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Determination of Energy and Time Requirement for Cooking Pigeon Pea (*Cajanus cajan*)

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Abstract

Purpose: High energy requirement and long cooking time are limiting consumption of pigeon pea (*Cajanus cajan*), a nutritious food. This study was performed to estimate energy and time demand by different methods of cooking pigeon pea. **Methods:** Pigeon pea (150 g) was soaked in 2.0 L of water at ambient temperature (29 ± 2°C) to determine hydration behavior. Cooking experiments were conducted using aluminum and pressure-cooking pots. Efficiency of cooking was evaluated using four types of cooking appliances (kerosene, liquefied petroleum gas (LPG), electric, and charcoal stoves). Normal (continuous heating until the food was satisfactorily cooked) and control (controlling the energy input to closely match the actual energy required) cooking were conducted. Energy requirement and duration of cooking were determined using standard procedures. **Results:** Soaking increased moisture content from 11.99 to 30.01% in 90 min, while water absorption rate decreased with soaking duration. In cooking 150 g of pigeon pea using kerosene stove, presoaked normal pressure-pot cooking method consumed the least energy (10 800 kJ) and time (205 min), while unsoaked normal cooking consumed the highest energy (18 450 kJ) and time (336 min). Using LPG stove, unsoaked normal cooking method required the highest energy (52 470 kJ), while presoaked control pressure-pot required the least energy (14 405 kJ). For electric stove, the lowest energy (15 560 kJ) and shortest duration (105 min) were recorded during control cooking of presoaked sample in the pressure-pot. **Conclusions:** Control cooking was not practicable using charcoal stove. Generally, kerosene stove consumed the least energy, while electric stove was found to have the shortest duration of cooking.

Keywords: Cooking device, Cooking duration, Domestic cooking, Energy demand, Pigeon pea

Introduction

Energy, the ability to do work, is the prime mover of any economy and the engine of growth around which all sectors of economy revolve (Aderemi et al., 2009). Recently, there has been a greater awareness of the energy problems facing the world than at any other period in history (Wang, 2009). It is now widely accepted that the current rate of energy generation and supply cannot match the rapid growth in energy consumption rate (Aiyedun et al., 2008). The importance of energy for sustained economic development is an accepted fact. Energy and foods are concerns of developing countries because chains of food production consume an enormous quantity of energy (Wang, 2009). Energy efficiency is a fundamental requirement for sustainable food and energy development. The food industry is one of the energy-intensive industries (Singh, 1986). Energy efficiency, environmental protection, and food processing waste management have attracted increasing attention in the food industry. Effective energy utilization and energy source management in food processing facilities are desirable for reducing processing costs, conserving non-renewable energy resources, and reducing environmental impact. Cooking energy accounts for approximately 90% of all household energy consumption in developing countries (Dincer et al., 2005).

Pigeon pea (Cajanus *cajan*) is an underutilized grain

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legume of the tropics and sub-tropics. The seed contains moisture (10.1%), protein (18.8%), fat (1.9%), carbohydrates (53.0%), fiber (6.6%), and ash (3.8%) (Saxena, 2008). Additionally, the mineral and trace elements present in the legume are calcium (120 mg/g), magnesium (122 mg/g), copper (1.3 mg/g), iron (mg/g), and zinc (2.3 mg/g); vitamins are carotene (469.0 mg/g), thiamin (0.3 mg/g), riboflavin (0.3 mg/g), niacin (3.0 mg/g), and ascorbic acid (25.0 mg/g). Processing of pigeon pea involves de-podding, cleaning, cooking, drying, and milling. The seed of the pigeon pea is enclosed in a hard, tough, and relatively thick skin that has a semi-permeable membrane. Movement of water through the mesocarp is restricted because the adhesive force that binds the mesocarp to the seed is relatively high (Ghadge et al., 2008). Therefore, cooking is necessary to soften the firmly attached seed skin for convenient dehulling. The traditional boiling time of 8-10 h discourages use. High energy demand is limiting consumption of pigeon pea. The study by Das et al., (2006) demonstrated that energy conservation is achievable during cooking. Studies on energy required for cooking pigeon pea and a conservation approach can alleviate certain identified problems of cooking pigeon pea and renew interest in the neglected and underutilized species. Therefore, this study was designed to estimate energy and time demand by different methods of cooking pigeon pea.

Materials and Methods

Hydration Behavior of Pigeon Pea

Pigeon pea weighing 150 g (approximately 1500 peas) was soaked in 2.0 L of water at room temperature (29 ± 2°C) and samples were drawn at different time periods (at intervals of 15 min up to 2 h and at intervals of 30 min from 2 to 5 h) to determine moisture content using oven-dry method as reported by ASABE (2008). Hydration curves were obtained by plotting the moisture content (% w.b.) of the pigeon pea against soaking time. In addition, rates of water absorption were determined using equation (1). These data were used to determine appropriate soaking duration.

$$R_a = \frac{Wu}{t} \tag{1}$$

where R_a is absorption rate (%/min)

W_u is water uptake (%)

t is time (min).

