COMPARATIVE STUDY ON THE PERFORMANCE OF SOYBEAN DEHULLING METHODS IN MOROGORO REGION

BY

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ABSTRACT

A study was conducted to assess soybean dehulling methods used in Morogoro region at village level and in peri-urban areas. Methods identified were: hand method (53.5%), hessian bag method (31.0%), mortar and pestle (9.9%), grinding stone (1.4%), and SUA wet dehuller (4.2%). Dehulling processes used were wet processing (91.53%) and dry processing (8.5%). Hand, hessian bag and SUA wet dehuller, were tested in a laboratory for dehulling efficiency on TGX1895-33F, TGX1895-4F, TGX1805-8E, TGX 1876-4E and sable varieties. Dehulling efficiency was measured by dehulling fractions and parameters produced in each method. Dehulling fractions in wet dehuller were; bean recovery (90.39%), hull recovered (8.85%), undehulled grains (1.26%) and fines (1.56%), while dehulling parameters were; coefficient of dehulling (0.98), coefficient of the wholeness of the kernels (0.97), hulling efficiency (95.99%), overall dehulling efficiency (95.59%), and dehulling index (0.94). However, the SUA wet dehuller proved unsuitable for dry beans. Hand method showed bean recovery of 88.18% where hull recovered was 8.43%, undehulled grains 1.35%, fines 1.19%, coefficient of dehulling 0.98, coefficient of the wholeness of the kernels 0.98, hulling efficiency 96.33%, overall dehulling efficiency 92.84%, and dehulling index 0.91. Hessian bag method showed slightly lower dehulled fractions and parameters which included bean recovery of 79.75%, hull recovered 8.32%, undehulled grains 2.62%, fines 4.87%, coefficient of dehulling 0.96, coefficient of the wholeness of the kernels 0.93, hulling efficiency 90.93%, overall dehulling efficiency 82.33% and dehulling index 0.77. Relative throughputs were 30, 2.27 and 1.38 kg/hr for dehuller, hessian bag and hand method respectively. Physical characteristics of the bean varieties significantly ($p<0.05$) influenced dehulling efficiency. Traditional method of processing used by 95.8% of households was the most popular in comparison to SUA wet dehuller 4.2%. The dehuller was found to be a useful method for lessening the dependence on traditional methods, reduce the drudgery and reducing dehulling time.

DECLARATION

I, Grasiana Manyara Mtey, do hereby declare to neither the Senate of Sokoine University of Agriculture that this dissertation is my own original work and it has neither been nor concurrently being submitted for a higher a degree award in any other University.

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DEDICATION

I wish to dedicate this work to my late parents Andrew Kare Mtey and Josephine Isheke Tairo who laid the foundation for my education and life career.

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
ATI	-	Appropriate Technology International
CIRAD	-	French Agricultural Research Centre for International Development
DMRT	-	Duncans Multiple Range Test
FAO	-	Food and Agriculture Organization
GDP	-	Gross Domestic Product
IDRC	-	International Development Research Centre
IITA	-	International Institute forTropical Agriculture
MAFSC	-	Ministry of Agriculture, Food Security and Cooperatives
NSRL	-	National Soybean Research Laboratory
PHTRG	-	Post Harvest Technology Research Group
SMEs	-	Small and Medium-scale Enterprises
SNAL	-	Sokoine National Agricultural Library
SPSS	-	Statistical Package for Social Sciences
SUA	-	Sokoine University of Agriculture
UNIFEM	-	The United Nations Development Fund for Women
URT	-	United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background information

Lack of sufficient protein in the diet of large percentage of people in developing countries is becoming a major setback for human development. This is complicated by the continuous increase in population coupled with increasing demand for plant protein as a substitute for scarce and expensive animal protein. Against this background, there have been intensive research efforts aimed at finding alternative sources of protein from underutilized grain legume seeds in order to meet the protein demands in developing countries, where animal protein is either grossly inadequate or relatively expensive (Adebowale and Lawal, 2003; Adebowale and Lawal, 2004; Lawal and Adebowale, 2004; Lawal and Adebowale, 2005; Lawal *et al.,* 2005; Adebowale *et al.,* 2005; Lawal and Adebowale, 2006). There has been renewed awareness on the utilization of legumes in the developed countries, as they are now regarded as versatile functional ingredients which could serve as replacement for animal proteins (Guillion & Champ, 1966; Sirtori and Lovati, 2001). Legumes are target crops in this regard because they are amoung the most important sources of proteins, carbohydrates and dietary fibre for human nutrition.

Generally, legumes have protein contents between 20 and 40% and a few range between 40 and 60 % (Emenalom and Udedibie, 1998; Maneepun, 2000). Today increased reliance on vegetable protein has become a major factor in preventing worldwide malnutrition and hunger (IITA, 1990). Soybean *Glycine max.* (L) Merril is a widely used inexpensive and nutritional source of dietary protein (IITA, 1990). The protein found in soybean is higher than in meat, eggs and in milk. This means that soybean is the cheapest source of protein for the low income people who cannot afford to obtain protein from milk, eggs and meat (Kimenya, 2006). The cost of protein from soybean is only about 10-20% of the cost of protein from fish, meat, eggs or milk. Therefore, soybean is suitable in areas where other protein sources are unavailable and/or too expensive (Malema, 2006).

The grain has been variously described as a "miracle bean" or "golden bean" because it is a cheap, protein rich grain (Rweyemamu, 2004). It contains all the three macro-nutrients required for good nutrition: complete protein, carbohydrates and fats as well as vitamins and minerals (NSRL, 2008). Soybean contains about 40% high quality protein, 20% edible vegetable oil and a good balance of all eight essential minerals including sodium, potassium, calcium, manganese, iron, copper, zinc, phosphorus, chlorine, iodine and selenium (Rweyemamu, 2004). Soybean has therefore, tremendous potential to improve nutritional status and welfare of the resource-poor farmers.

Along with nutritional importance of soybean are its potential preventive and healing properties for various diseases including chronic ones such as cancer, osteoporosis and many others (Rweyemamu, 2004). Many legumes have been used in folk medicine (Duke, 1992; Kindscher, 1992). Isoflavones from soybean and other legumes have been suggested both to reduce the risks of cancer and to lower the serum cholesterol (Kennedy, 1995; Molteni *et al.*, 1995). Soybean and soy food phytoetrogens have been suggested as possible alternatives to hormone replacement therapy for postmenopausal women (Kennedy, 1995; Molteni *et al.*, 1995).

As health food, soybean is good for diabetics, people with abdominal complaints and soy flour is recommended for patients suffering from high blood pressure, hypertonia and arteriosclerosis because it has high magnesium, calcium and potassium content (Kabigi, 2002). An interest in soybean as health and nutritional food relies on the role of soybeans lecithin in neurological and nervous disorders (Szuhaj, 1980). Because of its high nutritional and medicinal value soybcan is now used as a low-cost therapy for people living with HIV/AIDS (Rweyemamu, 2004). Protein requirements of HIV-infected persons jump to 50-100% higher than for uninfected persons. Soy protein and adequate calories can help to prevent body, from wasting, which is often associated with HIV/AIDS (Rweyemamu, 2004).

The crop can be processed into various products. In Tanzania, the various products produced from soybean include soy flour, soy drink, soymilk and soy flour mixed with cassava or cereals like finger millet, maize and sorghum (MAFSC, 2005; Laswai, *et al.*, 2005; Rweyemamu, 2004). In Tanzania, the common recipes at household level are: soy porridge, soy "ugali" (stiff porridge), soy biscuits, soybean/cassava cakes, soybean vegetables relish (similar to groundnut relish), soybean milk and soybean drink (MAFSC, 2005).

Although it is true that soybean is suitable for preparing foods for children, pregnant women and various people including those affected with HIV/AIDS, in Tanzania this fact is still not known to most of the people (MAFSC, 2006). Therefore, this opportunity has not been utilized effectively despite having 30% malnourished children and increasing number of people living with HIV/AIDS (MAFSC, 2006). If exploited fully the crop can highly contribute to poverty reduction and eradication of malnutrition among children and expecting mothers (Sicilima, 2005). Lack of knowledge on how to process and utilize soybean has made the crop to be one of the most underutilized crops in Tanzania

(Kimenya, 2006). Most of families lack knowledge on soybean processing technologies (Malema, 2005).

Consumption of soybean is restricted by two factors: the presence of toxic substances and anti-nutritional factors such as trypsin inhibitors (Irvin, 1979). Trypsin inhibitors are probably the best known, and certainly the most studied, of all the anti-nutritional factors known to be present in soybeans (Irvin, 1979). Trypsin inhibitors from soybeans can certainly interfere with protein digestion, cause pancreatic enlargement and enhance chemically induced pancreatic tumours in some animal species (Considine, 1982; Pomerans, 1991). The components decrease nutritional value of plant foods usually by making nutrients unavailable for absorption or indigestible when consumed (MAFSC, 2005; Enig and Fallons, 2005). They can also elicit adverse physiological responses in both human and animals (Considine, 1982; Pomerans, 1991). According to Kimenya, (2006) some households never use soybean based complementary foods because of diarrhea resulting from using soybean which is not properly processed. However, boiling beans generally reduces the trypsin inhibitor content by 80-90%. In humans, harmful effects have only been reported in instances where the beans were not properly cooked (Considine, 1982; Pomerans, 1991).

The seed coat of soybeans constitutes about 8-10% by weight, the rest being endosperm (Sessa and Wolf, 2001). The hull is basically fibres of low digestibility sugars (raffinose and stachyose), which may cause problems if consumed beyond certain limits (Silayo *et al.*, 2006). Removing these hulls prior to processing increases protein content of the desired end products (Riaz, 2006). Secondary is the presence of lipoxygenase enzyme, which produces off-flavour when in contact with fats in the soybean cells under cold water (MAFSC, 2005).

Due to these problems, the grains are virtually never eaten by smallholders at the village level. Smallholder farmers are ignorant of its simple processing method for utilization at village level (Rweyemamu *et al.*, 2003). Unlike other legumes soybean has to be processed to remove anti-nutritional factors before being utilized in food and feed formulations for human and animal use, respectively (Malema, 2006). Processing focuses on solving the problem of anti-nutritional factors, toxic substances and bean off-flavour while retaining valuable components in the required quantity (Rweyemamu, 2004). In many countries of the world, legumes are initially processed by removing the seed coat or hulls and splitting the seed into cotyledonous component (Grandison and Lewis, 1996). The removal of the seed coat often forms the first step in the processing of food legumes.

To produce high protein meal for animal feed and for human consumption, dehulling is very much needed (Grandison and Lewis, 1996). It is the major primary process that improves the cooking quality, digestibility and appearance of the product (DVC, 2001). When making edible flours more complete, removal of hulls is required, meaning that more than 90% of hulls from soybeans must be removed to assure that the minimum specification of 50% protein is met (Akoh and Min, 2008). Practically, it is not possible to get an absolute separation of the hull from the cotyledons, but the objective is to get sufficient separation to meet the standard meal analysis required (DVC, 2001). Generally if the fiber content is reduced to the desired value, the protein content will meet the specification (DVC, 2001).

The oldest and most common method of dehuling pulses at home level is by pounding them in pestle and mortar or on a stone grinder after drying the grains in the sun or after mixing with small amount of water. This method is still popular in rural sector (home level) in a few African countries (Chakraverty and Mujumdar, 2003). The maximum theoretical recovery from dehulling pulses is around 87–89% even though traditional dehulling recovers only about 65–75%. Modern dehulling methods can recover 82–85% (Kyi *et al.,* 1997). These methods mainly involve use of pre-treatments. Various pre-treatments for loosening the hull, such as wet method (WM), dry method (DM), chemical and enzymatic treatments have been reported by various workers (Sahay and Bisht, 1988; Phirke and Bhole, 1999). Legumes with good dehulling characteristics are required by processors to satisfy both domestic and the export markets. In other words, cultivars that are easy to dehull coupled with high splits yield recovery are required by processors (Chakraverty and Mujumdar, 2003).

Soybean dehulling in Tanzania is mainly done at household level by very few individuals for home consumption and small-vending (Silayo *et al.,* 2006). Recently many small-scale soybean processors have emerged. They are manufacturing foodstuffs for human consumption, mainly for making porridge (Malema, 2006). However; utilization of soybean at household level in Tanzania is still at very low level. This is because most of the families lack knowledge on soybean processing technologies. Dehulling is commonly done using the wet method whereby soybeans are soaked or boiled for a prolonged period of time, cooled then rubbed between fingers to loosen the hulls. Thereafter, hulls are washed away using water (Mpagalile *et al.,* 2006). This activity is usually carried out manually, which is labour intensive, with low productivity, inconsistent product quality, constituting a major bottleneck in its processing and utilization. This does not give opportunity for increased capacity that may be required as demand for soybean products increases (Silayo *et al.*, 2006). The demand may increase due to awareness campaign on nutritional qualities of soybean products (Silayo *et al.*, 2006). In the near past, Tanzania had only two large-scale soybean processors. One is for food and the other for animal feed processing (Malema, 2005).

In recent years concerted efforts have been made to eliminate the time consuming, labour-intensive manual dehulling and milling of cereal and grain legumes (Lusas *et al.*, 1995. These efforts have resulted in development of simple processing technologies that are appropriate and intended for use at the village level (Lusas *et al.*, 1995). Small-scale food processing equipment, which require simple maintenance and can be operated manually are more appropriate for developing countries than highly sophisticated processing equipment/technology (Lusas *et al.*, 1995).

1.2 Problem statement

A lot of problems still beset crop post-harvest handling and processing activities in Tanzania. Traditionally, women have been the custodians of most primary on-farm processing operations. Tools used by food processors are characterized by their simple nature (mainly traditional and manual) with little use of mechanical devices. Although traditional techniques give products that meet the organoleptic quality demands of consumers, they have limitations: poor hygiene, unstable utilization conditions and low yield, as well as inadequate efforts towards reducing losses.

Soybean has been faced with some problem vis-à-vis in the area of improper processing techniques and use of traditional processing equipment, which in most cases, could have negative impact in the consumption pattern and rate of production. For example, the traditional method of dehulling soybeans in the course of preparation of tempe is by treading underfoot. Dehulling by feet appears unhygienic. Some people do not eat tempe just because of this.

Over the years, soybean processing techniques has been presented as a major challenge to its acceptability and popularity in Africa. This is mainly due to lack of simple and efficient small–scale soybean processing technologies suitable for farmers and processors in rural areas. The process of dehulling that is still most commonly used in Africa is hand scrubbing or pounding dry grains in a wooden mortar. This is a laborious task, which is generally incumbent on the women. The drudgery of the task and the lack of services to hull the grain in urban areas are the principal constraints in utilization of soybeans, and if nothing is done this crop will be marginalized or might even disappear.

1.3 Justification of the study

In Tanzania, soybean processing is a very big constraint, especially in rural areas. Dehulling is mostly done manually, which constitutes a major bottleneck on its processing and utilization. Machines to simplify work are not available, meaning that other sources have to be used to have the dehulling done (Laswai and Mutayoba, 2006). Dehulling is commonly done manually using the wet method, whereby the soybeans are soaked, boiled for a prolonged period of time cooled then rubbed using hands to loosen the hulls (Mpagalile *et al.*, 2006). Thereafter, the hulls are washed away using water. In this method, a lot of water is wasted, important nutrients are lost and proteins are denatured. Excessive use of water necessitates prolonged drying periods that adds extra costs. If drying is not done properly the cotyledons become mouldy, leading to inferior final products (Mpagalile *et al.*, 2006).

The process is very tedious, time consuming and labour intensive (Laswai *et al.*, 2005) meaning that capacity to process large quantities of soybean to remove anti-nutritional factors is still low in Tanzania (Malema, 2006). The availability of knowledge and the level of technology employed have numerous setbacks, and thus the quality of soy foods under the current processing conditions could not be to the level of consumer expectation (Rweyemamu, 2004). This is a major bottleneck to its utilization in the country.

To eliminate these problems non-traditional less energy consuming processing methods are required. Attempts have been made to develop better dehulling methods for leguminous and non leguminous crops such as sorghum, canola, cowpeas and soybean (Lazaro *et al.*, 2002). At Sokoine University of Agriculture (SUA) study on the effectiveness of a novel steaming method in improving small scale soybean dehulling using abrasive surfaces by Mpagalile *et al.* (2006) was carried out. The study showed that simple steaming resulted in a significant improvement in the dehulling of soybeans. Again an attempt on adoption of the traditional coffee pulping machine to soybean dehulling studied by Silayo *et al.* (2006) at this institute, showed significant improvement in bean recovery. Moreover, in recent years, the University has developed an improved soybean wet dehuller to be used at household, small-scale and medium-scale levels. However, more data was required on its performance and be compared with traditional methods.

