$95.6 \pm 1.3^{**}$
November	95.0^{2a}	96.4^{3a}	71.7^{3b}	$87.7 \pm 1.3^{***}$

^{a,b,c}Values within a row (excluding means) with different superscripts differ ($p<0.05$).
^{1,2,3}Values with different superscripts within a column differ ($p<0.05$).
*,**,*** Means with different asterix within a column differ ($p<0.05$).

In all three soybean preparations, roasting temperature increased in the first 30 min of processing and fluctuated thereafter (Fig. 3). These fluctuations could be attributed to the periodic opening of the kit for sample collection during the experiment. According to TFL (1997), conditions in the pan/pot should always be airtight in order to maintain an optimum cooking temperature. The procedure used in the collection of samples in this experiment, although unavoidable under the circumstances, could have compromised the full potential of the panel cookers in heating the soybeans.

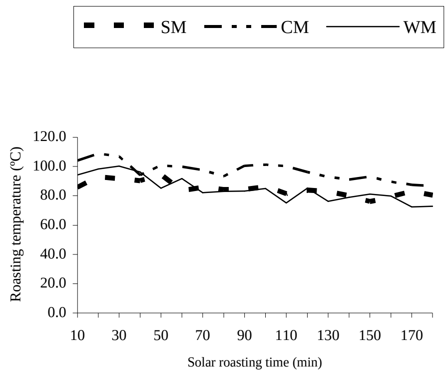
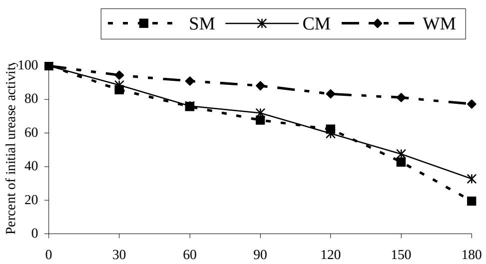


Fig. 3 Changes in solar roasting temperatures of soaked (SM), milled (CM) and whole dry (WM) soybean over time

There was no change ($p>0.05$) in dry matter content of the soybean before and after processing. After 180 min of roasting, urease activity in soaked soybeans had dropped to an average 1.16 *meq* NH_3/g DM (19 % of initial), compared to 2.17 *meq* NH_3/g DM (33 %) in milled dry soybeans and 5.08 *meq* NH_3/g DM (77 %) in whole dry soybeans (Fig. 4).



Solar roasting time (min)

Fig. 4 Effect of solar roasting time on total urease activity levels in whole dry (WM), milled dry (CM) and soaked full fat (SM) soyabeans

The reduction of urease activity was therefore more effective in the soaked soybeans than in the dry beans. This is consistent with findings by McNaughton and Reece (1980) and McNaughton et al. (1981), where soybean urease activity declined faster with increased moisture content during autoclaving. Moisture infiltration into the grain increases exposure of more anti-nutritional factors to heat; hence a greater reduction of urease in soaked soybean. By Analytichem (1999) standards, a urease index between 0.5 and 1 *meq*NH_3/g DM indicates adequate processing. Using the same method, urease in raw soybeans produces about 5 *meq*NH_3/g DM, and over-heating can lower the index to below 0.2 *meq*NH_3/g DM.

In soaked soybeans, urease levels dropped to an average of 1.16 *meq* NH_3/g DM. Thus, roasting soaked soybeans for slightly more than 180 min could have achieved the acceptable urease levels of Analytichem (1999) standards. However, milling the soybean grain resulted in a faster decline in urease activity than in whole dry grain (Fig. 4). Ishler and Varga (2000) reported that crushing soybeans for mixing with other ingredients exposes more urease-containing surface area. In our study, milling the beans before processing could, therefore, have increased the exposure of urease to heat resulting in a higher urease inactivation capacity.

