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EXPERIMENTAL INVESTIGATION OF PARAMETERS AFFECTING THE QUALITY OF PARBOILED RICE

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PROJECT ON:

EXPERIMENTAL INVESTIGATION OF PARAMETERS AFFECTING THE QUALITY OF PARBOILED RICE

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DECLARATION

We declare, hereby this thesis is our original work and performed by our effort with the willing of the God. During our project, we have spent full of our effort and time and all sources of material used for the thesis have been accordingly acknowledged.

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ABSTRACT

The aim of this study is experimental investigation of parameters affecting the quality of parboiled rice. At the time of sample preparation, approximately 20 kg of paddy rice was cleaned in to remove all impurities. The cleaned and sized rice sample was then stored in a sack under laboratory room conditions(approximately 28°C) and 500 gm sample were taken for each experiment trials. Initial moisture determination was performed in an oven at 130°C for 8 hours until the mass becomes constant. During the period of soaking (4 hours) the oven was set at a temperature of 70°C. At the end of the soaking period, the water is drained followed by steaming for 15 minutes. The main objective of the present study is experimental investigation of parameters affecting the quality of parboiled rice which maximize yield during milling, reducing breakage and cracking. The experiment has been conducted with three factor (moisture content, temperature and time). The moisture content, drying temperature and time has been varied from 14% -30%, 50 -130℃, and 40-120 minutes respectively. The maximum observed yield a moisture content of 15.5% the operating process variable at a temperature of 130 ℃ and a drying time of 60 minutes. Drying time and moisture content level have significant effect on the yield. However, high drying temperature as well as decreasing moisture content below 14% causes low yield. The economic viability of parboiled rice was evaluated as compared to rough rice. The study shows that, the parboiled rice price is greater than rough rice.

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List of Acronoyms

°C	Degree Celsius
d.b	Drying Basis
EIAR	Ethiopian Institute of Agricultural Research
EMoA	Ethiopia Ministry of Agriculture
IHR	Inspection Handbook for Rice
JICA	Japan International Cooperation Agency
MC	Moisture Content
MC_{DB}	Moisture Content in Dry Basis
MC_{WB}	Moisture Content in Wet Basis
RVA	Rapid Viscous Analyser
SAA	Sasakawa Africa Association
TA	Texture Analyser
%TY	Total Yield
USAARC	United State Of America Agricultural Research Centre
%W	Percent Whole Rice After Dehusking
w.b	Wet Basis
%WB	%Broken After Dehusking
W_D	Weight After Drying
%WH	Percent Husk
W_W	Initial Weight

CHAPTER ONE

INTRODUCTION

1.1 Background

Rice is one of the most important food crops in the world. It is reported that rice is the staple food for more than half the world's population. In some of the more densely populated areas, rice is also the main source of carbohydrates. Although rice is generally used as a staple, this cereal is processed into several different prepared products. Some of these are breakfast cereals, canned rice products, and quick cooking rice. Broken rice is used in flour production, brewing and fermented products. The rice obtained from milling pretreated paddy is known as parboiled rice, where as rice obtained from milling of untreated paddy is known as raw rice or white rice. Milling of paddy without any pretreatment is highly susceptible to breakage and loss of minerals and vitamins. To reduce breakage and loss of minerals and vitamins, pretreatment known as parboiling was developed. There is much in the literature available regarding the physicochemical properties, milling, cooking and eating quality of parboiled rice. To better understand the quality it is worth knowing how the physical properties affect the quality of the rice with the change of processing conditions.

This study was undertaken to provide useful information to the processors as well as to the consumers of parboiled rice regarding the change of quality for different processing conditions through the change of physical properties and to search for correlation of some quality indicators with others. The objectives of this paper are study the effect of parboiling on the physical properties of rice such as maximum viscosity and hardness of brown rice; to determine the physical properties of cooked parboiled rice using a method of evaluating those of cooked rice and the effect of parboiling on these properties such as hardness and adhesion of cooked rice, volume expansion ratio and solid content; to discuss how physical properties affect the qualities of parboiled rice; and to discuss the relationship between the physical properties of parboiled rice and parboiled cooked rice [7,11].

Parboiling of rice is one of the most widespread food processes in the world. This is hydrothermal process which consists of soaking rough rice in water until it is saturated, draining the excess water, steaming or otherwise heating the grain to partially gelatinize the starch and drying [1].

Paddy rice is only fit for consumption when its outer seed has been removed through the process of hulling. Parboiling may take place before or after this process. However, parboiling is necessary so as to obtain rice which is of good quality in terms of its physical, chemical and sensory properties. Therefore, parboiling is an activity of paramount importance and can be defined as a method for processing paddy which helps to mitigate the effects of poor drying (cracking) and improve yield quantitatively and qualitatively as the breakage rate is reduced. It gives the product better consumer appeal, thereby adding value to paddy rice and to the finished product. The process consists in increasing the water content of paddy grains, warming and drying them in preparation for hulling and polishing [1].

Partial boiling or parboiling of rice is believed to be an ancient process applied to rice. This process was probably invented to facilitate the easy removal of husk. The other beneficial changes were of less significance. This process has survived over the years due to its many advantages and improvement of mechanical milling equipment. Parboiling has spread to many countries as a result of the above. Gariboldi has reported that approximately one-fifth of the world rice crop is parboiled. Parboiled rice (also called converted rice) is rice that has been partially boiled in the husk. The three basic steps of parboiling are soaking, steaming and drying. These steps also make rice easier to process by hand, boost its nutritional profile and change its texture. About 50% of the world's paddy production is parboiled. The treatment is practiced in many parts of the world such as India, Bangladesh, Pakistan, Myanmar, Malaysia, Nepal, Sri Lanka, Guinea, South Africa, Italy, Spain,Nigeria, Thailand, Switzerland, USA and France [7].

Rice parboiling is a hydrothermic process applied as a treatment prior to the normal milling stage. The result is an increase of moisture content of the rice to approximately 35% on a wet basis (w.b.). Drying of parboiled rice to moisture levels suitable for milling and storage is an integral part of the overall process. The drying stage,though assuming different forms based on the practices in aparticular country, is a very important step in the process of parboiling. If the drying stage is not accomplished properly, the economic advantage of reduced breakage of rice due to parboiling will not be realized. Several studies have indicated that to obtain good yields, drying of parboiled rice must be temporarily stopped at a moisture level of approximately 14-16% (w.b.). At this point it is believed,the moisture distribution becomes more uniform.This is referred to as 'tempering. Tempering requirements have been reported in the literature for both sun drying and mechanical drying [5].

Parboiling is a process developed for improving rice quality. It consists of soaking, steaming and drying of the rough rice. The major reasons for parboiling rice include higher milling yields, higher nutritional value and resistance to spoilage by insects and mold. The parboiling process is applied to rice with a preliminary objective of hardening the kernel to maximize head rice yield in milling. Besides milling yield, it was also the realization of the nutritional and health benefits of parboiled brown rice compared to raw brown rice that created the awareness and importance of parboiling among consumers and manufacturers. Traditionally, parboiling consists of steeping rough rice in water at room temperature followed by steaming or boiling at 100ºC and sun-drying. Recently, more sophisticated procedures such as dry-heat parboiling and pressure parboiling have been applied [2].

Drying of parboiled rice in the U.S. is accomplished in mechanical dryers. Air heated to temperatures as high as 232.2°C is utilized in the dryers. In general, the parboiled rice is rapidly dried in the first stage at a high temperature and then subsequently subjected to a combination of slow drying (at lower temperatures) and tempering stages. Details of the drying parameters are not readily available as some of these are of a proprietary nature. It is believed that the combinations of treatments of drying and tempering vary within the industry. Previous studies in this area have shown that if drying was continued beyond a moisture level of 16% (w.b.) without any tempering/ very low yields of whole kernels would result. This indicates that changes in some properties of the grains occur after the initial drying stage. Breakage of non-parboiled rice during processing is caused by several factors. These are related to the physical properties of the rice grain and to the conditions under which the grain is milled. When rice is properly parboiled many previous short-comings such as cracks in the grains are eliminated**.** Thus the most appropriate drying and tempering treatments would be the key to obtaining good whole kernel yields in parboiled rice [7].

Rice in Ethiopia has big potential to contribute to food security and even to generate foreign currency from its export. It has been formally promoted through introduction of different improved varieties since 2002 by the Ministry of Agriculture (MoA), the Ethiopian Institute of Agricultural Research (EIAR), the Japan International Cooperation Agency (JICA) and Sasakawa Africa Association (SAA)/Sasakawa Global 2000 (SG2000). According to Halos Kim (2007), the farmers' practice on rice harvest, post-harvest handling, and storage in Ethiopia is mostly traditional methods, which are of poor performance and cumbersome. Improved rice post-harvest technologies are unknown by many farmers and extension officers, except in

Fogera and Gurafarda, where some commercial rice mills are in use. The current post-harvest system presents problems of high losses, poor product quality, and limited utilization of the crop. This is associated with the serious availability and lack of access to appropriate tools and equipment along with lack of market information about the tools [2].

Inherent grain properties, and the conditions of milling such as the grain temperature, moisture content, the temperature and humidity of the milling environment, the degree of milling, and condition and mechanical setting of the machinery, influence the grain breakage. All of the above factors control the amount of grain breakage in the industry. With the exception of the inherent grain properties, all of the above mentioned factors could be controlled quite adequately in a laboratory situation. The major thrust in this study is at the drying and post-drying treatments and their effect on the rice quality.