Cooking Test

The end of cooking was identified by using parallel glass plate method as proposed by Akinoso and Lasisi (2013). In this method, pigeon pea samples that were periodically drawn during cooking were pressed between two small glass plates, and at the point when no remaining core was observed, the sample was considered to be completely cooked. A trial experiment was first carried out to obtain an approximate cooking time. Subsequently, samples of the boiling pigeon pea were examined at 5 min intervals by pressing them between two small glass plates. Toward the close of cooking time, the interval between assessments was reduced to 3 min. This procedure was continued until no white color was apparent at the seed core. The duration of cooking was monitored using a stopwatch.

Cooking on Domestic Appliances

Unsoaked pigeon pea (150 g) and soaked pigeon pea (150 g in 2 L water at ambient temperature for 30 min) were used for the experiment. These were separately cooked in 2.5 L of water. Experiments were conducted using an aluminum pot (3 mm thickness and 200 mm diameter) and pressure-cooking pots (Model: 15 psi Marlex appliance, India). Efficiency of cooking was evaluated using four appliances, which were kerosene, LPG, electric (Model: ES-1020; 1000 W), and charcoal stoves. Normal and control cooking were conducted. For all types of cooking, the pots were covered. The normal cooking method is the general practice of continuous heating in closed pot until the food is satisfactorily cooked. On the other hand, controlled cooking experiments were conducted to achieve energy savings by controlling the energy input to closely match the actual energy required for cooking. The temperature was monitored, and the heat input was cut off at the boiling temperature (100°C) and was resumed whenever the temperature fell below 90°C. Temperature was monitored using thermocouple (Mastech 266C digital clamp multi-meter).

Determination of Energy Requirements

Kerosene, charcoal, and gas were used for kerosene, charcoal, and gas stoves, respectively. The weights of the stove were measured before and after cooking. The difference in weight was assumed to be the quantity of fuel consumed. Cooking time was also recorded. Equation (2) was applied to quantify energy input using kerosene, LPG, and charcoal as heat sources. Caloric values of kerosene, LPG, and charcoal were considered to be 45 000 kJ/kg, 47 700 kJ/kg, and 14 500 kJ/kg, respectively (http://www.lpgforyou.com/asp/datasheet.asp). Everest electric stove was used for electric cooking. Power consumption was estimated using equation (3).

$$E = (Q_1 - Q_2) \times C \qquad (2)$$

$$E = p \times t \qquad (3)$$

where E = energy consumed (kJ)
Q_1 = weight of fuel before cooking (kg)
Q_2 = weight of fuel after cooking (kg)
C = calorific value of the fuel used (kJ/kg)
p = power rating of the cooker (W)
t = duration of cooking (s)

Sensory Evaluation

The cooked pigeon pea from different cooking methods were coded and presented to a team of twenty panelists who are familiar with the organoleptic properties of the food. The panelists scored the color, taste, flavor, texture, and the overall acceptability of the sample using a nine point Hedonic scale, where nine indicated "like extremely" and 1 indicated "dislike extremely."

Statistical Analysis

All determinations reported in this study were carried out in triplicates. In each case, mean and standard deviation were calculated. Analysis of variance was also performed, and means were separated using Duncan's multiple range test at $p < 0.05$. Statistical Package for Social Sciences (SPSS) software version 16.0 was employed for the analysis.

Results and Discussion

Hydration Behavior of Pigeon Pea

Soaking increased moisture content of pigeon pea from 11.99 to 30.01% in 90 min (Figure 1); after this, no noticeable increase was observed. Moreover, water absorption rate attained a constant value at 90 min of soaking. The absorption rate decreased with soaking duration (Figure 1). Hydration is a complex process and indicates the physical and chemical transformations (Das et al., 2006). The absorption of water during soaking can be attributed to the nature of the starch structure of pigeon pea. Swelling upon hydration is a characteristic property common to starches and proteins. A solid swells when it absorbs a liquid, and at the same time, it does not lose its apparent (microscopic) homogeneity; its dimensions are enlarged, its cohesion is diminished, and it becomes soft and flexible (Das et al., 2006). Hydration is an important determinant of cooking quality. Seeds with high water absorption rate and lower cooking time are generally preferred for cooking purposes. High water absorption rate usually indicates good cooking quality in terms of reduced cooking time and better cookability.