The cooking time of more than 180 min that was required to adequately inactivate urease, by Analytichem (1999) standards, is comparatively longer than when using other heating methods (McNaughton and Reece, 1980; McNaughton et al. 1981). It can be argued that increasing the amount of the soybeans in the roasting pan would have slowed the roasting process, resulting in an even longer roasting duration (TFL, 1997). Thus, to shorten processing time less feed has to be processed at a time. This might be a disadvantage when large amounts of feed are required as in livestock feeding programs. It appears feasible, however, to use higher capacity solar cookers to process larger amounts of feed at a time.

4. <u>CONCLUSION</u>

There is potential in using panel solar cookers to process urease in soaked soybeans during the late dry season in Zimbabwe. Solar cookers can supplement other fuels and assist in balancing growing energy demand.

5. <u>ACKNOWLEDGEMENTS</u>

We would like to thank the Rockefeller Forum for funding the research work. The W.K Kellogg Foundation‘s Academy for Educational Development (AED, Southern Africa Programme) also funded part of data analysis for this paper. Heartfelt thanks are also extended to staff from the Development Technology Centre, Zimbabwe for providing technical assistance on the use of data loggers and the pyrometer.

6. <u>REFERENCES</u>

(1) AnalytiChem. Determination of residual urease activity in soybean. AnalytiChem Corporation: Tools for Lab and Line, 1999. Rockville, Maryland, USA.

(2) AOAC. *Official methods of analysis*, 15th Edition; Association of Official Analytical Chemists: Washington D.C, USA, 1990; Volume 1.

(3) Blum, B.L. *Spreading Solar Cooking: Field Guide*. 3rd Edition; Solar Cookers International: Sacramento, USA, 1998; 1 – 18.

(4) Ishler, V. and Varga, G. *Soybeans and soybean byproducts for dairy cattle*, Publication No. 00-3; College of Agricultural Sciences, Cooperative Extension, Department of Dairy and Animal Science: The Pennsylvania State University, USA, 2000; 1 – 12.

(5) Lampinen, A. Reduction of tropical deforestation by massive use of solar cookers; Technology for Life: Finland, 18/10/1994; Accessed on the web in July 2002. http://www.ismea.org/INESDEV/ala.html

(6) Littell, R.C., Henry, P.R. and Ammerman, C.B. Statistical analysis of repeated measures using SAS procedures. J. Anim. Sci. 1998, 76, 1216 – 1231.

(7) McNaughton, J.L. and Reece, F.N. Effect of moisture content and cooking time on soybean meal urease index, trypsin inhibitor content and broiler growth. Poult. Sci. 1980, 59, 2300-2306.

(8) McNaughton, J.L., Reece, F.N. and Deaton, J.W. Relationships between colour, trypsin inhibitor contents, and urease index of soybean meal and effects on broiler performance. Poult. Sci. 1981, 60, 393-400.

(9) Mupanda, K. *The potential of Solar Cookits in rural Zimbabwe: Results of the baseline survey carried out in Zvimba, Nerupiri, Nyanyadzi, Epworth and Seke*-Dema; Development Technology Centre, University of Zimbabwe: Harare, Zimbabwe, 2000; 1 – 13.

(10) Rodgers, P.M. *Solar box cookers in Zimbabwe: The introduction of a radical innovation in cooking*, Msc Thesis; University of California: Davis, USA, 1994.

(11) SAS. *SAS/STAT Guide to Personal Computers*, Version 6. 12 Edition; Statistical Analysis Systems Institute: Cary, North Carolina, USA, 1996.

(12) SCI. *Solar Cooker Review*, Solar Cookers International: CA, Sacramento, USA, 2002; Vol. 8 No. 1, 1 – 16.

(13) SCP. *Solar Cooker Project Quarterly Report*, 1st April to 30th June 2002; Development Technology Centre, University of Zimbabwe: Harare, Zimbabwe, 2002; 1 – 6.

(14) TFL. *Manual for solar cookers – How to use and build them*; Technology For Life: Helsinki, Finland, 1997; 1 – 36.