1.2 Statement of Problem

Nowadays in our country Ethiopia, use of rice for several prepared products is increasing from time-time. However, its quality is under question yet due to the difficulty to remove its husk. To remove the husk, it must be dried either directly to sun or any heat source before subjected to milling. But, rapid drying of the parboiled rice with hot air or sun result high breakage and fissuring. Currently to overcome this problem, parboiled rice is dried in the shade has excellent milling quality; but this is time consuming. In the present study, parameters affecting quality of Parboiled Rice are investigated to improve quality of parboiled rice and reduce drying time.

1.3 Objective

1.3.1 General Objective

The main objective of this study is experimental investigation of parameters affecting quality of parboiled rice.

1.3.2 Specific Objectives

- To collect and prepare sample of paddy rice
- To investigate effects of temperature, moisture content and time on quality of parboiled rice
- To evaluate preliminary economic feasibility of the parboiled rice

1.4 Significance of the Study

This study has great significance in terms of assuring the parameters affecting the quality of parboiled rice by overcoming the problem of cracking and fissuring of rice during milling; reducing the time required for drying, reducing spoilage, increasing elasticity of rice, adding nutritional value and increase the economy of farmers. This study also highly contribute the easy removal of the hull.

1.5 Scope and Limitation of the Thesis Project

1.5.1 Scope

The scope of this thesis covers the importance of parboiling of rice is carrying out the testing, analyzing and characterizing the results obtained. This process is, parboiled rice, using suitable parameters which are moisture content, time and temperature. This project is limited to upgrading of existing rice drying system in Ethiopia. The project also improves both quality and value of rice by using high temperature before subjected to miller and investigating parameter affecting the quality of rice.

1.5.2 Limitation of the Project

This examines the parboiling process may result germination unless each step conducted at right time which means the drying step under this study is going to be viewed in terms of only proper time drying to prevent germination of the rice. These is not intended to enter into technical description and technical assessment of germination process and this project does not consider the effects of rice variety throughout the study. It only looks at basic steps of parboiling have been conducted properly and production system including upgrading of rice quality and quantity by differentiating parameters that affect parboiled rice.

Due to the unavailability of a real case study, data are extracted from different sources and in the case of lack of data; assumptions had to be made accordingly.

CHAPTER TWO

LITERATURE REVIEW

2.1 Parboiling Technologies

Parboiling is the central activity in rice processing and an important operation that determines rice quality. Parboiling is the hydrothermal treatment of raw paddy before milling and consists of three major activities namely, soaking, steaming and drying. Other pre parboiling operations practiced to improve the quality of the raw paddy included sieving of paddy before washing and soaking. Soaking involves allowing the rice kernel to absorb water so as to increase its moisture content. There were basically two methods of soaking, namely, warm water soaking in which the paddy was heated in warm water and allowed to soak overnight. Hot water soaking in which paddy was heated with hot water and allowed to soak for about 4 hours. Steaming, which was a process of heat-treating wet paddy with steam followed soaking. Steaming equipment was usually with or without false bottom. Drying was done in order to bring down the moisture content after steaming. The paddy was either dried on drying slabs, tarpaulin and polythene mats or stone floor. Whichever methods adopted for soaking, steaming and drying, the essence was to improve the quality of rice by reconditioning its structure and making it harder so as to make it resistant to breakages during milling. The cooking characteristic was also improved in terms of lower starch content and longer storage after cooking. The general inputs required for any parboiling operations included the raw paddy, parboiler, firewood or charcoal, buckets, washing tanks or basins, water, drying slabs or mats and labour. Drying is broadly classified into three types based on the temperature requirement such as low temperature and high temperature [15].

The process of parboiling is carried out in three steps:

- **Soaking**
- **Steaming**
- **Drying**

2.1.1 Soaking of Rice

Soaking of rice is carried out by dipping in water. Dipping in water at ambient temperature takes long time for soaking, making rice susceptible to development of micotoxins. Hence, soaking at elevated temperature of water is considered better. The soaking duration varies with water temperature. The purpose of this stage is to absorb water up to 40% and facilitate steaming and heat transferring during next steps. For this purpose, three degrees of 45 ºC for 5 h, 65 ºC for 4 h which is bellow gelatinization temperature and 80^{o} C for 1.5 h which is above gelatinization temperature, are used. Hundred kg weighing double-walled stainless-steel cooking boiler equipped with water circulation was used for soaking. The saturated moisture content ranges from 58-90% at the four different soaking levels. The longer the soaking time, the more moisture in the grain. However, the rate of increase in moisture content was sharp at the initial soaking periods (between 0-20 h) after which the rate decrease drastically and almost static from 24 h and beyond [7,13].

2.1.2 Steaming of Rice

Steaming is carried out to gelatinize starch. The purpose of steaming stage is to complete parboiling operations and gelatinizing rice starch, which is done by two methods of steaming under atmospheric pressure and vertical autoclave is used for this purpose. In this method, after air exit, set the steam pressure on one atmosphere by using periods of 5, 10 an15 min. Generally, saturated steam will be used for steaming of soaked rice. Long steaming time and high steaming temperature provides the dark brown parboiled rice while short steaming time and low steaming temperature provides the light brown parboiled rice. The color change of parboiled rice can be explained by the Maillard reaction. It is a non-enzymatic browning reaction between amino acids and reducing sugars [8].

2.1.3 Drying of Parboiled Rice

Drying of parboiled rice according to Gariboldi the main objectives of drying parboiled rice are:

- To reduce the moisture content to an optimum level for milling and storage.
- To obtain the maximum mill yields in terms of whole grains.

In general, drying parboiled rice is different from the drying of 'raw' untreated rice. These differences are brought upon by the fact that the initial moisture content of parboiled rice is considerably higher than that of raw rice, and the texture of the rice is different due to the compact nature and gelatinized form of the starch [7,15].

Most of the research work conducted in the area of parboiled rice drying has been with the objective of optimizing the process conditions and maximizing the head rice yield of the parboiled rice. Bhattacharya and Subba Rao studied the processing conditions and milling yield of parboiled rice and made the observation that under adverse conditions of drying, good milling results could be obtained only if the prior heat treatment (steaming stage) had been severe [4].

Rama Rao and Bonde evaluated the drying characteristics of parboiled rice in a model Louisiana State University type dryer and reported that drying at 90°C air temperature in the first stage and 70°C in the second, with a six-hour tempering period between stages gave the best milling results. Bakker-Arkema et al. investigated the commercial drying of parboiled rice by replacing two rotary dryers with one three stage concurrent flow dryer. These authors have reported that this replacement resulted in a 34% saving of energy and a significant improvement in the quality of the final product. Evaluating the use of hot air for both parboiling and drying of rough rice, Vasan, Basheer and Venkatesan used air in the temperature range 200-220°C first for heating of soaked rice, and they dried the rough rice with air in the temperature range 100-130°C [7,9].

The heating of rough rice was accomplished in two passes, while the drying required only one pass at the lower temperature. This process was found to adequately parboil and dry the rough rice to storage levels, and the quality in terms of gelatinization and mill yields was comparable to conventionally parboiled rice [2,5].

In a study of the drying of high moisture parboiled rice, Bakshi and Singh reported that drying rates of parboiled rough rice, parboiled brown rice and raw brown rice were about the same. These authors found no constant rate drying even at a high moisture (60% dry basis, d.b.) and have reported that the energy required to evaporate 1 kg of water in parboiled rice was less than that for raw rice. Chandra and Singh conducted thin-layer drying experiments for long-grain parboiled rice at air temperatures in the range 37.8-158.3°C and relative humidity from 0.3 to 80%. They found that an exponential expression gave the best fit to the drying data at all conditions. Byler, Anderson, and Brook compared seven thin-layer models for parboiled rice drying using non-linear regression techniques. These authors reported that a four-term decaying exponential model was appropriate. It was also reported that Page’s equation and the geometry of infinite cylinder and sphere were unacceptable for this purpose [15].

In the food chain handling, drying is considered as one of the critical operations. The principle objective of drying is to supply the required thermal energy in an optimum manner yielding high-quality products. Drying of parboiled rice was done for proper milling and storage. Many studies have reported that production of parboiled rice that has a light or dark brown color can be done successfully during steaming step. For this purpose, dryers were used with ambient temperature, during which, paddies were wide spread in a shelter and after three days paddies are dried out and final humidity reached near 7%. [5,6,9].