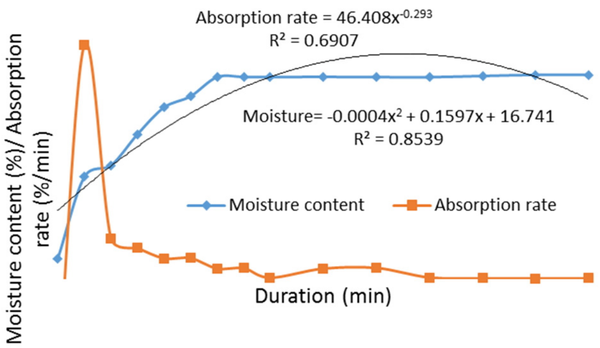

Figure 1. Hydration curve of pigeon pea.

Energy and Time Consumptions using Kerosene Stove

In cooking 150 g of pigeon pea using kerosene stove, presoaked normal pressure-pot cooking method consumed the least energy (10 800 kJ) and time (205 min), while unsoaked normal cooking consumed the highest energy (18 450 kJ) and time (336 min) (Table 1). Effect of cooking methods significantly ($p < 0.05$) influence energy and time requirements. Presoaked pigeon pea gelatinizes more easily than unsoaked pigeon pea (Akinoso and Lasisi, 2013). Uniformity of heat and mass transfer during cooking of presoaked grains was reported by Chakkaravarthi et al. (2008). This accounts for the lower cooking energy of presoaked samples.

Energy and Time Consumptions using Liquefied Petroleum Gas (LPG) Stove

Using LPG stove to cook 150 g of pigeon pea, unsoaked

Table 1. Energy and duration using kerosene stove

Cooking method	Energy utilized (kJ)	Duration (min)
Unsoaked Normal cooking	18 450 ± 0.01^{f}	336 ± 0.02^{d}
Presoaked Normal cooking	15 300 ± 0.23^{d}	255 ± 1.34^{b}
Unsoaked Normal Pressure-pot	12 600 ± 0.43^{ab}	250 ± 2.12^{b}
Presoaked Normal Pressure-pot	10 800 ± 0.01^{a}	205 ± 2.43^{a}
Unsoaked Control cooking	14 400 ± 0.08^{c}	340 ± 1.11^{c}
Presoaked Control Cooking	13 500 ± 0.08^{b}	310 ± 1.98^{c}
Unsoaked Control Pressure-pot	17 100 ± 1.12^{e}	307 ± 2.14^{c}
Presoaked Control Pressure-pot	11 700 ± 2.18^{a}	295 ± 2.21^{c}

Means with the same superscripts along a column are not significantly different ($p < 0.05$).

Table 2. Energy and duration using LPG stove

Cooking method	Energy utilized (kJ)	Duration (min)
Unsoaked Normal cooking	52 470 ± 0.12^{f}	330 ± 1.22^{d}
Presoaked Normal cooking	38 160 ± 3.11^{d}	245 ± 2.13^{c}
Unsoaked Normal Pressure-pot	33 390 ± 2.77^{c}	195 ± 2.27^{b}
Presoaked Normal Pressure-pot	28 620 ± 3.12^{bc}	135 ± 3.13^{a}
Unsoaked Control cooking	42 930 ± 2.44^{e}	415 ± 1.29^{e}
Presoaked Control Cooking	14 420 ± 0.41^{a}	340 ± 0.01^{d}
Unsoaked Control Pressure-pot	23 850 ± 1.12^{b}	285 ± 0.23^{c}
Presoaked Control Pressure-pot	14 405 ± 2.21^{a}	190 ± 1.97^{b}

Means with the same superscripts along a column are not significantly different ($p < 0.05$).

Table 3. Energy and duration using electric stove

Cooking method	Energy utilized (kJ)	Duration (min)
Unsoaked Normal cooking	51 200 ± 2.12^{f}	190 ± 2.12^{f}
Presoaked Normal cooking	44 120 ± 2.11^{e}	122 ± 1.12^{b}
Unsoaked Normal Pressure-pot	38 770 ± 1.22^{d}	155 ± 1.34^{e}
Presoaked Normal Pressure-pot	30 220 ± 1.43^{c}	141 ± 2.21^{d}
Unsoaked Control cooking	30 010 ± 1.11^{c}	145 ± 1.14^{d}
Presoaked Control Cooking	28 971 ± 2.23^{c}	130 ± 0.03^{c}
Unsoaked Control Pressure-pot	19 800 ± 1.34^{b}	132 ± 0.00^{c}
Presoaked Control Pressure-pot	15 560 ± 2.13^{a}	105 ± 0.01^{a}

Means with the same superscripts along a column are not significantly different ($p < 0.05$).

normal cooking method required the highest energy (52 470 kJ), while the energy requirement of presoaked control pressure-pot (14 405 kJ) was the least (Table 2). No significant difference ($p > 0.05$) was observed between the energy required by presoaked control (3 mm aluminum) and presoaked control pressure-pots. From table 2, it is apparent that cooking duration did not follow the pattern of energy used. Among all the methods, cooking of unsoaked pigeon pea was the least efficient. By soaking, water replaces air within particles of the food; this conducts heat better, which makes cooking faster and conserves energy (Amarasekara, 1994).