This study was an attempt to identify, document and assess performance of various methods used to dehull soybean in Morogoro region and compare them with SUA newly developed wet soybean dehuller. The results obtained from evaluating the dehulling efficiency of different options available for soybean dehulling, by putting more emphasis on technologies that will reduce workload, processing time and yielding good quality dehulled soy grains. This will ultimately produce a body of knowledge that will assist the developers of the new mechanical systems on the efficiency of machines developed, and assist the policy makers to come up with informed decisions with regard to utilization of this noble crop. Moreover, the results obtained will form basis for upgrading the traditional dehulling methods and standardizing other newly developed technologies.

1.4 Objectives

1.4.1 General objective

To investigate the different methods used for soybean dehulling in Morogoro region.

1.4.2 Specific objectives

a) To establish socio-economic characteristics of households involved in soybean processing activities.

b) To identify and document the methods used to dehull soybeans in Morogoro

c) To assess the perfoımance of the methods identified in (b) above

d) To assess dehulling performance of the SUA newly developed wet soybean dehuller for dehulling wet and dry soybeans.

1.5 Organization of the report

This report is organized into five chapters. The following Chapter gives a critical review of the literature relevant to the study while the third Chapter gives detailed description of the methodology employed for the study. The fourth Chapter presents results and discussion while the fifth and last Chapter provides concluding remarks and recommendations from the study. A list of references cited in the text and appendices is given at the end of this work.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

This Chapter presents reviews of what has been done in relation to studies on dehulling efficiency of soybeans and other related leguminous crops. Although literature pertaining to studies on soybean dehulling efficiency and related leguminous crops in Tanzania is scarce, studies from other countries are abundant. This Chapter is intended to cover: dehulling, dehulling methods, seed conditioning to improve dehulling, factors affecting dehulling, throughput of a method, dehulling losses, dehulling efficiency, description of dehulling technique and importance of dehulling oilseeds. The Chapter also covers the role of on-farm food processing, small-scale food industries, significance of small-scale industries, upgrading of traditional technologies and finally the choice of appropriate technologies as well as local manufacture of equipment.

2.2 Dehulling

There is increasing emphasis on utilization of legume grains in formulated foods, particularly in relation to relieving protein shortages in developing countries (Ehiwe and Reichert, 1987). As a result, the processing of legumes has become more attractive, and there is continuing effort to improve processing techniques. In many countries of the world, legumes are initially processed by removing the seed coat or hull and splitting the seed into cotyledonous components (Ehiwe and Reichert, 1987). Dry pulses seed have a fibrous seed coat, which is often indigestible and may have bitter taste. In such cases the skin has to be removed (Shakuntala *et al.*, 2005). Removing hulls prior to processing increases protein content of the desired products (Riaz, 2006). Furthermore removal of the hull results into: reduction in fiber and tannin content and improvement in appearance, cooking quality, texture, palatability and digestibility of the grains (Grandson and Lewis, 1996). The methods and scale of seed coat removal vary from simple, home-based mortars and pestles (Dovlo *et al.*, 1976) to large, industrial abrasive or attrition-type dehullers (DeMan *et al.*, 1973; Reichert *et al.*, 1984).

2.3 Methods of dehulling

2.3.1 Traditional dehulling

Traditional methods of milling or mechanical removal of the seed coat became established in many pulse producing regions of the world, often using a simple mortar and pestle system. In some cases, the hull is removed in small commercial or home-scale operations by grinding in a hand operated stone or wooden mill. The hull is then removed by winnowing (Kurien, 1984). Farmers use traditional soaking and manual grinding or pounding to dehull split pulses for home consumption (Rondot, 1993). The grains in protective hulls are released by pounding (impact and rubbing action) in a mortar using pestle (Gyang and Wuyep, 2005). This activity is usually carried out traditionally by women. Manual dehulling has a very low output, with each woman dehulling between 1 and 2 kg/h (Philip and Itodo, 2006). It is very tedious and time consuming (Vietmeyer *et al.*, 1966; Kwon-Ndung and Masari, 1999), constituting a major bottleneck in legume's processing and utilization.

In traditional method, grains are soaked in water for a short time to lend themselves to easy husk removal (Siegel and Fawcett, 1976). In addition, legumes may be steeped, soaked in hot water that is below its boiling point to allow the seed coat to swell and loosen from the cotyledon (Siegel and Fawcett, 1976). The husk takes up more water than the seeds and may be easily separated by rubbing while still moist (Shakuntala *et al.*, 2005). Alternatively, the soaked grains may be dried and the husks removed by pounding and winnowing. Soaking reduces oligosaccharides of the raffinose family as well as the amount of phytic acid in pulses (Shakuntala *et al.*, 2005). The germ is usually removed during dehusking and this may result in some loss of thiamine. Husked and split pulses may not be as good as the whole seed but its keeping quality and cooking time will be better (Shakuntala *et al.*, 2005).

Though manual removal of hulls from many legumes is a tedious task, the method is probably the only one which removes all the hulls and consequently is used for estimating the hull content of the seeds and also the theoretical yield of dehulling product which usually range between 85-95% (Gradison and Lewis, 1996). Some values for hull content expressed on dry weight basis are given in Table 1 (Reichert *et al.*, 1984).

Table 1: Dehulling performance of some different legumes

Legumes	Hull content [a]	Yield [b]	Dehulling efficiency [c]	Hull adhesion [d]	Intact Seed [e] %
Soybean	8.27	88.7	0.72	1	91.3
Fababean	11.92	83.3	0.71	1	59.9
Field pea	7.74	87.3	0.61	1	47.6
Lentil	8.47	85.4	0.54	1	98.2
Kidney bean	8.47	84.2	0.5	2	0
Mung bean	8.95	74.2	0.33	2	18.1
Cowpea (black eyed)	5.24	79.6	0.25	2	18.7
Cowpea (brown)	3.24	78.3	0.11	2	18.7

Source: Reichert *et al.* (1984)

[a] Dry weight basis.
[b] The yield of dehulled grain when 90% of the hull has been removed from the seed.
[c] DE=hull removed (g/100gseed/ (100-yield) (g)/100gseed.
[d] 1Designates loose adhesion, whereas 2 donate a tight binding.
[e] The weight of percentage of seeds which have cotyledons bound together after dehulling.

2.3.2 Commercial dehulling

Commercial processes are much more sophisticated, involving power operated grinders and aspirators. Mechanically, dehulling can be accomplished by attrition-type dehullers (DeMan *et al.*, 1973), roller mills (Singh and Sokhansanj 1984; Shyeh *et al.*, 1980; Kurien and Parpia, 1968), or abrasive-type dehullers (Reichert *et al.*, 1984). Attrition-type dehullers and roller mills are particularly suitable for dehulling and splitting legume grains with loose seed coats, whereas abrasive-type dehullers are suitable for dehulling grains with more tightly adhering seed coats (Kurien 1984; Brian 1976). Although all dehulling systems operate on the same basic principle of friction between the seed and a surface or another seed, a variety of horizontal and vertical shaft configurations exist. Depending on mill configuration, efficiency can be optimized in these systems by adjusting factors such as stone speed, diameter, texture and clearance, as well as the time each batch remains in the mill.

Traditional commercial methods of milling give an average yield of split of 73%, which is considerably less than that of the average maximum theoretical yield 88% (Alvin and Brian, 1976; Kurien *et al.*, 1972). This can relate directly to the method adopted for loosening the husk. Pre-treatment steps such as boiling, soaking or roasting may be employed to facilitate the husk removal that can be accomplished by subsequent pounding, grinding or milling (Siegel and Fawcett, 1976).

2.4 Dehulling processes

The soybean dehulling process consists of three steps. First, a heat treatment (93°C) for 15 minutes is required to break the bond between hulls and cotyledons for the most effective and efficient dehulling. The second step is the cracking of the beans and in the third step the hulls are separated (Thomas, 1989). Soybean can be dehulled either by wet or dry dehulling.

2.4.1 Wet method

Wet dehullng is generally done after pre cooking which facilitate hydration of the soybeans (Hui, 2006). Wet dehulling is performed by hand or foot after cooking and the hulls are separated by skimming. This type of dehulling requires no mechanical devices other than hands or feet to rub the hulls from the cotyledons. Therefore, this method may not be feasible for large scale soy food production (Farnworth and Edward, 2008). If sufficient water and cheap labour is available wet dehulling has the advantage that the beans suffer very little mechanical damage which indicates a good yield (Farnworth and Edward, 2008). A major disadvantage of this process is its laborious and complete dependence on climatic conditions. The entire process usually takes 5-7 days (Siegel and Fawcett, 1976).

2.4.2 Dry method

Dry dehulling is performed before any hydration procedure, and is desirable, efficient method provided that suitable mechanical equipment is available. The beans are heated for 10 minutes at 93° C to shrivel the cotyledons and loosen the seed coats (Farnsworth and Edward, 2008). Since soybeans hulls are attached to the bean with a proteneous material, exposure to heat treatment, releases the hulls (Riaz, 2006). Burr, corn or steel mills may be used to crack the hulls (Steinkraus, 2004). If the beans are first size-graded and the mill properly adjusted, hulls are loosened and the cotyledons remain intact. Without size graded smaller beans pass through intact and larger cotyledons are broken (Steinkraus, 2004). Following the dry dehulling, the hulls can be separated from the cotyledon by use of aspirator, a gravity separator or by winnowing process (Farthworth and Edward, 2008). It is also possible to remove the hulls from dry dehulled soybeans by placing the beans in water floating the hulls fall off during soaking and boiling steps (Steinkraus, 2004). Abrasive dehulling of dry beans requires less labour.

The major disadvantage of the dry method is the high milling loss due to breakage and powdering (Steinkraus, 2004). In addition, loosening of the husk in this process is not adequate, since the various grains milled are not of uniform size, small grains pass through.

2.5 Seed Conditionings to improve dehulling

Conditioning is a general term applied to heating, cooling, drying or any combination of these processes (Chakraverty and Mujumdar, 2003). The hull of the matured soybean kernel is loosely attached to the cotyledons, and therefore could be detached fairly easily in cracking of conditioned beans (Chakraverty and Mujumdar, 2003). The main purpose of preconditioning is to loosen the hull and facilitate its separation from the kernel, thereby reducing dehulling losses. Preconditioning methods to loosen the hulls may involve heat treatment alone or soaking in water or chemical solution for a period of time, together with heat treatment followed by hot dehulling or tempering before dehulling (Ramakrishnaiah and Kurien, 1983; Srivastava *et al.*, 1988; Phirke *et al.*, 1992; Phirke and Bhole, 2000).

The effect of conditioning on the seed coat could be to toughen the hull, loosen the bond between the hull and the cotyledon, crack the seed coat, and harden the cotyledon to resist damage (Chakraverty and Mujumdar, 2003). Heat treatment of moistened grains, or in some dry grains, makes the hull easier to remove as it becomes brittle and cracks. Also, the cotyledons tend to shrink more than the hull during this process, resulting in hull being loosened from the cotyledon (Chakraverty and Mujumdar, 2003). An addition of moisture softens the grains and makes them susceptible to scouring, whereas drying hardens the grains and increase their resistance to scouring. A 1-2% reduction in bean moisture content promotes dehulling, while heat treatment of beans at 93°C for 15 minutes breaks the bond between the hull and cotyledons (Chakraverty and Mujumdar, 2003).

Drying is carried out in grain drier to a moisture content of 10%. The temperature of the drier should be between 70°C and 76°C to achieve a desired moisture level. Uniform drying of the soybean is very important for removal of hulls, as it is necessary to remove the hulls from every individual bean, not just an average number of them (Riaz, 2006). Normally, sun drying is practiced in drying yards. Grains are spread in a thin layer (3-10cm) and turned frequently with a rake for even drying. The drying period for grains varies from 1 to 5 days depending on weather conditions, thickness of layer and pulse crop. Roasting legumes serve also as a preliminary step in facilitating husk removal during wet or dry grinding.

2.6 Factors affecting pulse dehulling

Theoretically, the endosperm of the pulses accounts for maximum of 87-89% of the whole grain legumes (Sahay and Singh, 1994), but in practice it is not achievable. Several seed characteristics affect the dehulling efficiency. These are; size and shape of the grain, husk content and its thickness, adherence of the husk to the cotyledons and moisture content of the endosperm (Chakraverty and Mujumdar, 2003). Seed size is one of the factors that affect the dehulling process in pulses. It is a varietal character that is influenced by the growing season and location. Uniformity in size is important for efficient dehulling (Chakraverty and Mujumdar, 2003). In general, the major factors affecting dehulling of pulses are seed diameter and thickness (Ehiwe and Reichert, 1987; Singh *et al.*, 1992).

Larger seeds tend to have lower percentage loss during decortications because the proportion of hull to seed mass is lower. More than 75% of the variability in dehulling efficiency is accounted by grain hardness and resistant to splitting into individual cotyledons (Reichert *et al.*, 1984). If grains are too hard, they require more abrasive force during dehulling, thus greater losses in terms of broken and powder fractions. Similar to size, seed shape is varietals characteristic in pulses. Pulses exist in various shapes such as spherical shaped, cylindrical, pyramidal and kidney shaped. These properties play a vital role in selection of dehulling devices (Chakraverty and Mujumdar, 2003). Although round seeds are considered better for dehulling, very angular seeds lose excessive amount of cotyledon material during dehulling. Sharper edges are preferentially lost from angular seeds, whereas more seed mass is removed from flatter seeds. The flatter the seeds the higher is the amount of powder and broken. In addition rounder seeds split more readily than flatter seeds, thus improving the efficiency of dehulling and splitting. The rounder the seed the better they are for dehulling (Chakravert and Mujumdar, 2003).

2.7 Throughput

Processing speed of dehulling method is measured in terms of the amount of output produced in a set period of time (usually one hour). It is a measure of time needed to complete a job (Yadav *et al.*, 2007). High throughput and a high yield of dehulled grain are desirable in commercial practice.

2.8 Dehulling losses

The primary objective of dehulling is to remove only the seed coat from the cotyledons, but quite often noticeable amount of cotyledon material and germ are also removed during the dehulling operation (Siegel and Fawcett, 1976). As a result, considerable quantitative and qualitative losses occur during dehulling of legumes. The dehulling losses would depend primarily on the machinery, dehulling method employed for dehulling and characteristics of the pulse being milled (Chakraverty and Mujumdar, 2003). An example of dehulling study by Singh *et al.* (1992), found dehulling losses in terms of broken quite high in the stone grinder and this might have been due to the attrition action of the dehulling stone employed. In commercial mills, product yield approach only 70%, which is much lower than the theoretical yield (Natarajan and Shankar, 1980). Another study by Parpia (1973) found the average dehusked splits yield of pulses from household and traditional commercial dehulling methods varies from 68-75%, which was 10-17% less than the theoretical average value close to 85%. These studies indicate that the dehulling losses vary with the scale of operation and the pulse crop.

2.9 Milling efficiency

Milling parameters for pulses may be defined in a variety of ways. Ehiwe and Reichert (1987) described dehulling efficiency as the percent of hull removed from the cotyledon and the yield of the dehulled grain obtained from this process. Reichert described dehulling efficiency as, a measure of the amount of hull in the abraded material. Wang (2005) defined milling efficiency as the sum of percent whole dehulled seeds and split dehulled seeds. Erskine *et al.* (1991) defined dehuling efficiency as the sum of split dehulled seed, whole dehulled seed, and whole hulled seed. Yadav *et al.* (2007) said that dehulling efficiency is an important parameter which determines the throughput of a dehulling method.

The extent of milling is measured in terms of hulling efficiency (EH) and milling efficiency (EM) whereas hull efficiency is merely a measure of the extent of dehulling, and milling efficiency takes into account both dehulling and yield of finished product (dehulled split and unsplit grains) during milling (Narasimha *et al.*, 2004). Several researchers have attempted to measure the hulling efficiency and milling efficiency taking various factors, such as extent of husk removal, weight of undehulled grains, extent of broken and powder formation under defined milling conditions (Prasoon *et al.*, 1995; Reichert *et al.*, 1986; Sahay and Bisht, 1988; Saxena *et al.*, 1990). Ramakrishnaish and Kurien (1985) measured milling efficiency (EM) using the following expression.

$$EM = \frac{\text{actual yield of dehulled grains}}{\text{theoretical yield}} \times \text{degree of dehulling}$$

Where:

The actual yield is the recovery of dehusked grains from the machine (%); theoretical yield is the maximum yield of dehusked grains that could be obtained (%) (i.e., weight of the whole grains – weight of husks).

$$\text{Degree of dehulling } \% = \frac{\text{Weight of dehulled grains}}{\text{total weight of sample milled}} \times 100$$

Whereas milling efficiency (EM) is the measure of performance of the dehulling unit, degree of dehulling is more a grain character and is a measure of ease with which the grain could be dehulled under a given set of conditions. The objective of any dehulling unit is to achieve complete (100%) dehulling (Chakaraverty and Mujumdar, 2003). In practice, it is difficult to achieve this and generally maximum achievable milling efficiency is about 91%. However, the milling efficiency for a machine should be at least 77% to obtain an acceptable product. Dehusked splits with less than 97% degree of dehusking are normally unacceptable in the market. High throughput and a high yield of dehulled grain are desirable in commercial practice.