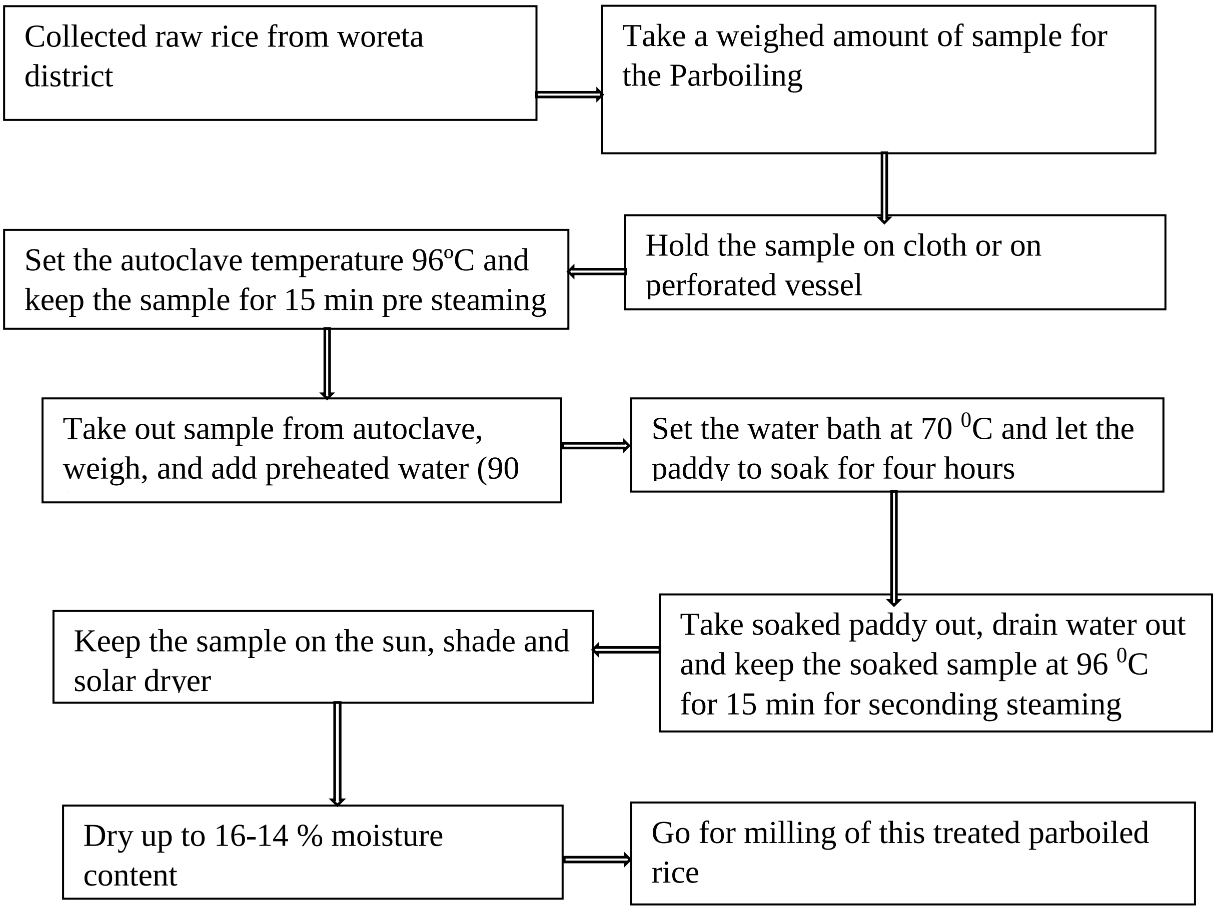

Figure 2. 1Process diagram of parboiling rice

2.2 Water Uptake Rate

In general, the absorption of water by a given rice is a function of time, temperature, and initial moisture content. In practice, variety, degree of milling, and storage conditions should be considered in evaluating the hydration rate of rice. Degree of milled rice also affect the hydration rate. This period corresponded to intervals of maximum water uptake, after which the water uptake slowed down as did the change in mass diffusivity. These results suggest that the diffusion coefficient of brown rice is constant regardless of the variety. The hydration rate of brown rice at 70 °C that the water absorption rate of brown rice had a positive correlation with numbers and thickness of aleurone layers of the kernel, implying that the differences in water absorption among brown rice are due to the differences in bran structure of the kernel [15].

Yoon (2002) demonstrated that moisture gain of brown and milled rice soaked in water for 20 min at 30 °C showed a linear relationship with degree of milling and the slope was essentially the same among three rice cultivars. An increase of degree of milling by 1% resulted in an increase of moisture gain by 1.06 times. Moisture gain was highly significantly related inversely to protein and fat contents. The water uptake rate constants of brown and milled rice linearly decrease as storage time increases when rice in laminated film pouch is stored at 4–30 °C for up to five months. The change in water uptake rate is more pronounced in milled rice and at elevated temperatures. The MC remains constant for both brown and milled rice, but the time to reach MC increases as storage time is prolonged and temperature is elevated. It was reported that MC of milled rice was very highly significantly related inversely to amylose content and directly to kernel chalkiness index [10,15].

2.3 The Need for Tempering

Tempering stage in drying allows the moisture within the kernels to be redistributed to reduce the gradient brought on by the previous drying stage. Whenever rice with a high initial moisture content such as early harvested rice or soaked rice for parboiling, is dried to levels of moisture acceptable for storage or processing, two key factors dictate the need for tempering. These are the rate of moisture removal and grain quality. The rate of moisture removal can be greater if the grains are tempered between drying stages, and the grain quality (in terms of head yield) was always found to be better when the rice was tempered. Several investigators have reported the beneficial effects of tempering. In a study of commercial sun drying of parboiled rice, Bhattacharya and Zakiuddin Ali have reported the results of earlier workers such as Sluyters in Nigeria and Crauford in West Africa who observed that damage (low head yields) occurred during rapid drying only below 16% moisture content (w.b.) and only after the drying had been terminated. Based on these results and their own observations, Bhattacharya and Zakiuddin Ali have reported that for safe drying of parboiled rough rice, the process must be conducted in two stages with tempering at a moisture level of approximately 16% (w.b.), followed by maintain the rice hot for two to three hours [2,5].

In this regard Bhattacharya and Subba Rao, and Bhattacharya, have cautioned that although kernel defects such as cracks, chalkiness, etc., are all healed during the parboiling process, proper drying procedures must be adopted to obtain good milling quality. These investigators have also reported that properly dried parboiled rice is very resistant to mechanical breakage, and that milling quality of parboiled rice is solely determined by the drying treatments and are independent of the previous history of the grains. Stipe et al., who conducted several studies on steaming and drying of naturally high moisture rough rice, have noted that drying down to 13% (w.b.) could be achieved in a single pass if the grains were tempered immediately for one hour at 70°C in a sealed vessel (the drying air temperature was 80°C). This procedure gave satisfactory results in the milling stage [2].

In a simulation study of rough rice tempering, Steffe and Singh have concluded that liquid diffusion theory could be used to simulate the drying and tempering of rough rice. In this study the product was considered as a composite material consisting of a spherical core (the starchy endosperm) surrounded by two concentric shells (the bran and hull layers). Steffe and Singh also measured the changes in relative humidity of the void space in a mass of rough rice that was being tempered and made the conclusion that these changes in relative humidity may be compared to theoretically predicted changes in surface liquid concentration of a rough rice kernel [12].

Gustafson, Mahmoud and Hall, conducted a study to assess the reduction in breakage susceptibility and the removal of moisture during cooling of short-term tempering of corn. They reported that short-term tempering effectively reduced the breakage susceptibility of the grain after cooling, and that tempering allowed more water to be removed during cooling, which in turn improved the efficiency of the drying process [1,4].

Based on these studies, several important aspects of the drying and post-drying treatments could be observed. First, if good mill yields are to be obtained, then drying must be conducted in stages with tempering between the drying stages. Second, if multi-stage drying is to be used, then the first stage must be terminated at approximately 16% moisture content (w.b.). Third, if drying in a single stage is attempted (usually at a high drying air temperature), then the grains must be tempered afterwards at approximately the same temperature as that of the drying air, and without any exchange of moisture from the grains. In this regard, Wasserman et al., have reported higher head yields when tempering was conducted at 40.6°C in comparison to the yields resulting from tempering at 23.9°C (the drying air temperature was 43.3°C).

2.4 Rice Fissuring and Breakage

Fissuring or cracking of rice grains has been the subject of many studies. In the literature, several different terms have been used to indicate that a grain kernel is cracked or partly broken. Sharma and Kunze clarify the term 'fissure' as the large internal fracture usually found to be perpendicular to the long axis of the grain [7].

It has long been known that when rice is subjected to an environment of temperature such as that encountered in drying, both thermal and moisture gradients are set up within the kernels. Several workers have concluded that moisture gradient is the major cause of grain fissures. Moisture gradients resulting from adsorption of moisture also have the potential to cause fissures in rice kernels. In this regard, Sharma and Kunze have stated that conditions such as the temperature and relative humidity of the environment only determine the magnitude of the moisture gradient produced in the grain. These authors have observed that fissures caused by moisture adsorption normally develop during the adsorption process, while fissures caused by rapid moisture desorption develop after the drying process ceases. In a study of single-layer drying of brown rice, Mannapperuma has reported that thermal stresses reached a maximum of 276 KPa (40 psi) when subjected to a temperature difference of 6 5.5°C, while moisture stresses reached a maximum of 13938 KPa (2020 psi) under a moisture difference of 20% (d.b.). On comparison with the tensile strength of rice grains, the thermal stresses were found to be harmless, while moisture stresses were destructive. This work agrees with the findings of Kunze and Hall who subjected rice kernels to a large temperature change (up to 34.4°C) while controlling the humidity such that no moisture changes occurred. This treatment did not cause any fissuring of the grains. Matthews et al., subjected long grain rough rice to a combination of time and temperature treatments in hermetically sealed containers to minimize moisture transfer at temperatures up to 120°C from 2 to 19 hours. The results indicated that heat by itself was not detrimental in causing breakage of the kernels. Ban, in a series of rice drying studies, has reported that fissuring does not necessarily occur immediately after quick drying, but increases as time lapses and that cracking was more frequent among kernels of larger size. Ban's observation that fissuring does not occur immediately after drying has been supported by the work of Sharma and Kunze [10].