Energy and Time Consumptions using Electric Stove

Cooking a similar quantity of pigeon pea on an electric stove, the lowest energy (15 560 kJ) and shortest duration (105 min) were recorded during control cooking of presoaked sample in pressure-pot (Table 3). The energy and time differences between the highest and least were

35 640 kJ and 85 min, respectively. Cooking under pressure reduced the requirement of energy and cooking time because the cooking was carried out at an elevated temperature (Akinoso and Lasisi, 2013). It saved energy as it was operated as a closed system, which minimized the rate of energy loss because of evaporation. In addition, the material (ceramic) that houses the heating element possesses low thermal conductivity (0.25-2.0 W/mK), which reflects the potential for retaining heat and high temperature during control cooking. Thermal mass and insulation are the two primary characteristics that describe an oven's ability to absorb and hold heat and render it suitable for cooking (Forno, 2012).

Energy and Time Consumptions using Charcoal Stove

Energy and time consumed for cooking pigeon pea on charcoal stove varied significantly with cooking methods (Table 4). Energy and duration of cooking followed the same trend. In addition, control cooking was not practicable because of difficulty in regulating charcoal stove. Time variation between the fastest (115 min) and slowest (170 min) was marginal compared to the other cooking devices. This characteristic is potentially advantageous for large quantity cooking.

Comparative Analysis of the Cooking Devices

Table 5 illustrates a comparative analysis of the cooking devices. The devices have comparative advantages in term of energy requirements and duration. Margins between the least and highest energy demands and time were not consistent. Amarasekara (1994) and Das et al. (2006) reported similar results. Thus, the choice of appropriate methods depends on the cooking device.

Sensory Attributes of cooked Pigeon Pea

There was no significant difference among the entire samples evaluated for taste at $p < 0.05$; this clearly demonstrates that the various methods of cooking carried out do not affect taste. Color provides information about the formation and quality of a product. There was no significant difference among the entire samples based on sensory evaluations of the color of cooked pigeon pea ($p < 0.05$). There was significant difference in the texture of cooked pigeon pea; this result demonstrates that pigeon pea cooked under pressure were different from those cooked by other forms of cooking, although there was no significant difference between pigeon pea cooked under pressure and with kerosene stove. Cooking under pressure retains the quality of foods (Fellows, 2000) and causes more uniform gelatinization of the starch, which can be attributed to texture. The evaluation of the overall acceptability of the cooked pigeon pea demonstrates that there was no significant difference among the samples as they are all rated equally ($p < 0.05$). Thus, it was established that the various methods of cooking utilized do not have significant effect on the acceptability of cooked pigeon pea.

Table 4. Energy and duration using charcoal stove

Cooking method	Energy utilized (kJ)	Duration (min)
Unsoaked Normal cooking	$40\ 600 \pm 0.12^{c}$	170 ± 1.21^{d}
Presoaked Normal cooking	$29\ 010 \pm 0.22^{b}$	125 ± 2.11^{b}
Unsoaked Pressure-pot cooking	$30\ 405 \pm 2.12^{b}$	145 ± 0.24^{c}
Presoaked Pressure-pot cooking	$24\ 657 \pm 0.11^{a}$	115 ± 1.11^{a}

Means with the same superscripts along a column are not significantly different ($p < 0.05$).

Table 3. Energy and duration using electric stove

	Energy (kJ)		Duration (min)	
	Least	Highest	Least	Highest
Kerosene stove	10 800	18 450	205	306
LPG stove	14 405	52 470	190	330
Electric stove	15 560	51 200	105	190
Charcoal stove	24 657	40 600	115	170

Conclusions

Soaking increased moisture content of pigeon pea from 11.99 to 30.01% in 90 min. On the other hand, water absorption rate decreased with soaking duration. For both parameters, constancy was achieved at 90 min. Controlled energy input, cooking under pressure, and soaking of pigeon pea prior to cooking conserved energy and time. The type of heat source, cooking device, and appliances were also important factors that decided energy requirements for cooking. Combination of controlled cooking and pre-soaking under pressure-cooking enabled minimization of cooking energy. There was no consistent correlation between energy demand and duration. Generally, kerosene stove consumed the least energy, while electric stove had the shortest duration of cooking. Control cooking is not desirable for charcoal stove.

Conflict of Interest

The authors have no conflicting financial or other interests.

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