2.10 Description of dehulling technique

In order to better understand the comparison of different methods of hulling, it would be worthwhile to recapitulate the definition of the dehulling parameters often used:

Dehulling quality describes both the rate of hull removed from the cotyledons and the yield of dehulled grains obtained.

Hulling yield measures the degree of hulling which the person supervising the operation, judges acceptable as an indication of the completeness of the operation. This is the proportion (as a percentage of the weight) of hulled grain compared with the initial weight of grain prior to hulling (FAO, 1992).

Theoretical yield is the proportion of grains (as a percentage of the weight) which represents the optimal consumable portion or the proportion acceptable by the consumer (FAO, 1992). Theoretical yield varies depending upon type of grain, hull, cotyledon, and germ proportion in a grain. This parameter can be obtained by taking 10 g of sample and manually removing hull using sharp knife and weighing each fraction separately.

Hulling efficiency (in %) provides an objective measure of the efficiency of the operation and a comparison between equipment and types of grain in terms of hulling performance.

Coefficient of dehulling (C_h) is the measure of the ability of the machine to remove hull.

Coefficient of wholeness of kernel (C_{wk}) is the measure of the ability of the machine to remove hulls without breaking the grain.

Dehulling index ($DI = \eta$) is the value, which reflects the quality of finished product, obtained (dehulled whole and splits).

Overall dehulling efficiency (η_o) is the quality of dehulling, which can be calculated as a ratio between the weight of dehulled kernel (both split and whole) and initial weight of material taken for dehulling. Higher the value of overall dehulling efficiency is considered as index for better process (Ikebudu *et al.*, 2000).

Efficiency of dehulling (η_d) is a ratio between the amounts of dehulled grains (DH) obtained both splits and whole to that of theoretical yield. Value of efficiency of dehulling can vary from 0 to +1, means there is no dehulling and value near to one shows complete dehulling without any broken and powdering loss (Ikebudu *et al.*, 2000).

2.11 Importance of hulling oilseeds

About 99% of oil is stored naturally in kernels and the hulls contain not more than 1% oil. If the hulls are not removed they reduce the total yield of oil by absorbing or retaining oil in the pressed cake (IDRC, 1998). In addition to this, the wax and colouring matters present in the hulls get mixed with the expressed edible oil. This necessitates the refining process, and therefore, increase the production cost of edible oil.

Table 2: Approximate hulls and kernel percentage in different types of oil seeds

S.No.	Oilseed	Percent kernel	Percent Hull	Percentage of oil		
				Whole seeds	Kernel seeds	Husk
1.	Cottonseed	55	45	19	30	1-2
2.	Rapeseed	82	18	42	-	-
3.	Mustard seed	80	20	40	-	-
4.	Sunflower	75	25	22-36	36-55	1-2
5.	Safflower	50	50	28-33	55-65	1-2
6.	Soybean	93	7	18	19	0.6
7.	Ground nut	75	25	38	50	5.1

Source: IDRC, 1998.

Moreover, processing oilseeds without dehulling reduces the capacity of the extraction equipment in addition to more repair and maintenance charges (IDRC, 1998). Large proportion of oil is retained by the high percentage of hull of oilseeds. If the hulls are removed from the seed before processing, it would yield comparatively more volume of oil (IDRC, 1998).

2.12 On-farm food processing

Processing of agricultural products at farm level in many developing countries has been identified to offer an alternative to diversification, income generation and rural development in the event of increasingly deregulated agricultural markets (Ekman and Anderson, 1998). The process has economic implications at both household and national levels. It may be argued that an increase in degree of on farm processing at various levels of food marketing chain may facilitate a transition from traditional agricultural policy, mainly characterized by price supports and direct income payments to an integrated rural development policy (Hayami *et al*., 1988).

Processing of agricultural products may be considered in a wider context as an activity for adding value to agricultural products before marketing the products to consumers (Ekman and Anderson, 1998). According to Slee (1991) processing is an activity creating utility by altering the product in some ways from raw state. Ekman and Anderson (1998) defined on-farm processing as activities of adding value to agricultural produce by growers before selling the produce to consumers.

According to Tanzania Agriculture Sample Census 2003, on-farm agro-processing in Tanzania is practised either to process crops into a consumable form or to increase the value of the harvested crop (URT, 2003). Agro-processing is practiced in most 89% of the total crop growing households in Tanzania. The percent of households processing crops is very high in most regions above 80% (URT, 2003). On-farm processing by hand accounts 17% and by machine is 4% only (URT, 2003).

In Tanzania, soybean can be processed into various products including complementary foods, soy drink, soy flour, soy milk, soy butter and defatted soy flour (Kimenya, 2006). All these products can be processed at household level or small-scale level. However, there is no specific processing and formulation method being applied. Most of the processors roast or just mix the raw soybeans with cereals then mill, pack and market as complementary foods. With the added value concept, soybean farmers can increase their income through processing and marketing of soybean products (Kimenya, 2006). Lack of knowledge on how to process and utilize soybean has made the crop to be one of the most under-utilized crops in Tanzania.

2.13 Small-scale industry

According to Nkonoki (1999), small-scale industry in Tanzania is vaguely defined to be any industrial unit whose control and management is within the capability of local people,- individually or collectively (in associations/cooperative societies/unions). Such local people or communities have also to own the capital required for such industrial units and have to have the skills or expertise required to operationalize such industrial production units. However, as a general rule, a small-scale industry is an enterprise whose initial capital investment is low. It employs a few people (ranging from 5 to 20) and requires minimum technical and managerial skills (Nkonoki, 1999). Small-scale industries are important to develop and developing economies because they generate employment and utilize mainly locally available resources. These industries produce items geared almost entirely for the local market and they provide a link to other sectors of the economy (Nkonoki, 1999). Enterprise organization is dominantly artisinal, with labour force drawn largely from family recruits: technical systems used are relatively simple and of low technical sophistication and, in most cases, such technical systems are manually operated.

2.14 Significance of small-scale industries

Small-scale industries are an important source of primary employment (Nkonoki, 1999). A substantial proportional of the urban poor-people and some rural based people derive their household income or supplement it from small-scale industrial activities. In poor developing countries like Tanzania, where capital is a scarce factor, small-scale enterprises are appropriate because they usually require small capital investment since they utilize inexpensive technologies (Nkonoki, 1999). Small-scale industries provide and supplement a wide range of basic goods and services whose costs are within the purchasing power and needs of poor people.

2.15 Upgrading traditional methods or introducing improved technologies

Technology is the applied science whose primary purpose is to solve social and economic problems in a society. Technology is called know-how (Nkonoki, 1999). Technologies are the key to increase the productivity of micro-enterprises while generating broad based sustainable economic growth. Home-based traditional methods of processing technologies impose a heavy burden on the families' labour supply, especially the women (Taiwo *et al.*, 2001). The upgrading of technologies can help to establish the growth of new types of manufacturing enterprises that allow more of the value addition during the processing of raw commodities to be captured in rural areas. Micro-enterprises can be strengthened through technological changes to become more self-reliant and thus less vulnerable in their links with their suppliers and markets (Taiwo *et al.*, 2001).

One of the greatest challenges facing food scientists/technologists is the upgrading of the traditional technologies of food processing and preservation (Aworh, 2005; Sanni, 1993). In most cases, the traditional methods of food processing and preservation remain at the empirical level. They are still rather crude, not standardized and not based on sound scientific principles making them, in their present form, unsuitable to large-scale industrial production. The processes are often laborious and time consuming and invariably the quality of the products require substantial improvements. In upgrading these technologies, the food scientist or technologist is faced with the challenge of modernizing the processes and equipment while still retaining the traditional attributes of the food products crucial to consumer acceptance. Although a technology may be tested technically in a research laboratory and proven, it may end up being inappropriate for its intended social setting (Taiwo *et al.*, 2001).

Therefore, before recommending methods for improving traditional processing systems it is essential to understand fully how they fit into local social conditions and the relevant food sciences (UNIFEM, 1993). Knowledge, preferences, and feedback are necessary for a proposed technology to fit its niche or to identify the niche for which the technology is needed (Paris *et al.*, 2001). There may also be a tendency to improve an aspect of the process not perceived as problematic. As an example, Taiwo *et al.* (2001) in a survey of processing centres reported that many palm kernel cracking machines were not in use because the female processors undertake this task as a leisure pass time in the evenings. Also, the quantity of palm kernels available for cracking to each processor does not justify the use of a machine at some cost. In addition, there may be social and cultural factors, which need to be taken into consideration, including distance from home, hours away from home and time of activity, cultural and sphere of activity (Gordon and Swetman, 1994).

An illustration of the cultural psychological barrier to utilization of machines was reported by Owolarafe *et al.* (2000) in Nigeria, where processors had the option of using the hammer mill in grating peeled cassava but clients preferred the grater because of the belief that the product from the hammer mill was too fine (less coarse) than that of the grater. *Gari* from the hammer mill is said to float in hot water (making for poor reconstituted product) and also yields very little by-product. Cassava chunks and pieces that escape grating (in the grater) are sun-dried and milled into flour thus creating additional source of income. The hammer mill grinds finely thereby eliminating the income derived from the by-product. The fact that the quantity of the milled product is larger is of no consequence nor the fact that the hammer mill is suited for milling several crops. The foregoing buttresses the fact that by-products should also be considered in the acquisition of a new technology (Sinkaiye and Olajide, 1996).

The selection of the most appropriate technology for a given situation therefore requires a careful examination of the social, economic, environmental and cultural factors as well as an analysis of the competitiveness of traditional processing under the given conditions. There is a need to reflect these in machine design considerations by equipment developers, so that technologies introduced to solve basic problems do not create more complex sets of problems. On a rice project, a thresher mounted on a bicycle frame was introduced to female processors to facilitate the threshing operation. The pedal operated thresher was rejected on the basis that its usage exposed the female thighs and the women are not allowed to wear trousers (UNIFEM, 1993). Since, technology is a function of culture, the extent to which a given technology is acceptable to a given culture may depend on a number of considerations beyond the mechanical efficiency of the device. This is why the food sector in Nigeria needs its own appropriate technologies that are developed, tested and trusted within the climatic, ecological, social and cultural settings where they would be used (UNIFEM, 1993).

2.16 Making the technological choice

The choice of a technology is a choice among alternative techniques and the knowledge about those techniques. The choice by a buyer depends upon the available technologies and their relative prices, the quality of the machines and equipment in terms of their perceived durability and availability of spare parts and the quality of the products of the technology. A choice presupposes that the buyer knows that there are available alternatives and has the necessary information about the alternatives. Results of a survey conducted by the Post Harvest Technology Research Group (PHTRG, 1998) (Nigeria), revealed that the basis on which rural processors made their choice of what equipment to purchase as ruggedness (40%), availability (22%), cost (18%), ease of maintenance and use (20%).

To move towards identifying suitable and appropriate technologies, it is vital that the 'user' is in the position to make an informed choice. Only the user is in the position to make the final judgment on the suitability or otherwise of a particular technique or piece of equipment. When considering choice, it is important to take into account the various groups in any community and recognize that they may have different patterns of choice (Croxton and Appleton, 1994). It is necessary to appraise existing processing technologies, identify and classify them into those that are effective and friendly (i.e., technologies that support and promote the social and economic wellbeing and are environmentally acceptable) and those that are not. When introducing a technology, crucial questions to be asked are, what type of technology is being promoted, capital intensive or labour intensive, who will introduce it, who will control it, who will maintain it and who will benefit from it? (Afonja, 1998).

2.17 Local manufacture of equipment

To stimulate the introduction of technology the facilitator has to provide or mediate for additional technical and financial (credit) support to ensure, as far as possible, that the equipment can be bought and repaired locally (Bruinsma, 1999). The local manufacture of equipment is a good way to ensure this. A good supply of spare parts and repair services is much more liked if the equipment is produced by local artisans (Wander, 1996). Training and after-sale services and spare parts stocking must be incorporated into the procurement agreement of machinery and equipment. Training in machinery repair and maintenance will provide operational and maintenance skills necessary to sustain small-scale enterprises, increase output and allow producers to ensure regular supplies of their products, as required by larger buyers. Special training programmes are needed both for processors and operators in machine maintenance. This will prolong equipment life beyond the five years that is the current average life span of most post harvest processing machines (Osunbitan *et al.*, 2000). A well programmed training of local artisans in small and diesel engines repair, fabrication of whole equipment and critical parts will provide necessary bedrock of reliability, economic wellbeing, and sustainability of rural agro-enterprises.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Overview

This Chapter presents the methodology used in this study. It covers description of the study area, research approach and research design, sampling technique, laboratory work on evaluating dehulling performance of the identified methods as well as evaluating dehulling performance of the SUA wet soybean dehuller on wet and dry basis.

3.2 Geographical location and description of the study area

The research was conducted in Kilosa district, Mvomero district and Morogoro Municipality in Morogoro region. Morogoro lies between latitude 5° 58′ and 10° 0′ South of Equator and between Longitude 35° 25′ and 38° 30′ east of Greenwich. The neighbouring regions were Tanga and Arusha to the north, Coast region to the east, Dodoma and Iringa regions to the western part and Ruvuma region to the south. Morogoro is the second largest region in Tanzania after Tabora with a total area of 73,039 square kilometers out of which 2,240 square kilometers is water bodies. The region comprises of six districts namely Kilombero, Kilosa, Ulanga, Morogoro rural, Mvomero and Morogoro urban districts. According to URT (2003) the productive sectors in Morogoro are agriculture, livestock, forestry, fisheries, beekeeping, wildlife, mining and industries. More than 85% of the people living in the region depend on agriculture and livestock as their major economic activities. The major food crops produced in the region are maize, sorghum, paddy, beans, bananas, sweet potatoes, cassava, Irish fruits and a variety of vegetables. The major cash crops are: tobacco, tea, cocoa, maize, sorghum, paddy, beans, bananas oranges and cassava.

3.3 Justification for selection of morogoro region

Morogoro region was purposively selected for this study for two ; (i) to make easy the evaluation and dissemination of a simple wet soybean dehuller developed by Sokoine University of Agriculture for use at village level so as to reduce the amount of time and labour required in the traditional manual dehulling of soybeans. (ii) Morogoro is one of potential regions for soybean production as reported by MAFC (2005) that "the leading regions for soybean production are Ruvuma, Mbeya, Rukwa, Iringa and Morogoro".

3.4 Field survey

The field survey was conducted to assess and obtain information on different soybean dehulling methods commonly used in the study area.

3.4.1 Sampling procedures

The study population was soybean processors grouped in two categories; landless processors in Morogoro Municipality who process soybean as a way of supplementing family income as well as improving their family food and soybean farmers in Kilosa and Mvomero districts who cultivated the crop and do on-farm soybean processing for home consumption. To obtain the desired population, probability and non-probability (purposive and simple random sampling) were employed. Purposive sampling was used to obtain soybean processing areas representing the population. Simple random sampling was used to obtain a sample of 71 soybean processors from the target population. In the randomly selected sampling areas the following information was collected and documented:

(i) Soybean dehulling methods used.

(ii) Dehulling performance of the methods.

(iii) Problems associated with soybean dehulling and

(iv) Quantities dehulled.

3.5 Data collection procedures

3.5.1 Primary data collection

Primary data was collected using a structured questionnaire with both close-ended and open-ended questions designed to provide answers to specific issues of study. Pre-testing of the questionnaire was done in Morogoro Municipality using 10 soybean processors, prior to the main survey to check the validity of the questionnaire in order to take into account the ambiguity of the questionnaire items. One enumerator was selected and trained on how to conduct interviews and fill in a questionnaire during each respondent's interview process.

3.5.2 Secondary data collection

Secondary data on soybean and related leguminous crops processing was collected from journals, books, Internet, Sokoine University of Agriculture National Library (SNAL) and from other resources.