Parboiled paddy dried in the shade had excellent milling quality, but rapid drying with hot air (40-80 ^{o}C) in the sun give high breakage. The damage started as the moisture content reached 15% and increased sharply with further drying. Milling at different time interval after drying demonstrated further that damage to the paddy occurred gradually only sub sequent to its removal from dryer. From this it was found that keeping the paddy hot after drying or conditioning for about 2 hr. prevented the milling breakage. Drying in two stages with tempering (2 hr. if hot, 8 hr. it at room temperature) just before attainment of the critical moisture content (at 15.5-16.5%) also preserved milling quality. Tempering at higher moisture contents was less beneficial and multiple tempering given no additional benefit. Drying in two passes with a tempering in the moisture range of 15 to 19%, followed by hot conditioning after the final drying was convenient in practice and satisfactory; a dried temperature up to 80 ^{o}C could be used. After parboiled paddy was dried in this way milling breakage would exceed 1-2% [6].

2.5 Grain Properties as Related to Temperature and Moisture Changes

Within the scope of this study, the treatments given to the rice samples include parboiling, drying, tempering or post-drying treatments, and finally processing. The changes brought about by these steps were measured in terms of certain specific characteristics such as head yield, color, texture (of the cooked product), strength in bending, and protein content. These attributes constitute some of the quality criteria for the rice grain under the broader heading of 'grain quality'. Thus, a review of the past work in this area, with special reference to how these attributes change under different types of treatments, would be appropriate [1,9].

On completion of the parboiling, drying and tempering treatments the samples were sealed in plastic canisters (after a 10-day stabilization period in the laboratory). Approximately three weeks later these samples were shelled, milled and hand graded for broken kernels. The equipment selection and settings utilized for the milling procedure were consistent with standard laboratory practice outlined in the Inspection Handbook for Rice (IHR). Color analysis of each of the samples was performed on a Digital Tristimulus Colorimeter. The samples that were analyzed in the Colorimeter consisted of whole kernels only. Six sound kernels from each replicate were tested in an Instron Universal Testing machine to determine the ultimate tensile stress. For this test, each kernel was freely supported between two horizontal cylindrical supports 1.6 mm in diameter and 3.5 mm between centers. This arrangement was placed over the base unit of the Instron containing the load cell. The loading force was applied through another horizontal cylinder (attached to the moving cross-head) of the same diameter as the bottom supports and centered between them. The drop-in head rice during drying is due to the stress induced moisture gradients inside the kernel in which the tensile stress is larger than the failure tensile strength. To reduce the stresses, tempering is recommended. The tempering step is generally practiced in rice mills [10,13].

During tempering, the moisture gradient developed inside the kernels during drying is reduced. Parboiled rice is produced by a hydrothermal process. Rice parboiling can increase milling yield because rice starch is gelatinized. In addition, parboiling improves the nutritional value. For the determination of dried parboiled rice quality, a sample was dried to the moisture contents of 27± 1 and 22 ± 1% d.b., and then tempered in a closed jar for 30–120 min to reduce stresses. In the last drying stage, the tempered sample was ventilated by hot air at temperature of 45 °C and a superficial air velocity of 1 m/s until the moisture content of the sample reached 16± 1 % d.b. After that, the sample was kept in cold storage at 4–6 °C for 2 weeks before determining quality. Each drying condition was performed in duplication. Moisture content of the samples was evaluated by drying 30–40 g of parboiled paddy at 103 °C in an electrical air oven for 72 h. All experiments were performed in triplicate and the average value was reported. Gustafson, Mahmoud and Hall, conducted a study to assess the reduction in breakage susceptibility and the removal of moisture during cooling of short-term tempering of corn. They reported that short-term tempering effectively reduced the breakage susceptibility of the grain after cooling, and that tempering allowed more water to be removed during cooling, which in turn improved the efficiency of the drying process [1].

2.6 Physical Characteristics of Parboiled Rice

All the latent or active biological processes (germination, proliferation of fungal spores, development of insects at varying phases) are terminated; the milling yield is better and quality is improved as there are less broken grains; parboiled rice, even without milling, can be better stored and for a longer period as germination cannot take place and the compact texture of the endosperm allows it to better resist insect attacks and not to absorb moisture from the surrounding environment and parboiled rice can be conserved longer and is less subject to rancidity. The process of drying makes it possible to reduce the water content of the rice to an optimal level for milling; the milling yield is better and the quality is improved as there are less broken grains [6].

This study was undertaken to generate useful information regarding the change of quality of parboiled rice for different processing conditions through the change of physical properties and to search for correlation among the quality indicators. Physical properties, namely, maximum viscosity, hardness of brown rice, hardness and adhesion of cooked rice, volume expansion ratio and solid content were investigated. A first order kinetic model predicted well the effect of processing conditions on the maximum viscosity and hardness of brown rice, indicating the quality index and rate of change of quality with their respective final and reaction rate constant values. The effect of steaming period was found to be greater on the quality indicators of cooked rice, such as adhesion, volume expansion ratio and solid content. Good linear correlation of gelatinization property with the cooking quality and rheological property of parboiled rice was achieved. The positive correlation between adhesion and solid content is assumed to be responsible for producing a less sticky product [1,11].

2.6.1 Effect of Parboiling on the Maximum Viscosity

Parboiling is the process of starch gelatinisation, which depends on the severity of the parboiling process. As a result, the gelatinisation properties of parboiled rice are changed. It can be seen that the gelatinisation property of parboiled rice of maximum viscosity decreased due to increase in steaming temperature and period. This decreasing pattern agrees well with other researchers in case of rapid viscous analyser (RVA) parameter as well as, amylograph viscosity. In this study the maximum viscosity value range was from 40 to 305 RVA units for different steaming temperatures and periods and was 412 RVA units for the raw sample. The temperature-time combination selected in this study was within the range used in different types of parboiling plants. Therefore, the maximum viscosity to the palatability of parboiled rice is assumed to be within the above range. The change in quality of parboiled rice with respect to maximum viscosity due to parboiling treatment can be understood from the least squares analysis using the first order kinetic model. It was found that the final value of maximum viscosity was lowest for the higher steaming temperature of 120˚C (33.92 RVA units) compared with 105 (43.39 RVA units) and 110˚C (78.24 RVA units) temperature, and that of reaction rate constant value was highest at the higher steaming temperature, in the order of 0.0452, 0.0880 and 0.1618. The final maximum viscosity and reaction rate constant value indicates the quality index and the rate of change of quality for the respective steaming temperature.Correlation among the physical properties of parboiled rice The maximum viscosity of rice flour depends on the swelling ability of the starch granules[9].

It was also reported that the lower maximum viscosity value due to parboiling is a reflection of the decreased swelling ability of gelatinised starch . In this study volume expansion ratio of cooked parboiled rice was evaluated, which might be considered as the index of softness of cooked rice. As mentioned earlier, the palatability of cooked parboiled rice is assumed to be within a certain range of maximum viscosity, therefore within that range the volume expansion ratio of cooked parboiled rice can be predicted utilising the correlation between volume expansion ratio and maximum viscosity [11].

2.6.2 Hardness of Parboiled Rice

Among the physical properties of parboiled rice hardness is the most important one because it reduces breakage during milling. The hardness depends on the severity of the parboiling treatment. Hardness of the rice kernels in this study was tested using an Instron Universal Testing Machine described earlier. The test was performed by attaching parallel aluminum plates to the moving crosshead and the load cell platform at the base. Six kernels of shelled rice were tested in direct compression in this test. As in the case of the bending tests, only sound kernels free of visible flaws were tested. Each kernel was oriented on its flattest surface on the bottom plate, and the cross head was moved down at a constant speed of 0.127 cm/min., on the kernel until failure occurred. The chart recorder, which was synchronized with the moving crosshead was driven at 12.7 cm/min. The hardness value of each sample was determined by averaging the yield point loads for each kernel.Many researchers reported that it is greatly affected by parboiling conditions, moisture content after drying, balance of starch gelatinisation and retrogradation and other factors. It can be seen that the hardness was increased with increasing of both the steaming temperature and period. The quality of parboiled rice depends on the hardness of rice, because head rice yield, the important indicator of the milling quality of parboiled rice, which also influences the market value and consumer acceptability, is greatly affected by this factor. The quality change of parboiled rice with respect to the hardness of brown rice due to parboiling can be understood from the least squares analysis using the first order kinetic model. It was found that final hardness value for the steaming temperature of 105 and 110˚C (0.2 and 0.4 kg/cm2 gage pressure) was almost the same (94.72 and 94.26 N); this might be due to a lower temperatures difference, but higher final hardness value (106.21 N) was obtained for the higher temperature (120˚C). More than 25 grains of rough rice were selected randomly from each sample. Hardness of 25 uncracked brown rice grains (husk removed by hand peeling), was measured using a Texture Analyser (TA). The average bio-yield point value of 25 determinations was expressed as the hardness in newtons (N). A rice grain was put on the sample table attached to the load cell and its bio-yield value measured in a flat position. A 25 kg load cell, probe of 2 mm diameter and 0.1 mm/s test speed were used [1,10,14].

2.6.3 Colour of Parboiled Rice

As we all know colour is the first sells man in the market. So, parboiling develops colour for the rice. Parboiled rice usually has attractive appearance that have a potential to control the costumer's perception. The apparatus required a warm up period of 30 minutes prior to calibration. After calibrating, the rice sample was placed in the cleaned glass sample cup (Plate 8) and the cup placed in the instrument sample port. The plunger provided with the instrument was then placed over the sample (to reduce the effect of stray light in the room) and the reading of the computed total color difference obtained and recorded. The total color difference was calculated by the micro-computer in the display unit, and is the square root of the sum of squares of the differences between the standard reflectance values and mean observed values on the laboratory scale. The total color difference values were obtained for three orientations of the sample cup in the instrument sample port. Care was exercised to measure the same volume of grains from each sample into the glass sample cup [1].

