COMPARATIVE STUDY ON THE QUALITY BETWEEN *MANSULI* AND *SONA MANSULI* RICE OF EASTERN AND CENTRAL TERAI REGION OF NEPAL

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Comparative Study on the Quality between *Mansuli* and *Sona Mansuli* Rice of Eastern and Central Terai Region of Nepal

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Approval Letter

This dissertation entitled *Comparative Study on the Quality between Mansuli and Sona Mansuli Rice of Eastern and Central Terai Region of Nepal* presented by *Sharad Adhikari* has been accepted as the partial fulfillment of the requirement for the B.Tech. in Food Technology.

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Abstract

Samples of *Mansuli* and *Sona Mansuli* rice were collected from different areas of Eastern and Central Terai region of Nepal. The physical parameters such as appearance, moisture content, thousand kernels weight, bulk density, L/B ratio, were examined. The cooking quality parameters of each samples of rice such as cooking time, alkali digestion character, water uptake ratio, gruel loss, starch iodine blue value, kernels elongation ratio and volume expansion ratio, were analyzed. From the analysis of physical parameters, the both variety fell under the medium variety. The average value for physical parameters were found as length 5.21 and 5.34mm; breadth 2.02 and 2.05mm; thickness 1.49 and 1.55mm; 1000 kernels weight 13.09 and 14.68gm; bulk density 78.88 and 77.91 Kg/Hl and L/B ratio 2.58 and 2.60 for *Mansuli* and *Sona Mansuli* rice respectively. On the basis of cooking characteristics, it was observed that *Sona Mansuli* rice needs less time (13.68 min.) for cooking, both variety have low alkali spreading and clearing score (2,3 & 2) and *Sona Mansuli* rice has higher water uptake ratio (0.55) and gruel loss (3.22%) as compared to *Mansuli* rice. In case of starch iodine blue value, it was 0.46 (expressed as O.D.) for *Sona Mansuli* and 0.28 for *Mansuli.* Similarly, kernel elongation ratio and volume expansion ratio were higher for *Mansuli* i.e. lengthwise kernel elongation ratio 1.53 and volume expansion ratio 3.60 as compared to kernel elongation ratio 1.51 and volume expansion ratio 3.17 for *Sona Mansuli*. From the overall analysis, *Mansuli* and *Sona Mansuli* rice were found to be significantly different in terms of thousand kernels weight, length & thickness of kernels, cooking time, water uptake ratio, starch iodine blue value and volume expansion ratio but not in terms of appearance, bulk density, L/B ratio, alkali digestion character, gruel loss and kernel elongation ratio.

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List of abbreviations used

GT	Gelatinization temperature
SIBV	Starch Iodine Blue Value
KER	Kernel Elongation Ratio
VER	Volume Expansion Ratio
FAO	Food and Agriculture Organization
NS	Nepal Standard
NFC	Nepal Food Corporation
NBSM	Nepal Bureau of Standard and Metrology
NARC	National Agriculture Research Institute
USDA	United States Department of Agriculture
IRRI	International Rice Research Institute
HYV	High Yielding Variety
CFTRI	Central Food Technology Research Institute
NRRP	National Rice Research Programme

Part I

Introduction

1.1 General introduction

The rice plant (*Oryza sativa* L.) is one of the major crops. It is a source of food for nearly one half of the world's population. The rice crop *Oryza sativa* is grown in tropics where rain and sunshine are abundant and in temperate regions. *O. sativa indica* is cultivated in the tropics while *O. sativa japonica* is grown mainly in temperate regions and *O. sativa Javanica* is grown in equatorial regions. Among these three, *japonica* gives higher yield than *indica* and *javanica* (Idudhara swamy**,** 1977).

Different people like different types of rice. For instance the Japanese and Koreans prefer round rice, whereas Americans prefer long grain. Most people prefer white rice but Indians and Pakistanies preferred purple or blue strains (Ban, 1988).

Cooking method of rice differs from place to place. In Nepal, rice is cooked in boiling water as '*Bhat*' mainly. However, there are other methods of cooking rice. For example, some Nepalese like '*Bhakka*' (steam cooked rice flour), others like *roti* (pan fired rice dough), Beaten rice etc. Among Americans, rice is most popular in preparing canned soup; where as in Philippines, fermented rice cake is preferred. Even though, preference is given to the steam-cooked rice. In world food economy, rice plays important role. It is staple food for half to two third of population in the world. In many Asian countries, it accounts for more than half of daily calorie intake and as the major protein source (Jonathan, 1979).