3.6 Data analysis

Data from primary source was verified, coded and analyzed using the Statistical Package for Social Sciences (SPSS) computer programme version 12.0. Descriptive analysis was carried out to obtain frequencies and percentages on the occurrences of various study attributes.

3.7 Laboratory work

3.7.1 Source of raw materials

Three soybean varieties TGX1895-33F, TGX1895-4 F and TGX1876-4 E were obtained from Ilonga Agricultural Research Institute while TGX1805-8E and Sable were obtained from Sokoine University of Agriculture. Three soybean dehulling methods were investigated in this study. Two traditional methods found commonly used in the study area (processing by hand and processing by using hessian bag). Dehulling performance of these methods was evaluated on wet basis. On dehulling experiments, 1000g of each soybean variety were dehulled in a manner comparable to the way as it was usually done by the interviewees in the study area. Second, the SUA newly developed wet soybean dehuller, was tested to dehull dry soybeans and its dehulling performance was compared with performance on wet soybeans.

3.7.2 Preparation of raw materials

3.7.2.1 Seed weight detemination and moisture content

Broken and damaged seeds along with foreign material were handpicked from a sample. A total of 100 soybean seeds were randomly selected from each variety and weighed using an analytical balance at an accuracy of ±0.01g, for the determination of the average weight of single seed. The results expressed in grams were obtained as the arithmetic mean for three replicates. Moisture content of each variety in both wet and dry conditions was determined in an oven set at 105°C for 24 hours.

3.7.2.2 Determination of seed coat content

The proportion of the seed coat content in whole grain of each variety was determined manually by soaking 100 seeds in distilled water overnight. The seed coats were separated manually followed by drying in oven at (100°C) for three hours, then weighed using an analytical balance at an accuracy of ±0.01 g. The results expressed in percentage to the whole seeds were obtained as the arithmetic mean for three repetitions.

3.8 Sample preparation for dehulling

Soybeans were first sorted, cleaned by removing foreign matters, broken beans, splits whole cotyledons and hulls. From the cleaned beans one kilogramme (1000g), in triplicate from each bean variety was taken and gradually dropped in boiling water at a ratio of 1:5 (soybean: water). Each replicate for each variety was boiled in a separate pot. The samples were boiled for 30 minutes for the purpose of hydrating the beans for easy hull removal and to inactivate the enzymes causing bean off-flavour as well as anti-nutritional factors. After boiling for 30 minutes the beans were removed and the blanching water was drained. The beans were poured in container with cold water and left to cool for 30 minutes, whereby no surface water was seen over the seed coats. A 100 seeds of the wet beans were randomly taken and the moisture content of the wet beans was determined. Thereafter, cold water was added to the sample followed by dehulling experiments using the dehulling methods on study. Each dehulling method in this study was tested on the five bean varieties using one kilogram seed sample. The three dehulling methods (processing by hand, processing by hessian bag and wet soybean dehuller) were tested on wet boiled soybeans whereas the wet dehuller was also tested on dried boiled soybeans.

3.9 Wet dehulling

3.9.1 Hand dehulling

The sample seeds submerged in cold water was dehulled manually by pressing a handful of seeds in between the palms. The process was done continuously until most of the hulls were removed. Time used to dehull 1 kilogramme manually was recorded for every replicate of each bean variety. Water used in dehulling and seed coats were decanted leaving behind the seeds (dehulled grains) in the vessel. This operation was repeated several times until all seed coats were removed.

3.9.2 Hessian bag dehulling

The sample was removed from cold water and placed in hessian bag tied at the end with a string, thereafter placed on a working table and effecting dehulling by squeezing the material in the bag with hands as it is done when washing clothes. The process was carried on continuously until most of the hulls were removed, followed by recording time used to dehull 1kg. Water used in dehulling and seed coats were decanted leaving behind the seeds (dehulled grains) and the remaining hulls in the vessel. This process was repeated several times until all seed coats were removed.

3.9.3 Mechanical dehulling

The sample was removed from water and placed in the dehuller through the hopper. Driving force was applied using handle that was rotated by hand. Dehulling of the seeds was effected by rotating the drum that forced the seed through a narrow opening or the chest of the machine. Dehulled beans came out via the front exit chute and were colleted in a vessel while hulls plus some other dehulled and undehulled grains from the rear exit chute collected in another vessel. A single pass of the beans in the dehuller was enough to remove most of the hulls. Again, time used to dehull 1kg of the beans was recorded. Thereafter water was added to the product, and hulls were removed by decanting.

At the end of each dehulling experiment, the product was sun dried for 2 days to reduce moisture to about 13%. Thereafter, products (cotyledons, undehulled soybeans, and fines) were separated manually and then weights determined using an analytical balance at an accuracy of $\pm$ 0.01g.

3.10 Dry dehulling

Dry dehulling of soybean was done using the wet soybean dehuller only. Soybean samples of each bean variety in triplicates, each weighing 1kg were boiled in the same manner as done in wet dehulling procedure. After draining the boiling water, the beans were sun dried for four consequent days to moisture level that ranged between 11.18 and 12.31 percent depending on bean variety. Dried soybeans were cleaned again to remove as much loose hulls, and other foreign materials as possible. This step helped to increase the efficiency of the dehulling method. The samples were then dehulled using the wet soybean dehuller. Unlike wet beans in which satisfactory products were obtained in a single pass, the dry beans were passed 5 times in the dehuller before satisfactory dehulled product was obtained.

After dehulling, the fines were collected using 20 mm mesh sieve and the rest of the product was manually separated into whole seeds, split seeds, broken seeds and hulls and then weighed using an analytical balance at the accuracy of ±0.01g. All the fractions weighed were expressed as a proportion of the total original weight. Dehulling efficiencies (%) of all experiments were calculated based on the obtained dehulling fractions ((cotyledons, hulls, undehulled soybeans, and fines) and dehulling parameters (coefficient of dehulling, coefficient of the wholeness of the kernels, hulling efficiency, overall dehulling efficiency and dehulling index).

3.11 Calculations on the dehulling fractions

The weight of each fraction obtained was expressed as a percentage of the weight of the sample before dehulling. The following calculations were made on dehulling fractions and parameters obtained by dehulling treatments, according to Singh *et al.* (2004).

3.11.1 Percentage of beans recovered

% Bean recovery = W_{fp} / W_{th} X 100

This was the ratio between the weights of finished products (W_{fp}) obtained both splits and whole to the initial weight of sample (W_{th}) used for the dehulling process times hundred.

3.11.2 Percentage of hull recovered

% Hull = W_h/W_{th} X 100

This fraction was the ratio of the weight of hulls (W_h) removed during dehulling to the initial weight of sample (W_{th}) used for the dehulling process times hundred.

3.11.3 Percentage of undehulled grains

% Undehulled grains =W_{uh}/W_{th} X 100.

This was the ratio between the weights of the material remaining undehulled (W_{uh}) and the initial weight of material (W_{th}) taken for dehulling times hundred.

3.11.4 Percentage of fines yielded

% Fines = Y_f/ W_{th} X 100

This was the ratio between the mass of fines (Y_f) generated during dehulling and the initial mass of sample (W_{th}) used for dehulling times hundred.

3.11.5 Coefficient of dehulling (C_h)

$Ch=1-W_{uh}/W_{th}$

3.11.6 Coefficient of wholeness of kernel (C_{wk})

$C_{wk}=W_{fp}/(W_{fp} +W_{br} +W_{po})$

3.11.7 Hulling efficiency (HE)

$HE = C_h \times C_{wk} \times 100$

Is the product of the coefficient of dehulling (C_h) and the coefficient of wholeness of grains (C_{wk}), expressed in percent.

3.11.8 Dehulling index (DI)

$\eta = [(W_{fp} + W_h) - (W_{uh} + W_{po})] / W_{th}$

The value reflects the quality of finished product obtained (dehulled whole and splits). The dehulling index (DI) may vary from a maximum value of +1 to a minimum of −1. A value of +1 indicates that all the samples are completely dehulled. A value of −1 indicates that the dehulling is not effected at all, thus the grains are either not dehulled properly or yielded to broken and powdering loss (Ikebudu *et al.*, 2000).

3.11.9 Overall dehulling efficiency (η_o)

$\eta_o = (M_h + Q_d) \times C_h \times 100$

Where;

W_{uh} = weight of undehulled grain after milling

W_{th} = weight of grains used for milling

W_{fp} = weight of finished product (splits and whole dehulled kernel)

$W_{br/Yf}$ = weight of broken

W_h = weight of hull

M_h = degree of dehulling

W_{po} = weight of powder

C_h= coefficient of hulling

C_{wk}= coefficient of wholeness of grains

Q_d= quality of dehulling

3.12 Statistical analysis

All experiments in the laboratory work were reported as mean of three replicates. Statistical analyses were carried out using the statistical software package SAS 8.1 (SAS Institute, Cary, NC). Completely Randomized Design was used. One-way Analysis of Variance (ANOVA) was carried out to compare the mean values of different methods and bean varieties. Differences in the mean values were determined at $p = 0.05$ and means were separated using Duncans Multiple Range Test (DMRT).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Overview

This Chapter presents results and discussion for the data obtained from survey and laboratory work. The results are divided into two parts: the first part presents results and discussion of the information obtained from field survey; characteristics of the sampled soybean processors, dehulling methods and dehulling procedures identified, throughputs of the methods, quantities dehulled, reasons for relying on traditional methods and problems associated with this process of soybean dehulling. Lastly, the Chapter addresses the results and discussion of dehulling efficiency of the methods identified as tested in the laboratory, as well as dehulling efficiency of SUA wet soybean dehuller on wet and dry basis.

4.2 Part I: Field /survey work

Part I of this study presents results and discussion of the data obtained during field survey.

4.2.1 Socio- economic characteristics of the processors

The characteristics mentioned in this section were as summarized in Table 3.

Table 3: General characteristics of the respondents

Variable	Frequency	Percent
Age of the respondents (years)		
25-34	12	16.9
35-44	41	57.7
45-54	18	25.4
Total	**71**	**100.0**
Gender		
Female	47	79.7
Male	24	20.3
Total	**71**	**100.0**
Education level		
Non-formal education	8	11.3
Primary school education	46	64.8
Secondary school	8	11.3
Post secondary education school	9	12.7
Total	**71**	**100.0**
Main income generating activity		
Crop production	16	22.5
Both crop production and livestock production	11	15.5
Business	21	29.6
Food processing	10	14.1
Employed	13	18.3
Total	**71**	**100.0**
Number of household members		
1-4	37	52.1
5-8	30	42.3
9-12	4	5.6
Total	**71**	**100.0**
Estimate monthly income (Tsh)		
<100,000	20	28.2
101,000-200,000	18	25.4
201,000-300,000	15	21.1
301,000-400,000	8	11.3
Above 400,000	10	14.1
Total	**71**	**100.0**

4.2.1.1 Age

The study indicated that 16.9% of the family members were, aged between 25 and 34 years, while 57.7% were between 35 and 44 years, 25.4% were between 45 and 54 years.

Majority of the soybean processors fell between 35 and 44years, which mean that they were in a productive and potential age for increasing family income as well as improving family health through value addition in processing this noble crop (soybean). Age of an individual has an important impact on the daily requirements of the family. Sango (2003) said that composition of household members in terms of their age distribution has implication on the household to meet its food requirement. Also Regnard (2006) urged that in total the accumulation of wealth is highly dependent on age of the individual whereby a direct relationship is experienced. It is believed that, having many members in any household who are not productive usually results to food insecurity as the labour force decreases.

4.2.1.2 Gender

Table 3 shows that, the majority of the respondents (79.7 %) were females and (20.3 %) were males. Some of the women, who were processing soybean in the study area, said that they were processing soybeans for the purpose of improving health of their families while others said for some additional income. Majority of men did processing as a means of supplementing their incomes. However, high percentage of respondents found involved in soybean processing (79.7%) were women. This can be related to reasons given by several authors. Bruisnma (1999) said that women's main reason for being involved in food processing is not to make large profit but to gain some additional income and obtain better economic security for the family. Another reason could be as said by Siegel and Fawcett (1976) that the processing of food legumes in developing countries has been done by women as part of their meal preparation. Moreover, a study in Nigeria has shown food processing as a major commercial focus for women in many settlements in the country (Asota and Kaul, 1991).

Men who were engaged in soybean processing said that due to difficulties in marketing soy products as well as lack of modern dehulling equipment were not much interested in this kind of activity. Furthermore, small volume they processed was not enough to support their families and thus they were forced to do other activities that were more productive. In addition to that, they said that, small-scale food processing like this one are best fit to be done by women. Thus, the small number of men (20.3%) participated in soybean processing in the study area might be due to the reasons given above, especially unavailability of modern dehulling equipment. Findings by several researchers had shown that; men's participating in food processing tends to increase when activities are mechanized (Ugwu and Ay, 1992). In addition, a slow return from the soybean processing due to low market demand was another reason, which can also be related to a report by UNIFEM (1993) that when the use of a new technology starts to produce income, it is often taken over by men.

4.2.1.3 Education level

The study indicated that 11.3% of respondents had no formal education, 64.8% had primary school education, 11.3% had secondary school education and 12.7% post secondary school education. The implication of this is that, majority of the respondents had basic education to seek or receive improved food processing technology from different sources such as extension agents, publications and mass media. According to Luhasi (1998), education is perceived as being among the factors that influence the individual perception of intervention before making decision to take part in income generating activities. Education is said to be a factor of growth and productivity as pointed out by Mwikila (1992).

Respondents with higher levels of education post secondary (12.7%) and secondary school education (11.3%) were women. Probably the main purpose for them to involve in soybean processing might be improving their family foods in an attempt to utilize the knowledge they have about nutritional importance of soybean as well as supplementing their incomes. This situation shown by women of higher education level agrees with the statement on women's incomes which states that; "women's incomes are more strongly associated with improvement in children's health and nutritional status". Again the statement above relates to an argument by Quisumbing *et al.* (1995) who pointed out that increased education for women was not only the matter of justice but would yield exceptional results in terms of world food security.

4.2.1.4 Size of the household

Distribution of respondent's household size was as presented in Table 3. The survey results showed that: 52.1% lived with 1-4 persons in the household, 42.3% lived with 5-8 persons in the household and 4.2% lived with 9-12 persons in the household. The results implied that soybean processing can be carried out successfully through utilizing the cheap labour supplied by family members. Sawio (1994) argued that, the number of persons in the household influences the amount of food consumed in that household daily and the amount of labour the household could expend on productive activities.

Households with larger family size in the study area were found processing large volume of soybeans than those with small household size. This was probably due to: availability of cheap labour, which was supplied by the family members, and an attempt to satisfy the high demand of the family caused by a large family size. This agrees with Stevenson *et al.* (1994) who reported that larger households have higher demand for family income and thus using their resources to produce more of their food. Also, Mbapila (2006) argued that, having more family members and dependants per household means more demands for the money to purchase food and other requirements.

However, current changes in the economic pattern and life style have created a lot of economic hardship to large families and therefore children are no longer counted as economic assets (Mkunda, 2006). Population increase had also made some rural families to have less land to cultivate while urban families have faced difficulties in securing income to support large families (Johsson, 1986).

4.2.1.5 Major sources of income

According to Table 3, 29.6% of the respondents depended on income from small business, 22.5% from crop production, 18.3% from salary, 15.5% from both crop and livestock and 14.1% from food processing. Businesses as a source of income occupied large portion of the respondents in the study area, following the scarcity of land in urban area. Majority of respondents interviewed in Morogoro municipality did off-farm activities as a way of generating income. This implies that non-farm income activities are important activities that help to earn some income to supplement household expenses especially in landless areas.

Off-farm activities have been reported by Malyamkono and Bagachwa (1990) to be contributing between 20 and 30 percent of the GDP. Corbett (1988) reported that households engaged in economic activities other than farming are more likely to be safe against other risks and uncertainties associated with farming. In Nigeria for example, the most important income generating activities for the Hausa tribe was processing of food for sale (Longhurst, 1985).

Although small–scale food processing activities represent a potential source of livelihood for many poor, people in Sub-Saharan Africa as said by Simalenga (1996), yet food processing in the study area accounted for only 14.1% of the respondents. Food processors in the study area complained of lacking capital and food processing technologies. This situation revealed the real problem facing small-scale food processing sector in the developing countries as was reported by IDRC (1984) that this sector is generally made up of family run businesses, which have evolved over the years, with little access to capital and technical services.