2.7 Principles and Benefits of Parboiling

The two major elements in the parboiling process are water and heat. The benefits of parboiling rice are three folds, as summed up below. It reduces the breakage rate during the hulling process, makes for improved yield and reduces losses of nutritive elements during the process of hulling and cooking the rice. Through the parboiling process, the rice undergoes chemical, physical and sensory changes as follows:

2.7.1 Chemical Changes

The water-soluble substances (vitamins and minerals) are dissolved and allowed to permeate the rice.

The lipoid materials in the endosperm are dissolved; the gelatinized starch appears like a compact and homogeneous mass; lipoid matter is separated and goes deeper into the compact mass of gelatinized starch and fat-soluble substances in the germ and the outer part of the endosperm are dissolved and disseminated in the grain [14].

2.7.2 Sensory Changes

The most significant advantage of parboiled rice has better digestibility ratio by reason of its texture and firm consistency; and after cooking, the grains are firmer and tend to be less sticky [1,15].

2.8 Rice Milling

The objective of a rice milling system is to remove the husk and the bran layers from paddy rice to produce whole white rice kernels that are sufficiently milled, free of impurities and contain a minimum number of broken kernels. The milling yield and quality of rice is dependent on the quality of the paddy, the milling equipment used and the skill of the mill operator. Rice milling can be undertaken as:

- One step milling process
- Two-step milling process and,
- Multistage milling process

2.8.1 One Step Milling Process

The single pass rice mill is an adaptation of the "Engleberg" coffee huller. This type of mill is still very popular in many of the poorer rice-growing countries and is widely used for custom milling of household rice. It is also still popular for milling parboiled rice in Bangladesh and many African countries. This mill is a steel friction type mill and uses very high pressure to remove the hull and polish the grain. This results in many broken kernels, a low white rice recovery of 50-55% and head rice yields of less than 30% of the total milled rice. The fine brokens are often mixed in with the bran and the ground rice hull and this is used for animal feed. The poor performance of the Engleberg mill has led some governments to discourage its use and in many Asian countries, the Engleberg mills can no longer be licensed to operate as service or commercial mills [14].

2.8.2 Two-Step Milling Process

Two stage mills are often called compact rice mills and, in many countries, have superseded the Engleberg mill. The two-stage mill has separate hulling and polishing processes. Rubber rollers remove the husk and the brown rice is then polished with a steel friction whitener similar to the Engleberg. These mills have a capacity of between 0.5 to 1 tons per hour paddy input and are often used for custom milling in the rural areas. The milling performance of the compact rice mill is superior to the single pass Engleberg huller with milling recoveries normally above 60%.

2.8.3 Multistage Milling Process

The milling process in larger commercial mills combine numbers of operations that produce higher quality and higher yields of white rice from paddy or rough rice. The process involves:

- Pre-cleaning the paddy prior to milling
- Removing the husk or outer layer from the paddy
- Polishing or whiting the brown rice to remove the bran layer
- Separating the broken grains from the whole kernels
- Bagging the milled rice
- Managing the by-products.

2.9 Pre-Cleaning of Paddy Rice

When paddy comes into the mill it contains foreign material such as straw, weed seeds, soil and other inert material. If this is not removed prior to hulling the efficiency of the huller and the milling recovery are reduced.

Most pre-cleaners separate three groups of materials:

- The first separation is done by scalping or removing the objects that are larger than the grain. Either a flat oscillating screen or a rotary drum screen that allows the grain to pass through but retains straw can do this.
- The second separation retains the grains but allows broken grains, small stones and weed seeds to pass through. An air aspirator may also be incorporated to remove the dust and the light empty grains [3,15].

2.10 Removing the Husk

The husk layer is removed from the paddy by friction and the process is called either de-husking or de-hulling. De-husking was traditionally done using mortar and pestles but, in modern rice mills, it is done by passing the paddy grains between two abrasive surfaces that are moving at different speeds. After separating the husk and paddy, the husk is removed by suction (aspirated) and then transported to a storage dump outside the milling plant. The percentage of paddy that is de-hulled to produce brown rice during this process is called the hulling efficiency. An efficient husker will remove 90% of the husk in a single pass. After the husk has been removed the brown rice goes to a paddy separator. The kernels that were not de-husked in the first pass will be separated and then returned to the de-husker [4].

2.11 Paddy Separation

The output from the huller is a mixture of paddy rice, brown rice, husk, broken paddy and sometimes bran. The huller aspirator removes the lighter material such as husk, bran and very small broken. The remainder passes onto the paddy separator where the un-hulled paddy rice is separated from the brown rice. The amount of paddy present depends on the efficiency of the husker and should not be more 10%. Paddy separators work by making use of the differences in specific gravity, buoyancy and size between paddy and brown rice. Paddy rice has a lower specific gravity, higher buoyancy and is physically bigger, longer and wider than brown rice [12].

2.12 Whitening or Polishing Process

White rice is produced from brown rice by removing the bran layer and the germ. The bran layer is removed from the kernel by applying friction to the grain surface either by rubbing the grains against an abrasive surface or against each other. The amount of bran removed is normally between 8-10% of the total paddy weight but this will vary according to whiteness required [15].

2.13 Separation of White Rice

After polishing, the white rice is separated into head rice, large and small broken rice by a sifter.ad rice is normally classified as kernels, which are 75-80% or more of a whole kernel.

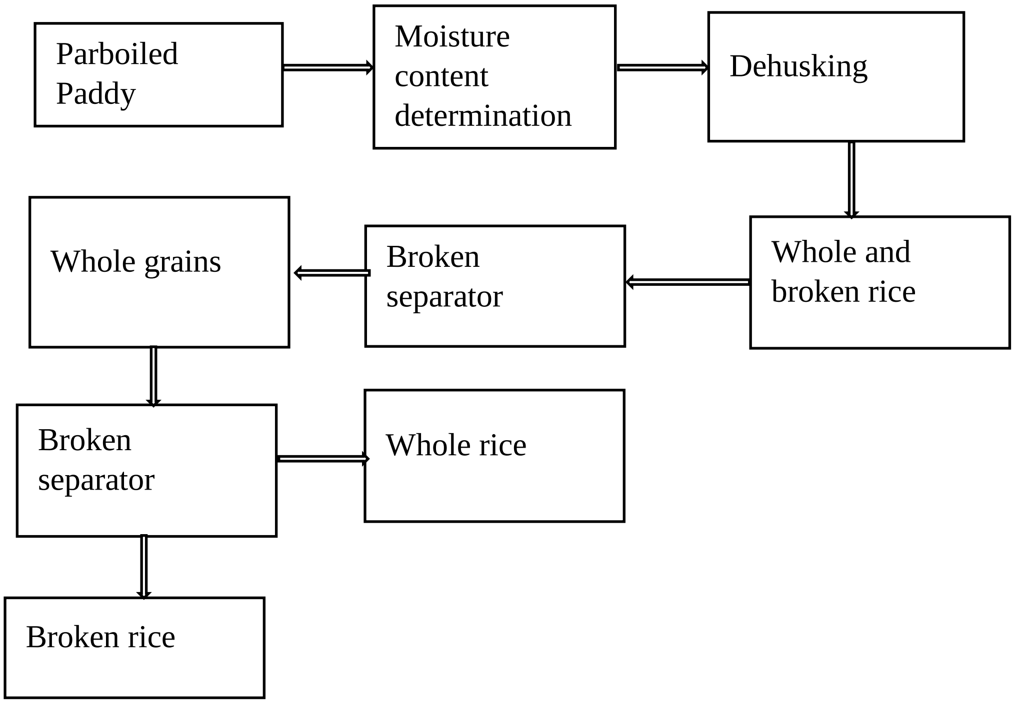

Figure 2. 2Milling operation of paddy rice

2.14 Financial Analysis of Parboiling and Milling Technology

Rice commodity chain analysis, one of its target commodities. The study revealed that improvement in all aspects of processing technologies and marketing was the key to moving the rice industry to higher levels of technical and financial efficiency. The study made a few propositions on the strategies for using the findings of the study to advance rice processing practices to higher level of technical and financial efficiency, quality driven international competitiveness and consumer acceptability. The technical and financial efficiency analysis of parboiling and milling technologies was designed to generate benchmark information for advising processors who engage in parboiling and milling, and/or integrated processing operations. The analysis would, in addition, identify key processing milestones, to advise existing rice processing stakeholders and other potential investors on the most technically efficient, cost effective and profitable combinations of integrated parboiling and milling technologies[12].

CHAPTER THREE

MATERIALS AND METHODS

3.1 Data Gathering Techniques

For this project two types of data collection have been used. These are:

- Data gathering by interviewing
- Data investigation on the field

3.1.1 Data Gathering by Interviewing

In Wereta most rice millers do not use parboiling process. They simply milled the raw rice for the purposes of dehulling. As Mr. Addis said, "Even if the price of parboiled rice has big difference in the market, we still do not practice it because of the time taken to parboil. Individuals have parboiled the rice; but the amount of rice that has been parboiled is not satisfactory in quality and quantity. So, we are being still enforced to mill the rough rice."