Rice grain contains about 80% starch, so provides a bulk of calorie. It also contributes proteins, fats, minerals and vitamins. So, rice has a great nutritional importance in low cost (Pillaiyer, 1988).

The starch granule is the major reserve material in rice grain. Composition of rice grain changes on maturation. In general, increase in content of starch and decrease in other component such as protein, lipids and ash. Rice starch is a typical compound and each contains 20-60 small polyhedral granules (Hayakawa, 1980).

The physiochemical properties of starch are governed by the amylose content in the starch largely influences the cooking quality and eating quality of rice. Amylose content ranges from

0% in gluteneous (waxy) variety to more than 30% in high amylose containing variety. *Indica* variety shows much wider variation in amylose content than *japonica*. The amylose content of milled rice are classified as low (below 20%), intermediate (20-25%), moderately high (above 27%) (IRRI, 1972). Gelatinization temperature (GT) varies from 58.0^{o}C to 79.0^{o}C. The final gelatinization temperature is classified as low (58.0-69.5^{o}C), intermediate (70.5-74.0^{o}C), and high (above74^{o}C) (Juliano *et al.*, 1964).

Raw rice needs about 15-20 minutes to become fully cooked in boiling water (Antonio *et al*., 1974). Beyond 20 minutes, continues to absorb water but the grain loss their shape, become almost flat burst along the ventral line of fusion and becomes pasty (Mahadevappa and Desikachar, 1968).

Gelatinization temperature and cooking characteristic are directly related to grain length. Short and medium grain rice shows low gelatinization temperature while long grain rice has typically higher (5-7^{o}C) (Webb, 1975). Gelatinization temperature strongly influence water uptake. Lower gelatinization temperature variety have higher water uptake at (70-80^{0}C) and vice versa (Julliano, 1985). The nutritional level of rice is highest among cereals. It has comparatively high content of essential amino acids. So, the true protein digestibility as well as biological value of rice protein is highest among cereals (Eggum and Cristensen, 1975).

Crushing and breaking hardness of rice increases during aging. Hence, greater resistance to milling and higher total and head rice yield from rice aged from three to six months. Aging increases cooking time 4 to 6 minutes longer on 6 months of storage (Pushpamma and Reddy, 1979).

Grain quality to a large extent determines market price and acceptance by consumers. Next 'yield' grain quality is the most important factor concluded by rice breeders. If the consumers don't care for taste, texture, aroma or appearance of newly developed rice variety, then other outstanding characteristics may be worthless (Limbu, 1987).

Quality characteristics of rice grain are related to the complex of physiochemical properties, dimensions, shape and weight, dormancy, pigmentation, hardness and other milling properties, chemical composition of the endosperm, aroma and nutritive value. Rice quality is usually evaluated according to its stability for a specific end use by particular consumer, whose preference may vary (Kaul *et al*., 1982).

1.2 Significance of the study

The *Mansuli* variety of rice is very popular among the middle class society in Nepal due to its appearance, taste, storage stability etc. *Sona Mansuli*, a similar variety with *Mansuli* rice but differ in taste and cooking quality has been found in the market for 4/5 years. The *Sona Mansuli* rice which is available in the market at Rs. 1.50 to 2.00 less than *Mansuli* rice being very much similar in appearance has caused difficulty in physical grading and ultimately direct impact on the purchasing.

Market quality or marketability of the grain largely depends upon the physical characteristics. The market quality of the rice can be defined as the composite of those characteristics that differentiate the individual lots and have significance in determining the degree of consumer acceptability of each.

Nowadays food technologists are facing some problems on grading of these two varieties of rice. On the one hand the availability of *Mansuli* rice in market is necessary while on the other hand availability of very much similar *Sona Mansuli* rice has created technical problem in the purity of *Mansuli* rice. From the technical point of view the *Sona Mansuli* rice is similar to *Mansuli* rice, so, a proper definition of *Mansuli* rice is needed in terms of standard international parameters which can be established on the basis of length, breadth, L/B ratio, 1000 kernel weight etc. Hence, a scientific basis for the identification between these varieties should be established. And the present work is focused on getting solution to the above mentioned problem.

1.3 Objectives of the study

1.3.1 General objectives

The general objective of the study is to study the quality of *Mansuli* and *Sona Mansuli* rice variety.