4.2.1.6 Monthly income

Monthly income of the household was as shown in Table 3. It was noted that 28.2% earn less than 100 000, 25.4% were between 101 000-200 000, while 21.1% were between 201 000-300 000. Less than 14.1% were above 400 000 TSHS and 11.3% were between 301 000-400 000 TSHS. Respondents with high income above 400 000 in the study area were government employees. These were the highest earner in the area. However, involvement of the government employees in soybean processing can be of beneficial effect to the government in making easy promotion of the soy products in different Agricultural Shows. Furthermore, the government through the Ministry of Agriculture, Food Security and Cooperatives can take this opportunity to disseminate the knowledge of soybean processing and utilization in areas where the crop is produced.

The 28.2% who had an income less than 100 000 were probably the on-farm soybean processors. Their incomes depend merely on farming or livestock keeping, which sometimes may be unreliable due also to unreliable weather conditions. Simple machines for processing their agricultural material to add-value are lacking. This situation corroborated well with the situation reported in literature (Adewumi, 1997; 1999; 2000; 2004) in Nigeria who said that rural communities in Africa are characterized by poverty and low income as a result of low industrial activities. The major preoccupation in such communities is agricultural production, mostly with traditional implements and tools. The development and use of simple machines for the processing of agricultural material is therefore essential. This will not only enhance mechanized agriculture in the rural communities but improve income, and increase the commercial values and quality of the processed materials.

In concluding, socio-economic characteristics as regarded by several authors is considered to have an effect in determining human potential to produce and capacity to change production practices and technology in this ever-changing social and economic environment (Ngailo, 1993).

4.2.2 Soybean dehulling methods and dehulling procedures in Morogoro

Methods and procedures of dehulling soybeans identified during the survey are summarized in Table 4.

Table 4: Dehulling methods and dehulling procedures identified

Variable	Frequency	Percent
Dehullng methods		
Processing by hands (wet process)	38	53.5
Processing by hessian bag (wet process)	22	31.0
Pounding in mortar and pestle (dry process)	7	9.9
Hand operated machine (wet process)	3	4.2
Grinding stone(dry process)	1	1.4
Total	**71**	**100.0**
Dehulling procedures		
Wet dehulling	65	91.5
Dry dehulling	6	8.5
Total	**71**	**100.0**

4.2.2.1 Dehulling methods

A total of five (5) soybean dehulling methods were identified from which 95.8% were traditional methods. These methods were: processing by hand (53.5%) respondents, processing by hessian bag (31%) respondents, pounding in mortar and pestle (9.9%) respondents, and grinding on stone (1.4%) respondents (Appendix1). Modern methods accounted only (4.2%) respondents and used a hand operated machine. The findings revealed the real situation of food processing in Sub-Saharan Africa. Taiwo (1995) reported that, in Sub-Saharan Africa tools used by food processors are characterized by their simple nature (mainly traditional and manual) with little use of mechanical devices. Of the four traditional dehulling methods, dehulling by hand and by the use of the hessian bag were most preferred due to low grain breakage compared to pounding in mortar and pestle and grinding on stone.

The small percent (4.2%) of respondents using modem soybean dehuller agrees to the findings reported on on-farm processing in Tanzania by URT (2003) during 2002 Population and Housing Census: that on-farm processing by hand accounts for 17% and by machine is 4% only. Machines for dehulling soybeans in the country are rare due to the fact that soybean is still new in the country with few people having knowledge on its cultivation, processing and utilization.

4.2.2.2 Dehulling procedures

Almost all the respondents in the study area used wet dehulling process which accounted for 91.5% of the population, while the remaining few (8.5%) used dry dehulling process. Wet dehulling as was explained by the respondents was that: the process was user friendly provided that water was available and that no special dehulling equipment was required (Appendix I). Water was highly needed for the protection of the grains from breakage since it acts as plasticizing agent so aids in easy and smooth hull removal, leading to little loss in form of broken. Farnworth and Edward (2008) pointed out the importance of water in dehulling when they reported that wet dehulling has an advantage of very little mechanical damage, which indicates a good yield. Steinkraus (2004) also reported on wet dehulling as the process which is always performed after hydration procedure and require no devices other than the hands or feet to rub the hulls from the cotyledons. However, the major disadvantage of this process as reported by the respondents was its laborious and complete dependence on climatic conditions during drying. They said that the entire process took about 5 days, while findings by Siegel and Fawcett (1976) reported the entire process to take about 5-7 days. In rainy seasons, products suffered much deterioration.

Dry dehulling as was explained by the respondents was a simple process in terms of preparation, which can either be roasted, dried or dry-fried. They said that after preparing the grains either by roasting or frying, dehulling was accomplished by pounding the grain in a mortar with a pestle (9.9% of the respondents). Small percent of the respondents

(1.4%) reported on grinding in a hand-operated stone after roasting. They did dry dehulling in the case of preparing soy drink. Though preparation of grain for dry processing was said to be simple, respondents complained the process suffer from excessive grain breakage and drudgery during pounding or grinding. A similar study by Steinkraus (2004) reported that dry dehulling is done before hydration procedure and is desirable and efficient provided that suitable mechanical equipment is available. However, it suffers from food loss due to abrasive force needed for complete dehusking of the grain, which results in high food loss in form of broken and powder.

4.2.3 Hourly throughputs of the dehulling methods

Throughputs of the different identified methods are as presented in Table 5.

Table 5: Hourly throughput of the different dehulling methods in Morogoro

Variable	Throughput	Frequency	Percent
Processing by hand			
	1kg/hr	31	43.7
	2kg/hr	7	9.9
	Sub total	**38**	**53.5**
Processing by hessian bag			
	2kg/hr	17	23.9
	3kg/hr	5	7.0
	Sub total	**22**	**31.0**
Pounding in mortar and pestle			
	2.5kg/hr	6	8.5
	2kg/hr	1	1.4
	Sub total	**7**	**9.9**
Hand operating machine			
	25kg/hr	3	4.2
	Sub total	**3**	**4.2**
Grinding stone			
	1kg/hr	1	1.4
	Sub total	**1**	**1.4**
	Total	**71**	**100.0**

According to this study (43.7%) respondents who dehulled manually by hand reported to process 1kg of soybean in 1 hour while the rest (10%) respondents reported to process 1kg in 2 hours. This shows how uneconomical and time consuming the task is, which impair soybean processing and consequently consumption. At that rate, one labourer can process only 8 kg of soybean in 8 working hours, thus making the method suitable only for processing small quantities for family use and not for commercial use. Hessian bag method, another traditional method showed a slight improvement in dehulling efficiency. About (23.9%) respondents using hessian bag reported to dehull 2 kg in 1hour, while (7%) respondents dehulled 3kg in 1hour. Hessian's users could benefit economically compared to hand users, since the amount dehulled by one labourer in 8 hours is doubled (16kg man-day). Pounding in mortar and pestle was another traditional method which also showed an improvement in dehulling efficiency. Nearly all respondents using mortar and pestle (8.5%) argued to finish processing 2.5kg in 1hour.

The findings on the traditional methods identified complied with studies by several authors who reported that manual dehulling has a very low output, with each woman hulling between 1 and 2 kg/h (Philip and Itodo, 2006). It is very tedious and time consuming (Kwon-Ndung and Masari, 1999), constituting a major bottleneck in legumes' processing and utilization. Also Chinsman and Fiagan (1987) and Jeans *et al.* (1991) said that, although traditional techniques give products that meet the organoleptic quality demands of consumers, they have limitations in the form of: poor hygiene, unstable utilization conditions and low yield, as well as inadequate efforts towards reducing losses. Trying to improve them, several initiatives have been introduced so as to increase the efficiency of manual dehulling. For example effectiveness of pounding was improved by fixing a metal plate or ring on top of the pestle (Bruinsma, 1999). Tests on this pestle by Appropriate Technology International (ATI) in Senegal showed a 25% increase in efficiency (time reduction). The author argued that such initiatives should be considered because mechanized mills are not within everyone's reach (Bruinsma, 1999).

Very small percent of respondents (4.2%) those used hand operated soybean dehuller originated from Sokoine University of Agriculture (SUA), reported the dehuller as an efficient equipment in terms of time and hourly throughput of (25kg/hr). Unfortunately such a dehuller is not within everyone's reach due to the fact that it has not yet fully evaluated for dissemination.

4.2.4 Quantity of soybean dehulled

Kilograms of soybeans that can be dehulled each month were as summarized in Table 6.

Table 6: Quantity of soybean dehulled per month

Kilograms/month	Frequency	Percent
<50	51	71.8
50-100	9	12.7
101-150	8	11.3
151-200	2	2.8
201-250	1	1.4
Total	**71**	**100.0**

Table 6 shows the amount of soybeans the processors can process. The movement of soy products in the market is very slow as claimed by the respondents in this study. This condition resulted in the processing of small quantities of soybean by the majority of the respondents mainly for home use. Of the respondents 71.8% processed less than 50 kg/month, 12.7% processed 50-100 kg/month, 11.3% processed 101-150 kg/month, 2.8 % processed 151-200 kg/month and 1.4% processed 201-250 kg/month. They complained that finding large market for soy products was somehow hard since not many people were aware of the existence of these products. They are marketing their products by selling in retail shops, or visiting their clients in their homes which is a hard task. Large percent of the respondents 71.8% (those processed less than < 50 kg/month) process mainly for home consumption. This is probably due to two main reasons: unawareness of the existence of the soy product to many thus low market demands and an increase in awareness campaign on nutritional importance of soybeans to some families which motivated them to incorporate soybeans in their meals. The second reason is supported by what has been said by Rweyemamu, (2004) and MAFS, (2005) that, following the increase in awareness on soybean's nutritional benefits, there has been the increase in processing and utilization of soybean in households.

4.2.5 Dehulling performance of the methods

Table 7 presents the dehulling performance of each of the identified method.

Table 7: Respondent's perception on dehulling performance of the investigated methods

Dehulling methods	Advantages			Disadvantages		
	Reasons	Frequency	%	Reasons	Frequency	%
Hand scrubbing	Less food loss.	27	38.0	Tedious and time consuming.	25	35.2
	Production of high quality grains.	11	15.5	Small quantities can be processed.	13	18.3
Hessian bag	Large volume can be processed.	13	18.3	Production of high % of undehulled grains.	12	16.9
	Saves time	9	12.7	Production of poor quality products	10	14.1
Pounding in mortar and pestle	Large volume can be processed.	5	7.0	Excessive grain breakage.	4	5.6
	Saves time.	2	2.8	Use human energy.	3	4.2
Machine	Reduces drudgery	2	2.8	Food loss.	3	4.2
	Saves time.	1	1.4			
Stone grinder	Inexpensive.	1	1.4	Excessive grain breakage.	1	1.4

Dehulling performance of the methods was evaluated through establishing advantages and disadvantages of the methods according to user's experiences. Dehulling by hand had advantages of less food loss (38%), and production of high quality dehulled grains (15%). Dehulled grains from this method were highly accepted in the market, but the time wasted (35.2%) and low throughput (18.3%) made the method unattractive for commercial purposes. Hessian bag method looked more effective than hand method by processing relatively large volume at a time (18.3 %) and shortening dehulling time (12.7%), but it suffers from production of undehulled grains (16.9%) and poor quality grains (14.1%). Thus, this led to less market acceptability of the dehulled grains when compared to hand method.

Similar to hessian bag, pounding in mortar and pestle revealed an ability of dehulling large volume at one time (7%) and a short dehulling time (2%) but had disadvantages of excessive grain breakage (5.6%) and poor quality grains (4.2%). Abrasive force exerted by the pestle to the grains led to grain breakage and grain crushing into powder. Respondent representing 1.4% using the traditional stone grinder said that the method was inexpensive but suffered excessive grain breakage. This was probably due to the attrition action of the stone. This corroborated to a dehulling study by Singh *et al.* (1992), in which dehulling losses in terms of broken were quite high in the stone grinder and this might have been due to the attrition action of the dehulling stone employed for dehulling. Kyi *et al.* (1997) pointed out that, although the maximum theoretical recovery from dehulling pulses is around 87–89%, traditional methods of dehulling recover only about 65–75% whereas modern dehulling methods can recover 82–85%.

Three people representing 4.2% of the respondents using hand operated machine said that, although the method showed high dehulling efficiency in terms of reducing drudgery and saving time, it suffers from food loss when compared to the hand method. Again, this can be related to a survey carried out in Bangladesh by Richard (1990) who compared economic efficiency of a legume dehuller with the traditional method using stone grinder. The dehuller showed similarity in yield and efficiency to the traditional method, but was found to break the legumes.

4.2.6 The use of traditional dehulling methods

Table 8 represents general reasons given by the respondents in the study, why they relied on these inefficient traditional methods. Respondents gave three main reasons.

Table 8: Reasons for preference of traditional dehulling methods.

Reasons	Frequency	Percent
Unavailability of modern dehulling equipment	18	25.4
Low market demand	23	32.4
Small quantity of products is processed for home consumption only	27	38.0
Total	**71**	**100.0**

About 38% of the respondents reported to process only small quantities for their families and thus, would be uneconomical for them to own modern dehulling equipment. Minimum weight of soybean processed by some respondents for their family use was 1 kg/month, which could easily be done by either hand or hessian bag methods. These hints how respondents are aware of the nutritional importance of soybeans thus try to adopt it as part of their meals. About 32.4 % reported low market demand of soybean products. The products they processed took long time in the market, thus they also considered this situation as uneconomical to own modern dehulling equipment, which would stay idle for most of the time. The maximum quantity that was found processed each month was 210 kg (1.4%). The rest processed less than 210 kg in a month. This explained the real situation of unreliable market for soybean in Tanzania. Malema (2005) has reported that underutilized potential of soybean was caused by lack of reliable market and knowledge of farmers on processing and utilization at household level. The rest of the respondents 25.4% gave the reason of unavailability of such kind of modem processing equipment. However, this problem is well known by the Ministry of Agriculture, Food Security and Cooperatives, whereby one of the strategies in the First National Soybean Stakeholder's Workshop, held in Morogoro 10-11 November 2006 was to provide soybean processors with affordable improved post-harvest technologies for value addition to soybeans.

Small percent that owned modem soybean dehuller (4.2%) complained of lack of soybean milling machine that made them to mill their dehulled soybeans in the late evenings. The owners of the milling machines feared the transfer of the bean off-flavour to the goods of their other clients that would use their machines for milling other grains immediately after milling soybeans.

4.2.7 Problems in soybean dehulling

Table 9 presents problems associated with this process of soybean dehulling as were reported by the respondents.

Table 9: Problems associated with dehulling soybeans

Problems	Frequency	Percent
Lack of improved soybean dehuller	16	22.5
The process is weather dependent	18	25.4
The process requires substantial amount of water and fuel	11	15.5
The process need to have drying yard	14	19.7
There is a need for quick drying equipment	12	16.9
Total	**71**	**100.0**

Apart from dehulling operation being tedious and time consuming, there are other constraints in soybean processing and utilization as were observed in this study, which were also seen as basic problems contributing to underutilization of soybean in the household. About 22.4 % of the respondents reported lack of improved technologies, which included modern dehulling equipment as well as technical know-how to be responsible for underutilized soybean. If it happens that there is an increase in the demand of soybean products, traditional methods will not be in a position to produce enough for the demand. This signals the need for replacement of traditional methods with more improved methods.

Processing was weather dependent as reported by 25.4% of the respondents. To produce good quality soy products the dehulled beans should be dried in the sun in less than 5 days to reduce moisture content to the point where moulds and other contaminating micro-organisms cannot exist. The first day of drying should have enough sunshine so that surface drying is achieved to discourage fermentation and rancidity that can change the organoleptic attributes of the soybean. If drying is not done properly the cotyledons become mouldy, leading to inferior final products, which may render soybean unfit for its commercial usage. To avoid this they are forced to stop processing during the rainy season or at times process limited quantities.

As sun drying is practised, this traditional method is not only weather dependent but also requires a large drying yard to match the milling capacity. Drying yard is necessary for production of good quality splits, as reported by 19.7% of the respondents. In other countries, enterprises with limited space use roof tops for drying whereby the beans are spread in a thin layer (3-10 cm) for even drying (Chakraverty and Mujumdar, 2003). Close to 17% of the respondents complained of lack of quick drying facilities by saying relying on sun drying was unreliable and sometimes they had their products spoil due to abrupt change of weather. They were probably meaning the need of solar drier. Solar drying of agricultural products is said to be a better alternative to sun drying. It can be a means of supplementing or replacing artificial dryers with consequential savings in fuels and costs. Solar drying provides higher air temperatures and lower relative humidity than simple sun drying. It enhances the drying rate and lowers the final moisture content of the dried products.