As Mrs. Momina said, "In the previous I have no idea regarding to parboiling. But now I only bring the technology and use it though the process is so tedious. After I bought the rice from the farmers, I cleaned and soaked in cold water for about twelve hours. Then after the soaked rice has been steamed by keeping the soaked rice over the boiling water underneath. This takes fifteen to twenty minutes. Then, the steamed rice has been dried in the shade for about six to eight days. Even if the process is so time consuming, the parboiled rice has greater market difference than rough rice."

Generally, breaking during milling is critical problem for all rice millers in Wereta. They try to overcome this problem by bringing advanced miller machine. But this machine is too expensive. So, they cannot afford it. One rice miller brings this advanced rice miller machine but there is still breakage of rice during milling.

3.1.2 Data investigation on the field

As we investigated on the field, there is the big difference between parboiled rice and rough rice in colour, appearance, texture and size. The price is also different in the market that is parboiled rice is more expensive than rough rice.

3.2 Equipment

The equipment used to run all experiments were listed below:

An oven is a thermally insulated chamber used for drying the parboiling rice. Thermometer is an instrument used to measure temperature. Stove is an instrument used to dry the sample of the rice. Miller is an equipment which is used for separating of rice and husk. Sieve is an equipment used to separate oversize and undersize rice kernels after milling. It is also used to steam the rice after soaking step. Desiccator has a cubic structure having three partitions to handle samples which prevent moisture exchange between the samples and the environment. This equipment is used to distribute the moisture within the samples. Aluminum paper is a heat resistance so, it is used to handle the samples inside the oven during drying stage. Pan is used to for the two basic steps in the laboratory those are soaking and steaming, digital balance is used to measure weigh of samples in successive steps.

Digital stove

Electronic mass balance

Desiccator

Drying oven

Figure 3. 1Equipment's

Raw material: raw material used throughout the experiment is paddy rice. The rice with its hull is investigated in different situations.

Figure 3. 2 Raw rice

3.3 Methods

The experimental work was done in the laboratory of Bahir Dar University Institute of Technology, school of Chemical and Food Engineering.

The paddy rice was collected in Woreta district. At the time of sample preparation, approximately 20 kg of this rice was cleaned in to remove all impurities. The cleaned and sized rice sample was stored in a sack under laboratory room conditions(approximately 28°C). Samples (500 gm) were then drawn from this sack for the experiments. Initial moisture determination was performed in an oven at 130°C for 8 hours. At necessary stages of the treatments the samples were weighed on electronic weighing scale.

For the initial moisture content determination five hundred grams of paddy rice was taken initially. Then, by keeping the samples in the oven by aluminium paper and recording the mass of samples by an hour interval. Finally, the mass of the samples become constant after 8 hours.

Table 3. 1 Initial moisture content determination

Time in hour	Sample (paddy rice) in gram
0	500
1	482
2	476
3	468
4	463
5	461
6	457
7	456.5
8	454.6

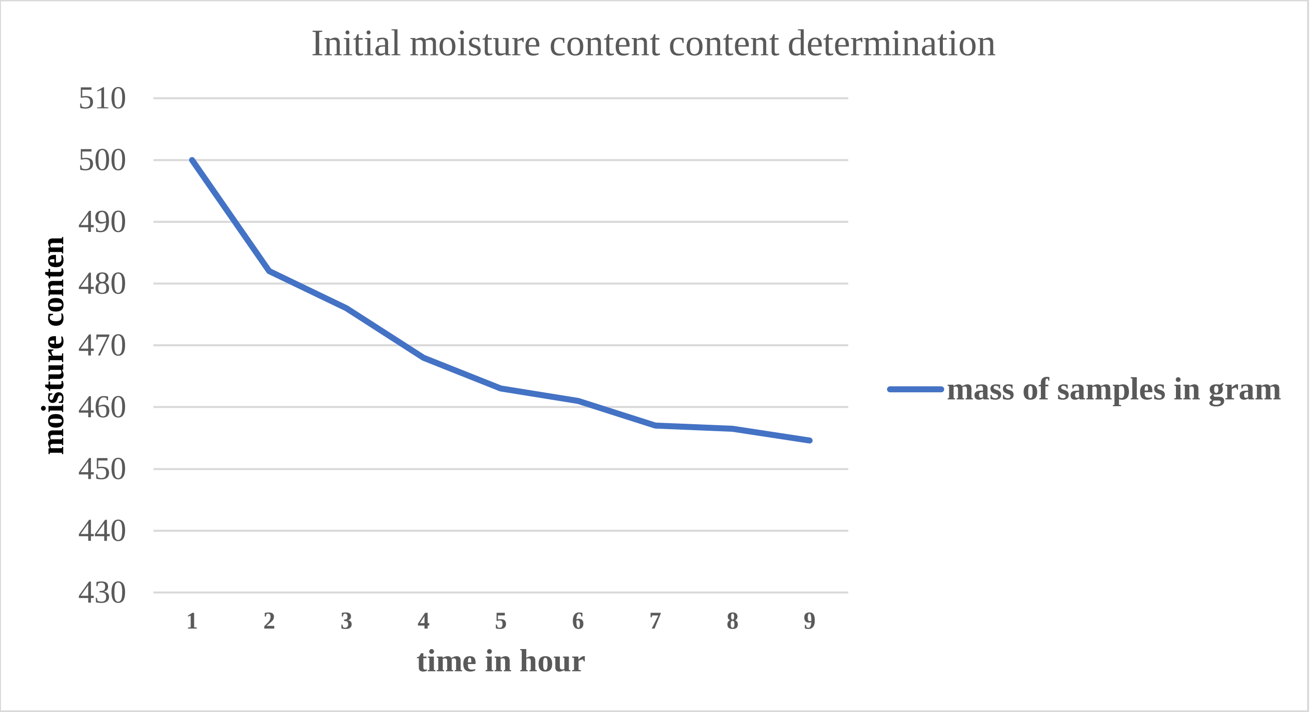

Figure 3. 3 Initial moisture content determination

During the period of soaking (4 hours) the oven provided automatic control of the temperature. At the end of the soaking period, the pans containing the sample were taken out, the water drained, and the rice samples were transferred to sieve for complete removal of water.At the end of 4 hours the samples were ready for the heat treatment (steaming) stage.


Figure 3. 4 Soaking of paddy rice

The equipment used for the heat treatment consisted of the following:

- Pan
- sieve and
- stove

The layout of these components is shown in figure 3.5

The rice was steamed by keeping it in a sieve over a boiling water pan for 15 minutes. After steaming the weigh was measured.


Figure 3. 5 Steaming

At the end of steaming, the samples were subjected to drying apparatus. The parboiled rice samples were dried in a drying apparatus, a schematic of which is shown in figure 3.6. The unit consists essentially of a blower, an air flow measuring section (that utilizes a flat plate orifice),a heating section and a drying section.

Figure 3. 6 Drying of parboiled rice

3.4 Collection and Characterization Rice

3.4.1 Moisture Content Determination of Raw Rice

Samples were weighed in aluminium paper of known weight by using sensitive balance. The sample and aluminium paper were kept in an oven 130°C for 8 hours. The samples covered with aluminium paper and transferred to desiccators, and weighed after reaching room temperature. This was repeated until constant weight was obtained. The loss of weight was calculated as percent of weight and expressed as moisture content.

$$\text{Moisture content } (\%\ MC_{WB}) = \frac{W_W - W_D}{W_W}$$

Where:

W_W = initial weight

W_D = weight after drying

Different methods are used to remove all the water but chemically bound water heating in an oven.

moisture content is given with the relation $\%\ MC_{WB} = \frac{W_W - W_D}{W_W} * 100\%$

where mc is moisture content expressed on wet basis or dry basis, MC_{WB} and MC_{DB} respectively.Moisture content on dry basis can be expressed as:

$$MC_{DB} = \frac{W_W - W_D}{W_D} * 100\%$$

The conversion MC_{WB} ⟷ MC_{WB} given by the following formulae

$$MC_{WB} = \frac{MC_{DB}}{1 + MC_{DB}} \quad \text{and} \quad MC_{DB} = \frac{MC_{WB}}{1 - MC_{WB}}$$

3.3.1 Experimental Design

In this project, there are three factors and three levels are determined. The factors are

- Moisture content of parboiled rice
- Time and
- Drying temperature

Numbers of experiment to be conducted were;

Number of experiment = $(\text{level})^{\text{factor}}$

$= 3^3 = 27$

Parboiled rice was used for all the treatments. The soaking and steaming stages of the experiment is maintained constant for all treatments. A soak water temperature of $70^{O}C$, under atmospheric pressure for a period of 4 hours is selected. An equilibration time of 4 hours was allowed for all treatments prior to the steaming stage. The rice samples were steamed at for 15 minutes.

After the rice is steamed, it was transferred to dryer. The dryer was preconditioned to the specific and drying temperature. Three temperatures of 50 °C, 90 °C and 130°C were used.

The samples were dried to approximately to 20%, 16% and 14% moisture content (wet basis) respectively at each temperature setting. Resident times to reach the above-mentioned moisture levels were first determined and used throughout the study for the drying stage.