1.3.2 Specific objectives

a. To determine the physical properties and cooking quality of the two varieties of rice.
b. To compare and identify the differences in quality of the two varieties of rice in terms of physical properties and cooking quality.

1.4 Limitations of the study

a. Due to the lack of required facilities and large no. of samples, nutritional quality of rice was not determined.
b. Due to the very expensive method and inadequate requirements, amylose content was not determined.

Part II

Literature review

2.1 Production and distribution of rice

2.1.1 Production

Rice is one of the main agricultural crops in the world. More than half of the people on the earth depend on this cereal for their basic diet. The world's production of paddy in 2005 and 2006 was 632.9 and 628.7 million tones respectively (Rice Market Outlook, 2007). Ninety percentage of the world's rice is produced and consumed in Asia, where the population is very high. China contributes 29% of the world's total production and India has 22% contribution for the same. In 2006 it was estimated that Asia produced 569.2 million tones and forecast for 2007 was 574.3 million tones (Table D.2, Appendix D).

Table 2.1 Area, Production, Yield of Paddy in Nepal

Year	Paddy Production		
	Area (ha)	Quantity (MT)	Yield (Kg/Ha)
2000/01	15,60,044	42,16,465	2,703
2001/02	15,16,980	41,64,687	2,745
2002/03	15,44,660	41,32,500	2,675
2003/04	15,59,436	44,55,722	2,857
2004/05	15,41,729	42,89,827	2,782
2005/06	15,49,447	42,09,279	2,717

Source: MOAC, (2005/06)

Rice is one of the major agricultural produce of Nepal. The annual production of paddy in fiscal year 2005/06 was estimated to be 42, 09,279 M. Ton and area covered was 15,49,447 hectare, from which Eastern Terai region of Nepal produced 11,53,895 M. Ton in 3,91,982 hectares and Central Terai region produced 8,96,222 M. Ton in 3,26,456 hectares (MOAC, 2005/2006) (Table 2.1).

2.1.2 Distribution

Rice is staple food for many Asians. It is the good source of energy and protein. The per capita consumption of rice therefore is much higher in Asia than in any other continent. Following this, there is the Asian's fashion for rice, a dietary preference and cultural bias they inherited at birth. Many Asian feel that they have not eaten meal if there is no rice is served. Most of the High Yielding Variety (HYV) are photoperiod insensitive and are early maturing (105-135 days). Shorter growing period facilitates intensive multiple temperature zone. The High Yielding Variety definitely contributed more to rice production in many areas (Jonathan, 1979).

Generally, in most of the Terai region, where irrigation facilities are sufficient double cropping of paddy is possible. The early maturing rice gives the higher yields as compared to late, because of utilizing higher solar radiation before harvesting (Mallick, 1981).

In the world food economy, rice plays important role such as:

a. It has staple food for half to two third of the population.
b. In many Asian countries it accounts for one third to half of the daily calorie intake and also as a major protein source. Besides these, it plays an important role in the economy (Jonathan, 1979).

Rice is cultivated around the world, in a broad range from 50°N to 40°S latitude and from sea level to altitude over 2,500 m of altitude. Although, there is different climatic and geographical condition of different part of Nepal excluding Manang District from 100 metre (328 ft) above the sea level to 3050 metre (10,007 ft) altitude. But, paddy cultivation is more in Terai region of Nepal where the climate is warm and land is plain (Manandhar, 1988).

2.2 Rice varieties

Several varieties of rice like *japonica, javonica and indica* are found in Nepal (Mallick, 1981). About 1836 varieties of rice were collected from 59 districts of Nepal in 1981-1982 among which there were 352 coarse varieties, 1252 medium & 32 fine varieties according to their size and shape classification(Gorkha patra, 1988). Some traditional varieties are:

a. Coarse: *Ratodhan, Andi, Thapachini, Sathiyari, Rahimanowa, Mawalee, Dulhania, Gorbhe, Thagiya, Sugapankhi, Laldan, Satraj, Katkomal, Katlaci, Atte, Backchi, Bijulibatti, Himali, Gamad.*

b. Medium : *Gopaldhan, Simetti, Anjana, Jumlamarsi, Najir, Nyali, Diwanji Anandi, Jamara, Poshara, Jhuppi, Pokhrelimasino, Nagina, Harinker, Madhukaria, Anapachi, Mansara and Khyamti.*

c. Fine: *Shyamjeera, Ratna, Lalmunia, Indrasen, krishnabhog, Barma,Tilko, Biranful, Kalanamak, Baharani, Basmati, Jeerasari, Chulthemasino, Kanakjeera, Kukurjali, Kalotude, Malbhog, Indrabeli, Tulsiful, Kariyakamat.*

On the basis of aroma, rice is also classified as aromatic and non-aromatic. Only 20 varieties of rice were reported as aromatic through out Nepal.