Water and fuel are also important items in the process especially in case of wet dehulling, as reported by 15.5% of the respondents. Water and fuel were needed for cooking the beans in the stage of hydration and inactivation of the anti-nutritional factors. Large amounts of water are also used during washing out the hulls after dehulling. When these two items become scarce processors stop processing soybeans.

4.3 Part II: Laboratory work

This secondary part presents results and discussion of the data obtained during laboratory testing of the soybean dehulling methods.

4.3.1 Physical characteristics of the investigated bean varieties

Physical characteristics of the soybean varieties tested were as presented in Table 10.

Table 10: Physical characteristics of the investigated soybean varieties

	Physical characteristics			
Variety	Seed size (g)	Hull content (%)	Moisture content on wet basis (%)	Moisture content on dry basis (%)
TGX1895-33F	17.72^{a}	7.04^{b}	52.62^{c}	12.31^{a}
TGX 1895-4F	14.92^{b}	7.98^{b}	48.18^{d}	11.80^{b}
TGX 1805-8E	13.52^{c}	9.20^{a}	52.31^{c}	11.78^{b}
TGX 1876-4E	13.46^{c}	9.21^{a}	53.19^{b}	11.83^{b}
Sable	12.69^{d}	9.50^{a}	53.84^{a}	11.18^{b}

$^{a,b,c\ d}$Values followed by same superscript letter in a column are not significantly different ($p > 0.05$)

Source: Experimental data, (2009).

The study findings showed significant differences ($p < 0.05$) in bean varieties used in testing the dehulling methods. The average seed weights for 100 seeds observed were highest with TGX1895-33F (17.72g) followed by variety TGX1895-4F (14.92g). The remaining varieties TGX1805-8E, TGX1876-4E and Sable weighed 13.52, 13.46 and 12.69g, respectively. The bean varieties also differed significantly ($p<0.05$) in the amount of hulls, where smaller seed size varieties showed higher percentages of seed coat. These were 9.50, 9.21, 9.20, 7.98, and 7.04% for Sable, TGX1876-4E, TGX1805-8E, TGX1895-4E and TGX1895-33F respectively. The study findings also showed statistical significant differences ($p<0.05$) in the moisture content of the beans on both wet and dry basis. The wet freshly boiled beans (on w.b) moisture contents were 52.62, 48.18, 52.31, 53.19 and 53.84 percent for TGX1895-33F, TGX1895-4F, TGX1805-8E, TGX1876-4E and Sable varieties respectively.

Moisture content in the boiled and sun dried beans (on d.b) were 12.31, 11.80, 11.78, 11.83 and 11.18 percent for TGX 1895-33F, TGX 1895-4F, TGX 1805-8E, TGX 1876-4E and Sable varieties, respectively. Physical characteristics, moisture content and method employed in dehulling, found to play an important role in determining dehulling performance of the bean varieties (discussed in subsections of 4.3.2). Chakraverty and Mujumdar (2003) reported seed size as one of the factors that affect the dehulling process in pulses.

4.3.2 Dehulling efficiency of different soybean varieties investigated

The performances of soybean varieties in the three investigated dehulling methods were as shown in Table 11. The dehulling efficiency was measured in terms of percentage of dehulled bean recovery, pe‹centage of hulls produced, percentage of undehulled grains and percentage of fines. These fractions were found to be significantly different ($p<0.05$) in each variety. The differences observed were due to physical characteristics of the bean varieties (seed size and percentage hull content) and the type of dehulling method employed.

4.3.2.1 Hand squeezing method

Beans recovery by hand squeezing method as shown in Table 11 was found to be proportional to seed size and seed coat. Amount of bean recovered were higher (89.91%) in TGX 1895-33F variety of larger seeds (17.72g) accompanied with thin seed coat (7.04%) while Sable a smaller seed size variety (12.65g) and of a thick seed coat (9.50%) had the lowest bean recovery (86.50%) and the differences between varieties were statistically significant ($p<0.05$). From the findings it can be concluded that, smaller seed size varieties with a high percentage of seed coat had smaller percentages of beans recovered. The amount of hull fractions produced were positively correlated to the hull content of a variety, i.e., varieties that contained large amount of seed coats revealed higher amounts of seed coats that were recovered.

Table 11: Dehulling fractions as influenced by varieties

Variety	Dehulling fractions											
	Hand method				Hessian bag method				Mechanical Method (dehuller)			
	Bean recovered (%)	Hulls (%)	Undehulled grains (%)	Fines (%)	Bean recovered (%)	Hulls (%)	Undehulled grains (%)	Fines (%)	Bean recovered (%)	Hulls (%)	Undehulled grains (%)	Fines (%)
TGX1895-33F	89.91^{a}	6.95^{d}	0.91^{c}	0.82^{b}	79.95^{a}	6.945^{d}	2.05^{b}	4.30^{a}	90.95^{a}	6.96^{c}	0.8^{b}	1.1^{a}
TGX 1895-4F	88.60^{b}	7.85^{c}	0.90^{c}	0.80^{b}	79.90^{a}	7.600^{c}	2.60^{ba}	4.20^{a}	90.70^{a}	7.50^{d}	0.7^{b}	1.5^{a}
TGX 1805-8E	88.50^{b}	9.01^{b}	1.55^{b}	1.15^{ba}	79.65^{ba}	9.030^{ba}	2.35^{ba}	4.55^{a}	90.24^{ba}	8.90^{c}	1.4b^{a}	1.3^{a}
TGX 1876-4E	87.40^{c}	9.03^{b}	1.50^{b}	1.70^{a}	79.80^{ba}	8.850^{b}	3.10^{a}	5.60^{a}	90.40^{ba}	9.06^{b}	1.7^{a}	2.0^{a}
Sable	86.50^{d}	9.32^{a}	1.90^{a}	1.50^{ba}	79.49^{b}	9.210^{a}	3.00^{a}	5.70^{a}	89.70^{b}	9.36^{a}	1.7^{a}	1.9^{a}

[a,b,c,d]Values followed by same superscript letter in a column are not significant ($p > 0.05$)

Source: Experimental data, (2009).

4.3.2.2 Hessian bag method

The amount of beans recovered with hessian bag method was higher in varieties with larger seed sizes also. In this method, TGX1895-33F the larger seeded type variety showed a higher bean recovery of 79.90% with the tendency for the small seeded type (Sable) to have a low bean recovery of 79.49 %. Although the results showed statistical differences ($p< 0.05$) between varieties, the varietal differences were small. Amount of hull recovered showed significant varietals effect ($p<0.05$) and the amount of hulls recovered were negatively correlated with the seed size of the varieties. That is, TGX1895-33F variety (with large seed size) showed the lowest hull recovery (6.45 %) while Sable (with small seed size) showed the highest hull recovery (9.21 %).

Observations on the amount of grains that remained undehulled indicated that they were related to seed size in which TGX1895-33F a larger seed size variety showed the lowest undehulled grains (2.30%) while Sable and TGX1876-4E the smaller seed size varieties showed high percent of undehulled grains (3.00 and 3.10%) respectively. The easiness, with which larger seeds have in dehulling, resulted in having a larger proportion of the beans being dehulled while smaller sized seeds had larger proportion remaining undehulled. The differences in amount of undehulled seeds proportion between larger seed variety and smaller ones was statistically different ($p<0.05$). The amount of fines generated were 4.30% for TG 1895-33F, 4.20% for TGX1895-4F, 4.55% for TGX1805-8E, 5.60% for TGX1876-4E and Sable had 5.70% fines. However, fines generated with this method had no significant variety effects ($p<0.05$). The method showed a slightly higher loss in terms of fines generated than the other two methods (hand and wet dehuller methods). This was probably due to an abrasive coarse surface of the bag. However the losses were not influenced by the size of the seeds.

4.3.2.3 Wet dehuller method

The amounts of bean recovery with wet dehuller method were higher with varieties that had larger seed size. TGX1895-33F showed the highest bean recovery of 90.95%, whereas Sable a smaller seed size with thick seed coat variety showed a lowest amount of bean recovery of 89.70%. The differences between varieties in amount of bean recovery were statistically significant ($p<0.05$). There was also a tendency of decreasing of beans that were recovered with decrease in seed size. This again showed the advantages the larger seeds had over the small seeds during the dehulling.

Hulls recovered in this method were highly correlated with hull content of each variety and were statistically significantly different ($p<0.05$). The amounts were 6.96, 7.50, 8.90, 9.00 and 9.36% for TGX1895-33F, TGX1895-4F, TGX1805-8E, TGX1876-4E and Sable, respectively. The same trend was also observed on the amounts of undehulled beans and fine fractions. The amounts of undehulled grains were lower in TGX1895-33F variety (a larger seed size) with the lowest score of 0.8 %. The highest percentages of 1.7% grains that remained undehulled were shown by the small seed size varieties TGX1876-4E and Sable. Amounts of fines also tended to increase with decrease in seeded with the lowest values observed in TGX1895-33F (1.1%), while TGX1876-4E and Sable had the highest percentages of 2.0% and 1.9%, respectively. The differences between varieties were not statistically different at ($p>0.05$). However, with this method the losses in terms of fines were not influenced by the size of the seeds.

These findings were found to concur with the conclusion of similar studies on legumes by several researchers. Black *et al.* (1998) while studying dehulling in field pea, noted dehulling efficiency to be positively correlated with seed size and negatively correlated with both seed breakage and hull content. A research by Reichert *et al.* (1984) showed that marked differences existed within and among soybean (*Glycine max* (L.) Merr.), faba bean (*Vicia faba* (L.), field pea, cowpea and green gram in terms of milling. Ehiwe and Reichert (1987) and Singh *et al.* (1992) found the major factors affecting dehulling of pulses to be seed diameter and coat thickness. Larger seeds tended to have lower percentage loss during decortications because the proportion of hull to seed is lower.

In an earlier study by Erskine *et al.* (1985) it was found out that within a given range of seed diameters, seeds with mean diameter of 4 mm lost an average of 8.19% of their weight during decortications whereas losses from 3 mm seeds averaged 9.80%. A negative correlation to seed size was found on the study of red lentil by Erskine *et al.* (1991) who found larger seeds (4-5 mm) milled less efficiently (80.1% yield) than smaller (4 mm) seeds (82.0% yield) on which they concluded that this difference in efficiency resulted from a higher level of broken seeds and split seeds with the fraction of larger seeds.

From these findings, it can be concluded that the hulling characteristics of grain legumes are influenced by variety in association with its physical characteristics. Larger grain varieties in the study were easier to dehull and gave higher yields on amounts of recovered beans, while the smaller varieties required repeated dehulling thus leading to higher amounts of breakages of grains.

4.3.3 Dehulling efficiencies of the investigated methods

Performance of different methods on dehulling fractions and dehulling parameters were as summarized in Table 12. The relative dehulling fractions and parameters used to measure dehulling efficiency of a method were determined and compared between the dehulling methods. The dehulling fractions investigated were: bean recovery, amount of seed coat removed from the grains, the amount of grains which remained undehulled and fines. The dehulling parameters investigated were: coefficient of dehulling (C_h), coefficient of the wholeness of the kernels (C_{wk}), hulling efficiency (HE), overall dehulling efficiency (ODE) and dehulling index (DI).

4.3.3.1 Dehulling fractions

Calculations used to find the dehulling fractions were as shown in (section 3.11). The results on dehulling fractions were as described in the following subsections.

(a) Dehulling efficiency in terms of bean recovery

As shown in Table 12, the wet dehuller yielded the highest proportion of dehulled grains of 90.39%, followed closely by hand method with 88.18%. The hessian bag method showed slightly lower yields of 79 75% and the differences between type of method employed on amounts of bean recovery were statistically significant ($p<0.05$). From these findings, it can be concluded that the traditional method (hand method) can work efficiently although slightly lower than the wet dehuller in terms of beans recovery. These findings were similar to comparative milling performance of chakki, commercial mill and Mini dhal mill by Pratape *et al.* (2004) whereby the performance of Mini dhal mill was comparable to the commercial milling system. Again, the results obtained on SUA wet dehuller were similar to another study by Reichert *et al.* (1984) on evaluation of performance of a batch dehuller that showed bean recovery ranging between 74 and 89% with 90% of the hulls being removed. The main factor that probably contributed to low bean recovery in hessian method might be the abrasive force exerted on the beans in the absence of water which, resulted into greater losses of grains through breakage. Dehulling operation in hessian method is always done in the absence of water (Appendix 1). Frictional forces generated by grains and the frictional forces between grains and the fabric materials forming the bag in the absence of water resulted in grain breakage leading to increased losses in the form of fines.

Table 12: Dehulling efficiencies of the investigated dehulling methods

Method	Dehulling Fractions				Dehulling Parameters				
	Bean recovered (%)	Hull (%)	Undehulled grain (%)	Fines (%)	Coefficient of dehulling	Coefficient of the wholeness of the kernels	Hulling efficiency (%)	Overall dehulling efficiency (%)	Dehulling index
Hand	88.18^{b}	8.43^{a}	1.35^{b}	1.19^{c}	0.98^{a}	0.98^{a}	96.33^{a}	92.84^{b}	0.91^{b}
Hessian bag	79.75^{c}	8.32^{a}	2.62^{a}	4.87	0.96^{b}	0.93^{c}	90.93^{b}	82.33^{c}	0.77^{c}
Dehuller	90.39^{a}	8.35^{a}	1.26^{b}	1.56	0.98^{a}	0.97^{b}	95.99^{a}	95.59^{a}	0.94^{a}

^{a,b,c}Values followed by same superscript letter in a column are not significant different ($p < 0.05$)

Source: Experimental data, (2009).

The yields of dehulled grains in hand method did not differ much from that of the dehuller. Unlike the hessian bag method where dehulling operation was done in the absence of water, dehulling operation in hand method was done in the presence of plenty of water that offered lubrication and thus less grain breakage (Appendix 1). Water was found to affect the mechanical properties of the cotyledons and the hulls, generally acting as a plasticizer, softening most biological materials and making easy separation of the two components (seed coat and cotyledon). These results agree with those found in a study on oats dehulling by Doehlert and McMullen (2001) and Peltonen-Sainio *et al.* (2004), who established a minimum for hulling efficiency at around 15-20% moisture and reported the distribution of water to be a factor.

Highest yield in the dehuller was suggested to be accounted for by a single pass and less dehulling time, whereby grains had less time to come into contact with the seed abrasive cylinder hence low grain breakage. Dehulled grains yielded by SUA dehuller and hand methods in this study were not far from the maximum theoretical yields of legumes which usually ranged between 85 to 95% as reported by Grandison and Lewis (1996). Furthermore, none of the traditional methods tested produced results below the maximum theoretical yield as reported by Kurien *et al.* (1972) on traditional methods, that the average yield of dehulled splits using traditional methods was only 73%.

Although tedious and time consuming, the traditional methods researched in this study were considered to be of economic importance in places where modern dehulling equipment are not within reach. However, the dehuller was found to be the most efficient method in terms of yields, less time requirement and high throughput.

(b) Dehulling efficiency in terms of hull fractions

From Table 12, the hull fractions from hand, dehuller and hessian methods were 8.43, 8.35, and 8.32%, respectively. All methods tested in this study showed success in hulls removal compared to the theoretical hull content of the soybean varieties used, which was found to range between 7.04 and 9.50%. Besides tediousness and time consuming of the traditional methods, their performance in hull removal were comparable to the dehuller method. However, the method of dehulling had no statistical significant effects ($p>0.05$) on the amount of hull removed. An observation on the two traditional methods, based on the high value of hulls recovered, agrees with the findings of Grandison and Lewis (1996) who reported that though manual removal of hulls from many legumes was tedious, the method is probably the only one which removes all the hulls and consequently can be used for estimating the hull content of the seeds and the theoretical yield of dehulling product, which usually ranges between 85 and 95%.

(c) Dehulling efficiency in terms of undehulled fractions

The percentages of grain by weight which remained undehulled were as shown in Table 12. The undehulled proportions accounted for: hessian bag method (2.62%) hand method (1.35%) and dehuller method (1.26%) and the mean weight for undehulled proportions by dehulling methods were statistically different ($p<0.05$). Hessian bag dehulling method had the highest percentage of grains which remained undehulled while undehulled fractions from hand and dehuller methods did not show significant differences ($p>0.05$) between them. This could be attributed by the way dehulling operation was handled. In hessian bag method the whole sample (one kg) was squeezed at a time which may have led to some of the interior material missing out the external abrasive force exerted by the bag (Appendix1). This force together with the abrasive force generated by grains themselves is responsible for separating hulls from the cotyledons. Another reason could be the potential injury the dehulling bag may have caused to the hands of the operator. The operator was forced to carry out the work with care by reducing the force to be exerted on the load.