Table 3. 2 Design of experiment and arrangement of treatments

Treatment Number	Drying temp (^{O}C)	Time (minute)	Final moisture level (g)
1	50	40	311.9
2	50	50	245.9
3	50	60	230.3
4	50	70	197.9
5	50	80	188.3
6	50	90	183
7	50	100	175.4

8	50	110	170.9
9	50	120	158.4
10	90	40	143.1
11	90	50	100.7
12	90	60	125.4
13	90	70	109.9
14	90	80	65.4
15	90	90	63.4
16	90	100	61.4
17	90	110	59.2
18	90	120	57.1
19	130	40	88.4
20	130	50	89
21	130	60	83.4
22	130	70	71
23	130	80	54.9
24	130	90	52.3
25	130	100	47.4
26	130	110	43.2
27	130	120	26.4

CHAPTER FOUR

RESULT AND DISCUSSION

Parboiling process for paddy was developed to reduce the amount of breakage grains and this process also aided in raising the long life of the final product and helped in long time storage before sold in the market. The obtained result in this study is provided in detail in the following tables and discussed accordingly. Paddy samples considered for this study was evaluated at every step; soaking, steaming and drying.

Table 4. 1 Experimental data

Samples	Intial weight (g)	Soaking time (hr)	Weight after soaking (g)	Steaming time (min)	Weight after steaming (g)	Drying temperature (^oC)	Drying time (min)	Weight after drying (g)
1	500	4	7374.1	15	796.5	50	40	766.5
2	500	4	753.4	15	793.6	50	50	700.6
3	500	4	750.4	15	783.4	50	60	684.9
4	500	4	763	15	788.5	50	70	652.5
5	500	4	773.5	15	788.7	50	80	642.9
6	500	4	769.7	15	780.6	50	90	637.6
7	500	4	771	15	781	50	100	630
8	500	4	769	15	775	50	110	625.5
9	500	4	711.5	15	728.5	50	120	613
10	500	4	715.5	15	760.5	90	40	597.7
11	500	4	727.7	15	764.9	90	50	580
12	500	4	737	15	758	90	60	564.5
13	500	4	729	15	747.5	90	70	555.3
14	500	4	729.4	15	760.2	90	80	520
15	500	4	747.8	15	768	90	90	518
16	500	4	763	15	773	90	100	516.2
17	500	4	766.3	15	774.8	90	110	513.8
18	500	4	757.8	15	767.3	90	120	511.7
19	500	4	746	15	752	130	40	543

20	500	4	761.8	15	770.6	130	50	540.6
21	500	4	769	15	775	130	60	538
22	500	4	711.5	15	728.5	130	70	525.6
23	500	4	693.5	15	726	130	80	509.5
24	500	4	764.1	15	774.5	130	90	507.1
25	500	4	766.7	15	777.8	130	100	502
26	500	4	770.7	15	779.7	130	110	497.8
27	500	4	764.6	15	777.4	130	120	454.6

From table 4.1, it is observed that after soaking and steaming the mass of samples increased because the paddy rice absorbs water. The amount of water to be absorbed depends on temperature and time. Since, the higher the temperature, the higher the water to be absorbed. In the same manner, the longer the time, the higher the samples mass becomes. But, in all experiments soaking and steaming stages conducted under constant temperature and time 70 ^{O}C, 15 minutes respectively.

In contrary; when the temperature of oven increased from 50 to 130 ^{O}C, the mass of samples decreased from 766.5 to 454.6 grams. In addition to this, the drying time has its own impact on final mass of the paddy rice. The longer the time, the lower the moisture content.

Table 4. 2 Moisture content determination

Samples	Intial weight (g)	After soaking weight (g)	After steaming weight (g)	After drying weight (g)	Moisture content gained after soaking (g)	Moisture content gained after steaming (g)
1	500	737	758	580	237	258
2	500	729	747.5	564.5	229	247.5
3	500	715.5	760.5	597.7	215.5	260.5
4	500	727.7	764.9	555.3	227.7	264.9
5	500	729.4	760.2	520	229.4	260.2
6	500	747.8	768	518	247.8	268
7	500	746	752	543	246	252

8	500	769	775	538	269	275
9	500	711.5	728.5	525.6	211.5	228.5
10	500	693.5	726	509.5	193.5	226
11	500	750.4	783.4	684.9	250.4	283.4
12	500	774.1	796.5	766.5	274.1	296.5
13	500	753.4	793.6	700.6	253.4	293.6
14	500	763	788.5	652.5	263	288.5
15	500	773.5	788.7	642.9	273.5	288.7
16	500	769.7	780.6	637.6	269.7	280.6
17	500	771	781	630	271	281
18	500	765	776.5	625.5	265	276.5
19	500	759	768.2	613	259	268.2
20	500	763	773	516.2	263	273
21	500	766.3	774.8	513.8	266.3	274.8
22	500	757.8	767.3	511.7	257.8	267.3
23	500	761.8	770.6	540.6	261.8	270.6
24	500	764.1	774.5	507.1	264.1	274.5
25	500	766.7	777.8	502	266.7	277.8
26	500	770.7	779.7	497.8	270.7	279.7
27	500	764.6	777.4	454.6	264.6	277.4

From table 4.2, the moisture content gained after soaking and moisture content gained after steaming are illustrated. The moisture content gained in soaking stage for all experiments almost the same and the same is true for the moisture content gained in steaming stage.

Table 4. 3 Sample oven drying

Time (min)	After drying weight (g)	% moisture (b.d)
60	580	21.6
70	564.5	19.4
40	597.7	23.9
50	555.3	18.1
80	520	12.6
90	518	12.2

40	543	16.3
60	538	15.5
70	525.6	13.5
80	509.5	10.8
60	684.9	33..6
40	766.5	40.7
50	700.6	35.1
70	652.5	30.3
80	642.9	29.3
90	637.6	28.7
100	630	27.8
110	625.5	27.3
120	613	25.8
100	516.2	11.9
110	513.8	11.5
120	511.7	11.1
50	543.6	16.4
90	507.1	10.3
100	502	9.4
110	497.8	8.6
120	481	5.4

From table 4.3 the moisture content by percent is calculated in wet basis. Each moisture content by percent is obtained by subtracting the final mass of paddy rice after drying from the initial mass of paddy rice. The final mass of paddy rice is constant whereas, the initial mass of paddy rice after drying depends on the temperature and time during drying.

4.2 Milling Analysis

All treated samples were stored in the laboratory for a minimum period of three weeks prior to the milling analysis. The samples were weighed and shelled in plastic bags. The sheller was manually cleaned of any trapped grains before and after the shelling of each sample. The weight of the rice was recorded. The rice was then transferred to a cleaned mill for bran removal. All of the milled rice grains were carefully removed from the machine and spread on a clean piece of cloth to cool under room conditions. The grains were then rubbed gently to remove any particles of bran that were adhered to the rice kernels. The rice was then weighed and graded into broken kernels and whole kernels. These were then computed as percentages of the total milled rice. The head rice portions were then sealed in plastic plastic bags for the subsequent analyses.

Table 4. 4 Milling analysis

Samples	Temperature	Time	Weight after milling(g)	Sieve size	Respective weight after se
1	130	60	486	1.7	480
				1.4	4
				0.595	2
2	130	80	468	1.7	460
				1.4	6
				0.595	2
3	130	40	492	1.7	428
				1.4	8
				0.595	6
4	130	50	490	1.7	473
				1.4	13
				0.595	4
5	130	70	471	1.7	464
				1.4	4.5
				0.595	2.5
6	130	90	456	1.7	428
				1.4	12
				0.595	6
7	130	100	428	1.7	412
				1.4	13

				0.595	3
8	130	110	398	1.7	382
				1.4	12.5
				0.595	3.5
9	130	120	377	1.7	365
				1.4	6
				0.595	6
10	90	70	468	1.7	460
				1.4	5.5
				0.595	2.5
11	90	40	484	1.7	468
				1.4	14
				0.595	4
12	90	50	482	1.7	466
				1.4	10
				0.595	6
13	90	60	469	1.7	453
				1.4	9
				0.595	7
14	90	80	452	1.7	437
				1.4	8
				0.595	7
15	90	90	430	1.7	416
				1.4	6
				0.595	8
16	90	100	428	1.7	415
				1.4	6
				0.595	7
17	90	110	426	1.7	414
				1.4	5
				0.595	7
18	90	120	425	1.7	413

				1.4	5
				0.595	7
19	50	40	613	1.7	583
				1.4	18
				0.595	12
20	50	50	560	1.7	531
				1.4	18
				0.595	11
21	50	60	547	1.7	518
				1.4	16
				0.595	13
22	50	70	522	1.7	493
				1.4	15
				0.595	13
23	50	80	514	1.7	487
				1.4	16
				0.595	11
24	50	90	510	1.7	484
				1.4	14
				0.595	12
25	50	100	504	1.7	477
				1.4	13
				0.595	12
26	50	110	501	1.7	477
				1.4	16
				0.595	8
27	50	120	490	1.7	467
				1.4	13
				0.595	10

From table 4.4, the milled rice consists of head rice and broken rice. Parboiling and milling systems give rise to different broken/head rice ratios. The efficiency of parboiling and milling system determine the broken/head rice ratio and the proportion of broken/head rice impacts on the quality and, consequently, the price of milled rice. The method of drying as well as post parboiling storage before milling affect broken/ head rice ratio. Shade drying and post parboiling storage before milling affect the proportion of broken/head rice ratio.