On the basis of maturity days, rice can be classified as early maturing varieties (*Bhadaiya)* and late maturity varieties (*Agahani).* Early maturing rice can be planted any times from April to August and harvested in Bhadra i.e. in between August to September. Late maturity varieties can be planted any time but matures only in November & December. The early rice is also called *Aus, Upland, Ghaiya, Saro or Gaddar*. *Agahani* is also called *Aman, Sarihan*. Early rice matures in between 100-200 days (Mallick, 1981).

2.3 Composition of paddy

Fig 2.1 illustrates the part of the paddy grain. It consists of an edible portion which is a fruit of the grass plant known as caryopsis and an inedible covering hull or husk. The caryopsis is called brown rice because of its brownish color (pericarp). Red rice has a red pericarp or tegmen or both. The hull is composed of cellulosic and fibrous tissues. The pericarp layer is thin with cross layer of varying cell shapes (Santos, 1933). The pericarp layer is highly impermeable to foreign material and gives protection against enzymatic deterioration of the underlying tissues. Beneath the pericarp is tegmen, rich in oil and protein (Juliano, 1972). Both the endosperm and embryo are enclosed by the aleurone layer which lies beneath the tegmen. The aleurone layer may be composed of one to seven layer of parenchyma cell (Little, 1960).

The embryo or germ is extremely small and is located on ventral side of the caryopsis. The parenchyma cells of plumule and radicles together with epithelial cells are filled within the minute protein granules and fat globules. The endosperm consists of parenchyma cells, usually radially elongated and heavily loaded with compound stanch grains. Starch granules are present only in the endosperm of mature rice grain (Julliano, 1972).

Proteins and fats are uniformly distributed in the aleurone layer. During the milling operation, seed coat, germs and the aleurone layer of the endosperm along with starchy endosperm are also removed (Bhole, 1967).