In hand dehulling only a handful of grains was squeezed at a time in the presence of plenty of water which improved the force for hulls removal (Appendix1). In the case of dehuller, only small quantities of grains passed through the feed gate to the abrasive surface thus nearly all grains had a chance of being exposed to the abrasive surface (Appendix1). The study revealed that while expecting modernizing soybean dehulling methods the two traditional methods can funher be improved. For example, instead of using the hessian bag of coarse fabric materials softer materials could be used, but is a subject warranting further research to confirm the effectiveness of the method.

(d) Dehulling efficiency in terms of fines fractions

Results in Table 12, show high fines of 4.87% observed with hessian bag method followed by wet dehuller with fines of 1.56% while hand method showed 1.19% of fines. The dehulling losses in form of fines were higher in hessian method and this might have been due to the attrition action of the coarse fabric material forming the bag. Dehulling in the absence of water is another major factor which also contributed to a high percentage of losses in hessian bag method. The two other methods performed well with little percentages of fines. Reasons behind could again be related to the use of water in case of hand method while in case of dehuller a single pass of the grain in the dehuller and a shorter contact time. The methods of dehulling showed significant effects and were statistically different ($p< 0.05$) on the amount of fines generated during dehulling.

4.3.3.2 Dehulling parameters

The effects of methods of dehulling on dehulling parameters were as shown in Table 12. Calculations used to find the dehulling parameters were as shown in (section 3.11). The results on dehulling parameters were as described in the following subsections.

(a) Coefficient of dehulling (C_h)

The coefficient of dehulling which is a measure of the ability of the method to remove hulls, showed less variations ($p<0.05$) from each dehulling method. Lower value of 0.96 coefficient of dehulling was observed from hessian bag, while dehuller and hand showed the same value (0.98) coefficient of dehulling. These observations revealed that all dehulling methods under study were efficient in hulls removal. Furthermore, unlike other traditional dehulling methods which are generally considered inferior, the two types investigated in this study could be used with similar effectiveness to improved methods where modern methods are unavailable.

(b) Coefficient of wholeness of the kernels (C_{wk})

The parameter measures the ability of removing hull without breaking the grains.
Values of this parameter as observed in Table 12 were: hand method 0.98, hessian bag method 0.93 and wet dehuller 0.97. Methods of dehulling had statistically significant differences ($p<0.05$) in the ability of removing hull without breaking the grains. Food loss in the three dehulling methods was somehow minimal and thus the use of these methods in soybean dehulling can be of beneficial effects leaving aside the drudgery and time consuming nature associated with the traditional ones.

(c) Hulling efficiency (HE)

Hulling efficiency, which provides an objective measure of the efficiency of the operation and a comparison between equipment and types of grain in terms of dehulling efficiency, was evident. Comparison of the three dehulling methods in terms of hulling efficiency was highest (96.33 %) in hand method, while in wet dehuller method the observed hulling efficiency was (95.99 %) and a little lower value (90.93%) was observed in hessian bag method. The hulling efficiencies of the three methods observed were significantly different at ($p<0.05$).

(d) Overall dehulling efficiency (ODE)

This parameter explains the quality of dehulling. The three dehulling methods showed significant differences ($p<0.05$) in the overall dehulling efficiency. From the study, wet dehuller was observed to have the highest value (95.59%) followed by the hand method (92.84 %) and hessian bag method (82.33 %). A high value of overall dehulling efficiency is considered as an index for a better process. The dehulling methods including the traditional ones are considered to be good and suitable methods for dehulling soybeans due to high values of overall dehulling efficiency observed in this study. However, the drawback is that the traditional ones took longer time to get the process completed.

(e) Dehulling index (DI)

Dehulling index is a measure of the quality of the finished product obtained (dehulled whole grains and splits) from each dehulling method employed. In this study wet dehuller had the highest dehulling index of 0.94, while hand and hessian bag showed values of 0.91 and 0.77 dehulling index, respectively. Higher value of dehulling index the more efficient the method was. Observations revealed significant differences ($p <0.05$) in the quality of finished product obtained (dehulled whole grains and splits) in each of the dehulling methods. The findings indicated wet dehuller method was the most efficient method due to high value of dehulling index followed by the hand method (see Table 12).

Comparison of the means of three soybean dehulling methods (dehuller, hand and hessian bag) showed that the dehulling efficiency of the hand method was not much different from that of wet dehuller in terms of dehulling fractions and parameters let aside drudgery and time consumption associated with this method.

4.3.4 Dehulling characteristics

The time which was required to dehull 1 kg of soybeans in each method as well as dehulling capacity (throughput) of each method were as shown in Table 13.

Table 13: Time and throughputs of the dehulling methods

Dehulling methods	Time (min/kg)	Time ratio (compared to hand method)	Throughput (kg/hr)	Throughput ratio (compared to hand method)
Hand squeezing	43.60^a	1.0^b	1.38^b	21.7^a
Hessian bag	26.90^b	1.6^b	2.27^b	13.2^b
Wet dehuller	2.10^c	21.0^a	30.00^a	1.0^c

^{a,b,c}Values followed by same superscript letter in a column are not significantly different ($P < 0.05$)

Source: Experimental data, (2009)

4.3.4.1 Dehulling efficiency in terms of time

Time of dehulling is one of the important factors, which affect the dehulling efficiency and dehulling loss. The dehulling efficiency of a sample of 1 kg of soybeans in terms of time used to completely finish the sample, showed statistically significant differences ($p<0.05$) between the dehulling methods. Comparison of time required and dehulling capacity on one kilogramme of soybeans was as shown in Table 13. Minimum time required for dehulling was revealed with application of wet dehuller and tended to increase with the use of hessian bag and finally hand method, respectively. About 43 minutes were required to dehull one kilogramme of soybean using hand method. The wet dehuller took less time (2.1 minutes) to dehull 1 kg of soybean in a single pass, followed by hessian bag which took 26.90 minutes to dehull the same amount of beans. Comparing the dehulling efficiencies of the three methods in terms of time required to dehull one kg of soybeans, the dehuller was found to be 21 times as efficient as the hand method and 13 times as efficient as the hessian bag method. The hessian bag method was found to be 1.6 times as efficient as the hand method.

From these findings it was concluded that the SUA wet dehuller was the best and most economical method since it could save time and thus can allow the user/processor to engage in other activities. In the case of the traditional methods, considerable amount of time was required. Therefore, there is a need of replacing the traditional dehulling methods with improved methods so as to reduce time and drudgery.

4.3.4.2 Dehulling efficiency in terms of throughput

Throughput of a dehulling method is an important factor that determines the economic importance of the dehulling method. Soybean processors at a commercial scale require processing methods of high capacity. The SUA developed wet soybean dehuller in Table 13, showed a high throughput of 30 kg of soybean in an hour while the two traditional methods hessian and hand showed very low throughputs of 2.27 and 1.38 kg /hour, respectively. When efficiencies of the methods in terms of throughputs were compared, wet dehuller was found to be 21.7 times the throughput of the hand method and 13.2 times the throughput of the hessian bag method. The SUA wet dehuller throughput value approached that of a low cost manual dehuller developed by Singh and Sinha (1990) for use by unskilled people in rural areas without electricity, which showed a capacity of 35kg/hour with 96% dehulling efficiency. Again, the throughputs of the tested dehulling methods were found to be statistically significantly different ($p<0.05$).

If extrapolated and compared their processing capacity based on an eight hour working day, the working capacity of wet dehuller could reach 240 kg about (2 .5 bags) of soybeans, while that of hessian bag and hand methods could reach 18.16 and 11.04 kg, respectively. A similar study, on evaluation of traditional methods by Philip and Itodo (2006) and Kwon-Ndung and Masari (1999), found out that traditional methods gave very low outputs per day with only 1 and 2 kg/hour /person let alone being very tedious and time consuming. Of the three methods the wet dehuller was found to be the best for dehulling larger samples within a short time.

The findings from this study and previous related researches confirmed that traditional dehulling methods are unsuitable to large-scale industrial production. This calls for modernization of the dehulling process and development of simple machines so as to reduce the drudgery associated with traditional operations, increase throughput and make life a lot easier. This will be a step forward in helping the SMEs in this country to be able to serve the Tanzanian community.

4.3.5 Comparative dehulling efficiency of the soybean varieties on wet and dry process based on wet dehuller

Dehulling fractions that were used to compare dehulling efficiency of the bean varieties in wet and dry dehulling processes were as appear in Table 14.

4.3.5.1 Dehulled grains recovered

The performances of bean varieties on wet and dry dehulling processes were as shown in Table 14. The results revealed that wet process for TGX1895-33F, TGX1895-4F, TGX1805-8E, TGX1876-4E and Sable were 90.95, 90.70, 90.40, 90.24 and 89.70 %, respectively. In dry process the results were 65.73, 37.33, 30.35, 30.00 and 45.81 percent for TGX1895-33F, TGX1895-4F, TGX1805-8E, TGX1876-4E and Sable, respectively. Varietal differences were found to be significantly different ($p<0.05$) in processing types following their physical characteristics. Decrease in dehulling fractions was observed, which were related to physical characteristics (as discussed in (4.3.2) subsections.

Table 14: Dehulling efficiencies of the two dehulling processes

Variety	Dehulling fractions							
	Wet process				Dry process			
	Bean recovered (%)	Hull (%)	Undehulled grains (%)	Fines (%)	Bean recovered (%)	Hull (%)	Undehulled grains (%)	Fines (%)
TGX 1895-33F	90.95^{a}	6.945^{d}	0.8^{b}	1.1^{a}	65.73^{a}	5.30^{c}	24.66^{b}	51.06^{b}
TGX 1895-4F	90.70^{a}	7.600^{c}	0.7^{b}	1.5^{a}	37.33^{c}	6.00^{b}	24.20^{b}	50.66^{b}
TGX 1805-8E	90.24^{ba}	9.030^{ba}	1.4^{ba}	1.3^{a}	30.35^{d}	7.26^{a}	20.53^{b}	58.36^{a}
TGX 1876-4E	90.40^{ba}	8.850^{b}	1.7^{a}	2.0^{a}	30.00^{d}	7.31^{a}	20.66^{b}	56.33^{ba}
Sable	89.70^{b}	9.210^{a}	1.7^{a}	1.9^{a}	45.81^{b}	5.26^{c}	39.33^{a}	44.00^{c}

^{a,b,c,d}Values followed by same superscript letter in a column are not significantly different ($P < 0.05$).

Source: Experimental data, (2009)

Generally, larger seed size varieties revealed higher bean recovery whereas the small seed size varieties revealed small percentages of beans that were recovered, with the exception of Sable in the dry process, which showed an increased bean recovery and a decrease in hull recovered. This case in sable may be accounted for by the small seed size of the variety and the hardness character of the variety in resisting grain breakage despite several passes in the dehuller. Noticeable amounts of cotyledon material and germ were removed on dry dehulling resulting in considerable loss. This could have been attributed to the nature of the abrasive surface designed for wet processing, several passes of the dry beans through the dehuller and a prolonged dehulling time. This revealed unsuitability of the dehuller for dehulling dry beans.

Comparing the two processes, the wet process performed better and would be of economic importance in dehulling soybeans than dry process. The above argument is justified by the higher bean recovery ranging from 89.70 to 90.95% in wet process and a lower bean recovery from 30.00 to 65.73% in dry process. For a good milling efficiency the following observations are worth noting as reported by Vandenberg and Bruce (2008).

(i) Milling efficiency lower than 80% is uneconomical.

(ii) The theoretical maximum milling efficiency is about 92% (complete dehulling, no splitting – all the seed coat is removed).

(iii) Millers would be comfortable if they can maintain an 85% milling efficiency.

4.3.5.2 Residual fractions

The residual fractions of hulls, undehulled grains and fines observed were as shown in Table 14. Hulls in wet method were 6.94, 7.60, 9.03, 8.85, and 9.21 percent for TGX1895-33F, TGX1895-4F, TGX1805-8E, TGX1876-4E and Sable, respectively. In the dry process hulls were 5.30, 6.00, 7.26, 7.32 and 5.21 percent for TGX1895-33F, TGX1895-4F, TGX1805-8E, TGX1876-4E and Sable, respectively. Sable variety in dry process had the lowest fractions of hulls. This again could be associated with the small size of the grain as well as the hardness of the grain that resisted breakage and leading to higher percentages of grains that remained undehulled. A higher percentage of undehulled grains resulted into lower percentage of hulls in this variety than the other varieties. The mean differences of varieties in hulls revealed, were significantly different ($p<0.05$).

The grains that remained undehulled in the wet process after a single pass were 0.8, 0.7, 1.4, 1.7 and 1.7 percent for TGX1895-33F, TGX1895-4F, TGX1805-8E, TGX1876-4E and Sable, respectively. Again, under dry process, grains that remained undehulled after five passes were 24.6, 24.20, 20.53, 20.66 and 39.33 percent for TGX1895-33F, TGX1895-4F, TGX1805-8E, TGX1876-4E, and Sable, respectively. Fines generated in wet process were 1.1, 1.5, 1.3, 2.0 and 1.9 percent for TGX1895-33F, TGX1895-4F, TGX1805-8E, TGX1876-4E and Sable, respectively and varietals differences were not statistically different at ($p<0.05$). Small percentages of fines that were exhibited by the wet beans showed how better the process was in terms of preventing dehulling losses and hence the dehuller can be used with effectiveness in wet beans only. The differences between varieties in amounts of fines generated in dry process were statistically significant ($p<0.05$) and the results were 51.06, 50.66, 58.36, 56.33 and 44.00 percent for TGX1895-33F, TGX1895-4F, TGX1805-8E, TGX1876-4E and Sable, respectively. Greater percentages of fines in dry beans showed clearly how unsuitable the dehuller was for dehulling dry beans.

4.3.6 Comparative dehulling efficiencies of the two dehulling processes

Mean comparison of dehulling performances of the two dehulling processes when the wet dehuller was used on wet and dry beans were as shown in Table 15.

Table 15: Means and t-values for comparison of dehulling efficiencies of wet and dry beans

Performance indicators	Mean		t-test	Probability
	Wet samples	Dry samples		
Time (min/kg).	2.10 ± 0.51	8.93 ± 1.22	19.992	0.000
Throughput (kg/hour)	30.00 ± 6.55	6.87 ± 1.14	13.478	0.000
Hull %.	8.42 ± 0.94	6.23 ± 0.95	6.374	0.000
Undehulled grains %.	2.73 ± 2.78	25.88 ± 7.49	11.226	0.000
Fine %.	1.61 ± 0.49	52.09 ± 6.02	32.349	0.000
Bean recovered %.	90.29 ± 0.42	41.85 ± 3.95	13.440	0.000
Coefficient of dehulling.	0.98 ± 0.01	0.74 ± 0.07	12.589	0.000
Coefficient of the wholeness of the kernels.	0.97 ± 0.01	0.17 ± 0.05	66.599	0.000
Hulling efficiency %	96.00 ± 1.00	11.81 ± 4.37	72.632	0.000
Overall dehulling efficiency %	95.60 ± 0.91	12.51 ± 3.37	91.994	0.000
Dehulling index.	0.94 ± 0.01	-0.62 ± 0.07	78.798	0.000

Source: Experimental data, (2009).

Comparison of the different dehulling processes on various performance indicators were as shown in Table 15. Differences between mean yields as shown by t-values in various fractions and parameters on comparing the two dehulling processes were statistically different and were highly significant ($p<0.001$). The dehulling processes showed highly significant differences ($p<0.001$) in yields of various fractions, that is bean recovery, amount of hulls produced, amount of grains that remained undehulled and fines generated. Similarly, as shown in Table 15 the differences in yields of various dehulling parameters, i.e., coefficient of dehulling, coefficient of the wholeness of the grain, hulling efficiency, overall dehulling efficiency and dehulling index also were statistically different ($p<0.001$). The statistical differences shown could be attributed to moisture content of the sample at the time of dehulling and the time used to process 1kg of soybeans. Moisture content in the wet beans ranged between 48.18 and 53.84% and dehulling time was 2.10 min/kg whereas, in the dry beans moisture content ranged between 11.18-12.31% and dehulling time was 8.93 min /kg.