Figure 4. 1 Sieve analysis

In this process, percent husk (WH) and percent whole rice after dehusking (%W) was calculated following the below mentioned formulae. Similarly, %Broken after dehusking (%WB) and Total yield (%TY) was also calculated as follows:

$$\% \text{ Husk (WH)} = \frac{WH}{W} * 100$$

Where, WH is husk weight in grams. W is total parboiled paddy taken for the milling in grams.

$$\% \text{ Broken after dehusking (\%WB)} = \frac{WB}{W} * 100$$

Where, WB is weight of broken in grams and W is the total weight of rice.

$$\% \text{Total yield (\%TY)} = \frac{WP}{W} * 100$$

For the first sample, let us calculate percent husk, percent broken rice, percent total yield.

$$\% \text{Husk(WH)} = \frac{(538-486)}{538} * 100$$

$$= 7.7\%$$

$$\%\text{Total yield } (\%TY) = \frac{486*100}{538}$$

$$= 90.3\%$$

$$\%\text{ Head yield } (\%HY) = \frac{WH}{TY} *100$$

$$\%\text{ Broken after dehusking } (\%WB) = 100-90.3-7.70$$

$$= 2\%$$

4.3 Cost Visibility

4.3.1 Preliminary Cost Analysis

Cost analysis helps to identify profit enhancing variables that require special attention of management during rice processing business. Cost analysis is used to determine the effects of changes in the level of some variables considered to be crucial to productivity and profitability, and whose changes could significantly modify the projected levels of key performance indicators, particularly profit. Two of such crucial variables examined in this study were:

- changes in the prices of raw paddy; and
- changes in the price of parboiled rice.

Assumption

- Market price of parboiled rice = 40 birr/kg.
- Parboiled rice in the market consisted of 100% whole kernels.
- Price of broken rice parboiled rice = 28 birr/kg.
- price of rough rice =28 birr/kg
- Price of broken rough rice = 19 birr/kg

Price of Rough Rice

500 grams rough rice has been taken and has become 408 grams after milling stage. Then, the yield is sieved with 1.7,1.4 and 0.596 mm to obtained 340,45 and 23 grams respectively. Price of rough rice becomes;

$$\text{market price} = \frac{(83.3*28 \text{ birr/ Kg}) + (16.7*19 \text{ birr/Kg})}{100}$$

$$= 26.5 \text{ birr/ kg}$$

Assume a ton of paddy rice is milled per day;

market price = 26.5 birr/Kg * 1,000 Kg

= 26,500 birr/day

If the miller dehull raw paddy rice for two hundred sixty-four days per year.

Market price = 26,500 birr/day * 264 day/year

= 6,996,000 birr/year

Price of Parboiled rice

If the price of a kilogram head yield parboiled rice is 40 birr and the price of broken parboiled rice is 28 birr, the market price of the sample can be calculated as follow.

$$\text{market price} = \frac{(98.78*40\ \text{birr/Kg}) + (1.22*28\ \text{birr/Kg})}{100}$$

= 39.85 birr/ kg

Assume a ton of parboiled rice is milled per day;

market price = 39.85 birr/Kg * 1000 Kg

= 39,850 birr/day

If the miller dehull parboiled rice for two hundred sixty-four days per year.

Market price = 39850 birr/day * 264 day/year

= 10,520,400 birr/year

Assume three persons are employed in parboiling process and their salary is 2500 birr per month for each, the labour cost can be calculated as follow.

Total labour cost per month = 2,500 birr * 5

= 12,500 birr/month

Total labour cost per year = 12,500 birr/month * 12 month/year

= 150,000 birr/year

Cost of Energy

The energy requirements for soaking of paddy rice under the conditions of this study at the 70 ^{O}C and 4 hours.

To evaluate the cost of energy consumption in soaking stage;

$Q = mCp\Delta T$ where, Q is energy

m is mass of water

Cp is specific heat capacity of water

ΔT is change in temperature

Specific heat of water is constant i. e is 4186 J/Kg ^{O}C

$\Delta T = 70\,^{O}C - 28\,^{O}C = 42\,^{O}C$

The temperature should be in kelvin scale.

Q = mCpΔT, where as mass of water can be calculated as;

m = ρ*V, where ρ is density of water (1000Kg/m^3)

V is volume of water (1 litre =0.001 m^3)

m = 1000 Kg / m^3 * 0.001 m^3

= 1 kg

Q = 1 Kg * 42 ^{O}C * 4.186 KJ. /Kg ^{O}C

= 175.812 KJ

Assume the soaking time per a day is sixteen hours;

Power = $\frac{energy}{time}$

P = Q/t = 175.812 KJ/4 h*3600 sec h^{-1}

P = 0.012 KW

Q = 0.012 KW * 16 h

=0.195 KWh

0.195 KWh is required to soak 0.5 Kg of paddy rice. So, 1,000 Kg of paddy rice requires;

Q = 0.195 KWh * 1,000 Kg/0.5 Kg

= 390 KWh/day

cost per year = 390 KWh * 0.57 birr/KWh * 264 day/year

= 58,687 birr

The energy requirements for steaming of paddy rice under the conditions of this study at the 90 ^{O}C and 15 minutes.

To evaluate the cost of energy consumption in steaming stage;

Q = MLv, where, *Q* is the amount of energy absorbed during the change of phase of the water,

m is the mass of the substance (in kg), and

Lv is the specific latent heat of water (2,230 KJ kg^{-1})

m = ρ*V, where ρ is density of water (1,000Kg/m^3)

V is volume of water (1 litre =0.001 m^3)

m = 1,000 Kg / m^3 * 0.001 m^3

= 1 kg

Q = 1 Kg * 2,230 KJ kg^{-1}

Then, let us calculate power required;

Power = $\frac{energy}{time}$

P = Q/t = 2,230 KJ/4 h * 3,600 sec h^{-1}

P = 0.155 KW

Q = 0.155 KW * 0.25 h

Q = 0.024 KWh * 1,000 Kg/0.5 Kg

= 48 KWh/day

Cost of energy is calculated as;

Cost per year = 48 KWh/day * 0.57 birr/KWh * 264 day/year

= 7,223 birr

The energy requirements for drying of parboiled rice under the conditions of this study at drying temperatures of 130 °C has been computed.

The initial conditions for the study were;

- Ambient air temperature = 28 °C
- Ambient relative humidity = 52%

From psychrometric charts the enthalpy and specific volume at the above conditions were obtained as 60 KJ/kg dry air, and 0.855 m^3/kg dry air respectively. After the process of sensible heating, the enthalpy corresponding to drying temperature and moisture content 130 °C, 15.5% is 178 KJ/kg dry air respectively.

Assuming the air flow rate of 3.5 m^3 /min. used in the oven, the mass flow rate of air would be;

mass flow rate of dry air = 3.5 m^3min^{-1}/0.855 m^3/kg

= 2.993 kg/min

The heat requirement to heat the air from ambient conditions to 130 °C is calculated as;

= 2.993 kg/60 min * (178 KJ/kg-60 KJ/kg)

= 353.174 KJ/60min

The energy required per a day becomes;

Q = 5.88 KW * 16 h

= 94.08 KWh

Then, the cost is calculated as;

Cost per year = 94.08 KWh * 0.57 birr/ KWh * 264 day/year

= 14,157 birr

Profit

Parboiled rice price per year = 10,520,400 birr/year

Rough rice price per year ton = 6,996,000 birr/year

Total labour cost per year = 150,000 birr/year

Steaming cost per year = 7,223 birr

Soaking cost per year= 58,687 birr

Drying cost per year = 14,157 birr

To calculate the profit parboiled rice

10,520,400 birr/year – (150,000 birr/year + 7,223 birr/year +58,687 birr /year+14,157 birr/year)

= 10,290,333 birr/year

Net profit = 10,290,333 birr/year - 6,996,000 birr/year

= 3,294,333 birr/ year

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

- The maximum rice yield is obtained at 60 minute and 130°C. At all moisture levels, tempering treatments (post drying treatments) produced the highest yield rice at the temperature 130°C. At this treatment stage the amount of whole grain after dehusking is 486 grams and yield obtained is 480 grams, where its size greater than 1.7 mm and the remaining 6 grams is broken, which is below 1.4 mm in size.
- The project revealed further that using parboiling process has great market potentials for generation of income.
- Also in this project, it has been found that drying temperature variation, time and moisture content, post drying treatments are some of the factors that affected the head yield of rice.
- Parboiling of rice has some benefits. As a result, breaking and fissuring of rice during milling are reduced. In general, parboiled rice grains were more resistant to breakage during milling than rough rice grains because of their homogenous and compact microstructure, obtained as a result of full starch gelatinization and moisture equilibration after drying stages. Thus, starch needs to be gelatinized in the heat treatment stage (steaming stage) ensures minimizing fissuring in the parboiled end product.
- Parboiling process is relatively simple, cheap, reliable and easy to construct the process steps as such is a necessary technology which needs exploration to benefit the people as well as the county.

5.2 Recommendation

- Even if the production of rice is high in Ethiopia, the amount of rice during hull removal is decreased due to breaking. Most rice millers try to maximize the yield by using advanced miller technology. But, this technology cannot be easily affordable for all rice millers in our country.

  Nowadays to remove the hull easily, individuals try to parboil the paddy rice and dry in the shade. However, this technique of drying is too slow and cannot be available for all rice millers.

  We strongly recommend that by using renewable energy source, which is high temperature solar dryer, for all parboiling steps. This high temperature solar dryer reduces the time required for drying. By doing so, the amount of breakage and fissuring will be minimized.
- Further investigation may be conducted by varying the soaking and steaming time, but we conducted all experiments by constant soaking and steaming time.
- In our experiment we didn't investigate in various varieties of rice. So, we recommend that variety of rice may has its on effect on the final characteristics of parboiled rice.
- Pilot studies on an industrial scale should be carried out to examine the benefits of the use of 130°C (in comparison to the higher air temperatures presently used in the industry). These benefits should be explored from the view point of heat energy savings and rice yield improvements.

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