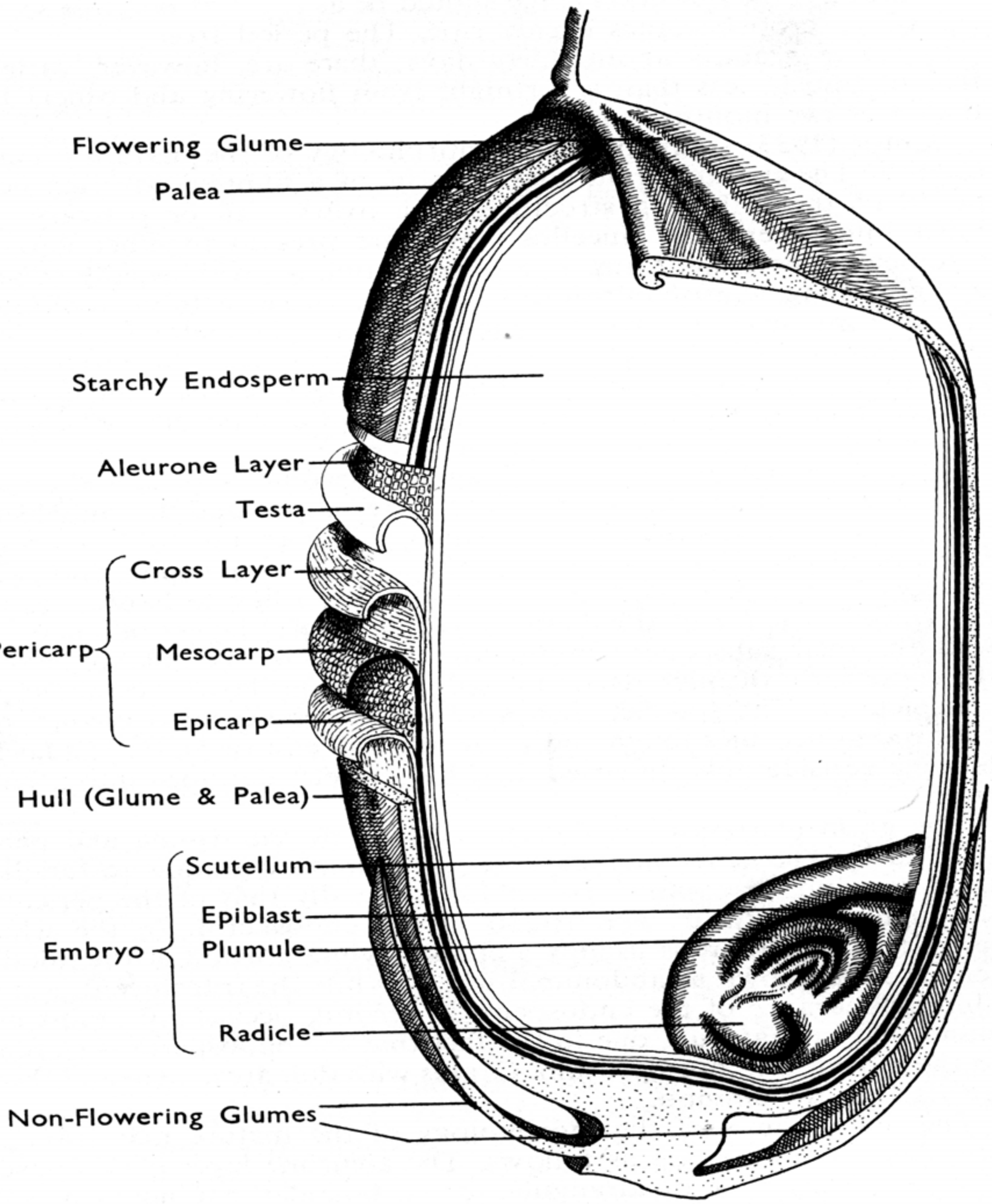

Fig 2.1 Rice grain showing its different parts

2.4 Chemical composition of rice

The grain of rice consists of carbohydrate, nitrogenous compounds (mainly proteins), lipids (fat), mineral salts and water together with small quantities of vitamins, enzymes and other substances, some are important in the human dietary. The proximate composition of rice is as shown in the Table 2.2.

Carbohydrate is, quantitatively, the most important constituent forming about 83% of total dry matter of rice. The carbohydrate present in rice grain mainly starch which is composed of cellulose, hemi cellulose, pentosans, fiber, dextrin and sugar. Starch, a polymer of glucose, occurs in the endosperm as compound polyhedral granules 3 to 10 µm in size. Protein is present as discrete particles, 1 to 4 µm in size, between the starch granules. Amylopectin is the major and branched fraction of starch; amylose is the linear fraction of starch. Amylose is absent from waxy (gluteneous) rice, but in non waxy rice it consists of 7 to 34% (dry basis), of the milled rice or 8 to 37% of the starch. The amylose content of the same non waxy variety may vary by as much as 6% (Juliano *et al.*, 1964), as it does from 27 to 33% for the variety IR-8. Individual grain of a sample of a variety may range in amylose content up to 5% (Juliano, 1972).

Table 2.2 Proximate composition of rice

S.N.	Constituents	Brown Rice	White Rice (milled rice)
1	Moisture (%)	12.0	12.0
2	Energy (Kcal/100gm)	360	363
3	Protein (%)	7.5	6.7
4	Fat (%)	1.9	0.4
5	Ash (%)	1.2	0.5
6	Total carbohydrate (%)	77.4	80.4
7	Fibre (%)	0.9	0.3
8	Calcium (mg/100gm)	32	24
9	Phosphorous (mg/100gm)	221	94
10	Iron (mg/100gm)	1.6	0.8
11	Sodium (mg/100gm)	9.0	5.0
12	Potassium (mg/100gm)	214	92
13	Thiamine (mg/100gm)	0.34	0.07
14	Riboflavin (mg/100gm)	0.05	0.03
15	Niacin (mg/100gm)	4.7	1.6

Source: Watt and Merrill, (1963).

The protein content of milled rice is low in comparison with other cereals, although milled rice contain from 5 to 14% protein at 14% moisture content. The protein found in the kernel of rice, within the same variety, shows a variation of 6% due to environment (Juliano *et al.,* 1964). It varies from 8 to 14% for BPI-76 (Cagampang *et al.,* 1966).