4.3.6.1 Dehulling fractions

The findings from this study showed that wet process had higher bean recovery (90.29 %) while dry process showed relatively low bean recovery (41.85 %). The results are in agreement with the findings by Chakverty and Mujumdar (2003) who observed that moisture softens the grains and makes them susceptible to scouring, whereas drying hardens the grain and increases their resistance to scouring. The results also were in agreement with a study on pigeon pea by Tiwari *et al.* (2008) who found that the hydrothermally treated pigeon pea gave the highest amount of dehulled grains, followed by the dry method. Another similar study by Ehiwe and Reichert (1987) revealed that the seed coat breaking of field peas was affected by seed moisture content. The percentage of grains that remained undehulled in the wet process was (2.73 %) while in the dry process was (25.88%). A similar study on evaluation of performance of centrifugal dehulling system for sunflower seeds by Gupta and Das (1999) found dehulling efficiency and non-recoverable kernel fraction increased with decrease in the seed moisture content. Hulls produced in wet dehulling were (8.42 %) while dry process produced (6.23 %). Fine fraction generated during wet process was (1.61%) while that from dry process was (52.09%). The results from study can be supported by a study on lentil (*Lens culinaris*) by Wang (2005) who revealed that increasing seed moisture content decreased powder and broken fractions.

High differences in dehulling fractions observed were associated with moisture content of the soybeans at the time of dehulling. In wet process moisture content was high and ranged between (48.18-53.18%). Moisture plays a significant role in softening and loosening the bindings between seed coat and cotyledons and the softening of the seed coat itself that improves the effectiveness of hulling. Thus, high moisture content of the beans leads to easy removal of the seed coat with minimum grain breakage. In such case high moisture content of the beans in wet process resulted into a yield of a higher percentage of dehulled fractions, while low values were obtained in dry beans of low moisture content. Moisture has opposite influence on the adherence of husk to the cotyledons and the bonding between the two cotyledons.

Lower dehulling fractions in dry dehulling were due to tight adhesion of the seed coat to the cotyledons following bean shrinkage after sun drying of the boiled beans. Shrinkage as an effect of drying made the seeds vulnerable to breakage. Tight adhesion of the seed coat to the cotyledons necessitated the use of high dehulling strength / power in an attempt to achieve dehulling of the dried beans, which led to excessive grain breakage thus high losses in the form of fines. Another reason for the lower dehulling efficiency obtained in dry beans, was the tendency of the tightly adhered seed coat to resist separation hence left behind many undehulled beans. In addition to that greater parts of the few cotyledons obtained were broken due to the hardness character of the seeds acquired on drying. A similar study by Barriga (1961), found that seeds which were too dry were more prone to mechanical damage and losses during handling and milling. With high moisture content (i.e., in the case of the wet beans) the seed coats were softened and less brittle therefore it was easy for the machine to dehull most of the beans with minimum breakage. Again, a related study by Audu *et al* (2004) showed cotyledons of the wet beans were more elastic than that of dry beans hence they were not easily broken during dehulling.

In this study it was found that the dehuller was designed and fabricated for dehulling wet beans only. Boiled soybeans followed by sun drying to low moisture content between (11.18-12.31%) was observed not to perform well in this kind of dehuller due to the nature with which the abrasive surface was designed. This surface broke most of the beans into small particles instead of splitting them into two cotyledons. In addition, sun-drying of the boiled beans to such low moisture content resulted in shrinkage of the beans and the seed coat became tightly attached to the cotyledons and hence was difficult to separate. An overall observation when assessing dehulling performance of wet and dry beans using the wet dehuller revealed that, dehulling losses tended to decrease with increase in moisture content of the beans.

4.3.6.2 Dehulling parameters

The effects of dehulling processes on parameters yielded were as shown in Table 15. Coefficient of dehulling (C_h) which measures the ability of the machine to remove hull and coefficient of wholeness of kernel (C_{wk}) a measure of the ability of the machine to remove hull without breaking grain; were 0.98 and 0.97 in wet process and 0.74 and 0.17 in dry processes. The hulling efficiency (HE) of the two processes was found to differ significantly. The wet process had higher hulling efficiency (96.00%) as compared to the dry process that had a lower value (11.81%). The overall dehulling efficiency (ODE), which is a measure of the quality of dehulling, differed greatly between the two processes. Higher percentage value (95.60 %) of overall dehulling efficiency was observed with wet process, while the dry process revealed a lower percentage value of (12.51%) overall dehulling efficiency.

Dehulling index (DI) which reflects the quality of finished product obtained, revealed a very high value (0.94) in the wet process and a lower value (-0.62) in the dry process. A longer dehulling time (8.93 minutes) experienced by the dry beans in the wet dehuller, resulted in scouring of the seed coat as well as the upper surface of the cotyledons thus, higher percentage of abraded fines hence a very low dehulling index. Ikebudu *et al.* (2000) reported the dehulling index with a value of -1 indicates that dehulling is not complete, thus the grains are either not dehulled properly or yielded broken and powdering losses. Dehulling fractions and parameters observed under dry process in this study were in agreement with Ikebudu's arguments. Comparison between the two dehulling processes on the various parameters considered was found to be significantly different ($p<0.001$) on the parameters obtained under each process. Moisture content of the samples and the dehulling time were factors that were responsible for differences in dehulling parameters obtained. The coefficient of dehulling, coefficient of the wholeness of the grains, hulling efficiency, overall dehulling efficiency and dehulling index were statistically significant ($p<0.001$).

4.3.6.3 Effect of dehulling time

Mean comparison on effect of time on dehulling were as shown in Table 15. Less time (2 min) was used in wet process while (8.93 min) was used in dry process. The increased dehulling time in dry process increased dehulling losses, which is expected as grains were being subjected to more abrasion forces. The dry process produced higher levels of undehulled and fines fractions and lower yields of dehulled grains and hull fractions. This findings concurred with a report on longer dehulling time by Singh *et al.* (1989) on pigeon pea and chickpea Singh *et al.* (1992), that longer dehulling period could result in lower dhal (dehulled splits) yield and higher powder fractions.

In this study, time used in dehulling was found to be an important parameter, which affected dehulling efficiency and dehulling losses under the two dehulling processes. The effect of dehulling time on dehulling efficiency was observed in the dehulling fractions obtained. The percentage of bean recovered with wet processing was (90.29%) very far from that observed with dry process (41.85%). Grains that remained undehulled in the dry process were (25.88%) compared to (2.73%) that remained undehulled in wet process. Percentage of fines generated during dry process was (52.09 %) compared to (1.61%) in wet process. The longer the dehulling time the higher the content of the fines generated. The differences between the two dehulling processes were statistically significant ($p<0.001$) in time used to dehull 1kg of the sample. A similar study on optimization of the pigeon pea dehulling process by Goyal *et al.* (2008) found moisture content and dehulling time affected dehulling losses significantly. Percentages hull produced was found to be lower (6.23 %) in dry process compared to (8.42%) in wet process, respectively.

4.3.6.4 Throughput

Throughput measured under the two dehulling processes was as shown in Table 15. Wet dehuller had the highest throughput of 30.00 kg / hour of soybeans that could be dehulled whereas only 6.87 kg / hour could be accommodated with dry process. Low throughput in dry dehulling could be related to low moisture content that ranged between 11.18 and 12.31% attained after sun-drying of the boiled beans. Sun-drying of boiled beans resulted into shrinkage of the grains and tight adhesion of the thin seed coat to the cotyledons, thus making it difficult to separate. An attempt to achieve dehulling using the wet dehuller; 1 kg of the sample was forced to pass five (5) times through the dehuller contrary to one pass that was found enough when beans of high moisture content were used. Comparison between the dehulling processes were found to have significantly influenced throughput ($p<0.001$) as shown in Table 15.

From this study it was seen that the wet dehuller performed better with wet soybeans and could dehull soybeans successfully at a single pass. Therefore, the findings necessitated further research on different designs of a dehuller suitable for dry dehulling with improved throughput by reducing the dehulling time. Dry beans are sometimes found to perform well in hand or power-operated under-runner disc-shellers or grinders with emery or stone contact surfaces. A plate mill with a blunt contact surface is sometimes recommended for dry grains.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

i. The study results investigated five soybeans dehulling methods: processing by hand, processing by hessian bag, pounding in mortar and pestle, grinding stone and simple soybean dehuller. Majority of the respondents (%) processed less than 50 kg of soybean in a month mainly for family use due to low market demand as a result of unawareness of the nutritional importance of soybean products. It was noted that lack of improved and efficient soybean dehulling methods, made the respondents to rely on inefficient traditional dehulling methods.

ii. Traditional processing of soybean using simple methods (hand, hessian bag, mortar and pestle and grinding stone methods) was the dominant ones besides being highly labour intensive and low productivity in terms of working capacity. The method cannot in any case contribute sufficiently to meeting socio-economic imperatives. They are inadequate to cope with present needs by small scale processors. Time was the major constraint for processors practising these traditional technologies.

iii. Dehulling efficiencies of the methods tested in laboratory (hand, hessian and dehuller) were significantly different in their dehulling efficiencies. Although hand method was found to be a reliable and efficient method based on observation of the factors that were used to determine dehulling efficiency, it was the most time-consuming and tedious of all the methods studied. Processing using hessian bag provided reliable results. However, results were slightly influenced by the coarse fabric materials forming the bag that led to lower bean recovery compared to the other two methods. Furthermore, the method produced high percent of fines and undehulled grains due the coarse fabric texture that caused damage to the cotyledons.

iv. Application of the dehuller was found to be a simple method which if available could be easily adopted with beneficial effects in rural areas for dehulling soybeans as it improved dehulling capacity with less time needed and had higher potential in drudgery reduction. Of the three methods studied, wet dehuller was the best for dehulling larger samples within a short time and showed a potential of offering promising solution to the inefficient traditional methods. However, it was unsuitable for dehulling dry beans.

v. Physical characteristics of bean varieties (seed sizes and percentage hull content) were studied and found to significantly influencing dehulling efficiency of the (varieties and the dehulling methods). Larger seeds dehulled more efficiently resulting in higher yield of dehulled grains than smaller seeds. Soybean varieties used in the study and the dehulling methods (bean varieties and dehulling methods) tested on various dehulling fractions and dehulling parameters produced significant differences in their dehulling efficiencies

5.2 Recommendations

From the findings of this study the following recommendations need consideration for improvement of the small-scale soybean processing methods.

i. Identification and recognition of various newer and improved soybean processing methods should be encouraged as can provide the various bases for further development of soybean processing technology in rural and poor peri-urban areas.

ii. Research efforts are needed to refine the traditional methods of dehulling soybeans such as shortening processing time without affecting the product quality.

iii. Promotion of the efficient and low cost soybean dehulling machines, developed by various research and development institutions (like the SUA dehuller), by MAFSC and policy makers in the country is highly desirable, so that many of the inefficient approaches such as use of stone grinders, mortar and pestle hand abrasion and hessian bag could be replaced for efficient soybean dehulling.

iv. Furthermore, developing more SUA wet soybean dehullers and making them available to processors need to be given special attention. It is certain that the SUA dehuller could be a successful stepping stone for socio-economic development of rural and peri–urban areas promoting employment and better returns to soybean processors. Use of the SUA dehuller at village level would also help in mobilizing farmers to grow more soybeans, which in the long run will put the soybean processors in a position of processing at large industrial scale.

v. The findings suggest further research on different designs of a dehuller suitable for dry dehulling with improved throughput by reducing the dehulling time.

vi. Development of products and processing machinery for diversified soybean products such as soy milk, soy flour, soy coffee and soy baked foods should be given special attention in order to increase soybean utilization options. Dissemination of such technologies during agricultural shows is important.

vii. Since soybean recovery was found to depend on the seed size, proportion of hull to the cotyledon as well as moisture content of the beans, there is need to evolve suitable varieties with low hull contents that could easily be separated from the cotyledons. Also, there is need to develop varieties with larger sized grains to increase dehulled splits yield. Identification and development of varieties with improved dehulling characteristics therefore need to receive a greater attention in the near future.

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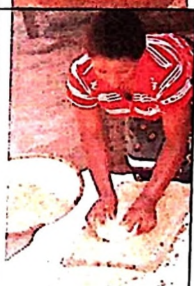
APPENDICES

Appendix 1: Soybean dehulling method identified during study in Morogoro region

Method	Photographs	Description	Operation
Processing by hand (wet process)		No special equipment is required. Any vessel that can hold water can be used in dehulling operation. Water facilitates easy removal of hulls as well as preventing breakage of the grains.	Boiled beans are dehulled while contained in a vessel, half full of water. A Hand full of beans in turn is squeezed between palms repeatedly. Dehulling water is renewed several times until most of the hulls are removed and then washed out by alternating water. The product is then sun-dried.
Processing by hessian bag (Wet process)		Is a bag made up of coarse fabric materials with open at one end. The rough surface of the bag assists in removing hulls by providing an abrasion force.	Boiled beans are placed in the bag. A string is used to tie at the open end. Dehulling is done by squeezing whole contents in the bag with hands, while the bag supported on a working table. Dehulling operation is done continuously until the operator is sure that most of the hulls have been removed. The content is then poured into a vessel contain water for wash out hulls.
Pounding in mortar and pestle (Dry process)		Pestle and mortar are carved from wood. The mortar is about 60-80cm high with a diameter of about 30cm. The pestle weighed about 3kg, is about 1,2m long, 6-8 cm diameter and has a bulbous ends one more pointed than the other	The method is suitable for dry dehulling. A small quantity of water is added to the seeds and mixed and/or dried in the sun for a few hours. Then seeds are pounded by mortar and pestle for several minutes. The shearing action between the pestle and seeds and the scarification between seeds effect dehulling. After pounding operation, hulls are removed by winnowing. This method is used for
Grinding in stone (Dry process)		The stone grinder consists of a stone slab, often fluted, and usually placed on leveling stones so that it slopes away from the operator who sits, kneel or squats behind it, and rolls the grain with a round stone roller. A container or mat is placed in front of the base stone to receive the ground material.	A hand full of grain is placed on the stationary grinding stone and by working the upper stone forwards the grain is crushed. By working back the upper stone a portion of the grain is dragged back to be crushed again in the next action. The ground grain falls behind and to the sides of the stationary stone on to a piece of fabric placed underneath. The material undergoes 2-3 rubbing motion, with a length of 15-25cm.
Hand operated (SUA wet dehuller) (Wet process)		Is a small machine made up with woods .A folded iron sheet form the surface of the hopper. It has a roller made up of woods but enclosed with a perforated iron sheet which effect abrasion on the beans when driving force is applied to the roller. Hulls come out via the rear exit while the products in the front exit.	Boiled beans are put into the hopper. Driving force is applied by hand. Hulls are removed by the sharp edges or projections of the perforated iron sheet in the roller. Product through the front exit is received in the vessel placed for that purpose.

Appendix 2:Questionnaire for identification of soybean dehulling methods and their significance athousehold level.

Q No................

Please tick where appropriate or fill the blanks

A socio – demographic and economic characteristics

1A District

1. Mvomero 2. Kilosa 3.Morogoro Municipality

2A. Respondents name..Date.................

3A. Ward .... Village ....

4A. Sex of the respondent...

5A.What is your education level

[1]Non formal education

[2] Standard vii

[3] Adult education

[4]Secondary school

[5] Post secondary school

6A what is your age

[1] 25-34years

[2] 35-44 years

[3]45-54 years

[4] 55 -64years

[5] Over 65 years

7A. what type of income generating activities do you undertaken?

[1] Crop production

[2] Livestock production

[3] Both crop and livestock production

[4] Business (like shop / kiosk)

[5] Others (specify)

8AWhat is the amount of income generated from you income generating activities (per month)

[1] Less than 100,000

[2] 101, 000-200,000

[3] 201, 000-300,000

[4] 301, 000-400,000

[5] Above 400,000

9A. How many people live in your household in your household?

[1]1-4

[2]5-8

[3]9-12

[4]Above 12

B. Information on soybean dehulling

B1. Do you dehull your produce?

[0] No

[2] Yes

B2. What process/procedure do you use in dehulling?

[1]Wet process

[2]Dry process

[3] Others (specify)

B3. What kind of dehulling method do you use?

[1] Local methods

[2] Modern methods

B4. Mention it/them

[1] ....

[2]..

[3]..

[4]..

[5]..

B5. What is the dehulling capacity of your method?

B6. In using your method how many kilograms of soybeans can dehull in a month?

[1] <50

[2] 50-100

[3] 101-150

[4] 151-200

[5] 201-250

B7. What are advantages associated with your method?

[1]..

[2]..

[3]..

B8. What are disadvantages associated with your method?

[1]..

[2]..

[3]..

B9. If using local dehulling methods, tell what made you to choose such kind of inefficient method?

B10. What kind of problems do you face in this process of soybean dehulling?

[1].Lack of improved dehulling methods

[2] The process is weather dependant

[3] Need to have enough water and fire woods

[4] The process need to have enough drying yard

[5] A need of quick drying equipment

Thank you for your cooperation