Table 2.3 Amylose content of milled rice

Category	Value
Low	below 20%
Intermediate	20-25%
Moderately high	25-27%
High	above 27%

Source: (IRRI, 1972)

Starch content decreases with an increase in protein content. The nutritive value of protein depends upon its amino acid content and is reported that eighteen different amino acids occur in the protein of cereals. The protein is rich in arginine but poor in lysine and threonine. The amino acids in protein of six Indian type of husked rice were found to be argenine, histidine, lysine, cysteine, tryptophan, metheonine, leucine, isoleucine, phenylalanine etc. The lipid content of rice is very low i.e. 1-2%. Rice mainly contains phospholipids; palmitic, steric, oleic, lenoleic and lenolenic acids. The kernel of rice consists of the phosphate and sulphate of potassium (K), magnesium (Mg) and calcium (Ca). The important minor elements found in rice are iron (Fe), magnesium (Mg) and zinc (Zn). Generally, husk of the rice has a higher content of mineral matter than that of kernels (Kent, 1966).

The human nutritional requirements of iron is estimated to be about 10-15 µg daily where husked rice will supply about 19 µg and polished rice not more than 6 µg. The calcium (Ca)/phosphorous (P) ratio is unfavorable, being about 1:10 instead of 1:2 which is regarded as the optimum ratio (Grist, 1975).

In relation to vitamin, the amount of fat soluble vitamins A and D in rice is negligible, but the vitamin E content of whole rice is considerable. Husked rice has a high content of vitamin B at least one tenth of dried yeast; riboflavin content is low and vitamin C practically absent. The average of the vitamin of the B complex, particularly thiamine (B_1), riboflavin and niacin are found in rice. It has been found that high milling of rice resulted in the incidence of beriberi, assuming that thiamine content of the rice is mainly present in the pericarp and aleurone layer which is completely removed during polishing (Grist, 1975).

2.5 Grading of rice

Rice grading is useful tool for assessment of the value of grain. It is important for both producer and consumer to get the best grade and price for the quality of the product. Grading and its standard are necessary in the marketing process because they furnish the means of describing varieties in quantity and conditions. It also provides a basis for merchandizing contracts, for quoting prices and incentive to farmers to produce better crops. Good milling results and their storage stability can only be obtained when the rice or grain is graded (Arraullow *et al.,* 1972).

FAO (1972) has recommended the standard for rice in international trade and classified on the basis of size and shape & weight is given in Table 2.4, 2.5, 2.6.

Table 2.4 Classification of rice on the basis of length breadth ratio (L/B ratio):

Category	Value
Slender	: more than 3.0
Medium or bold	: 2.0 to 3.0
Round or short	: less than 2.0

Source: FAO, (1972)

Table 2.5 Classification of rice on the basis of length of grain (for milled rice):

Category	Value
Extra long	: more than 7.0 mm
Long	: 6.0 to 6.99 mm
Medium	: 5.0 to 5.99 mm
Short	: less than 5 mm

Source: FAO, (1972

Table 2.6 Classification of rice on the basis of 1000 kernels weight of rice (at 14% m c):

Category	Value
Extra heavy	: 25 gm and over
Heavy	: 20 to 25 gm
Moderately heavy	: less than 20 gm

Source: FAO, (1972

2.5.1 Grading and marketing of rice in Nepal

The semi governmental organization Nepal Food Corporation (NFC) is dealing with rice trading in Nepal. The corporation employed two grades for the rice grading & this is based on an individual basis (Karki, 1976).

NFC has prepared two standards for marketing of parboiled rice.

a. Quality standards from Aswin to Marg for *Bhadaiya* Rice.
b. Quality standards after Marga for *Agahani* Rice.

However, the standards for raw rice in both are same given below. The mixture of coarse varieties along with medium should not be more than 13% in *Aruwa Mansuli* rice. In medium *Aruwa Mansuli* rice, coarse kernel should not exceed 10%. Rice should be free from live insects and mold; in clean condition as well as polished characteristics is the essence. (NFC, 2062).

Table 2.7 Grading standard for raw rice.

S N	Factors	Tolerance limit (%)	Rejection limit (%)	Price reduction
1	Broken	20	25	1/4 the value
2	Foreign matters	0.5	1.0	Full payment
3	Damaged by insects	2	5	1/2 the value
4	Discolored grain	2	4	1/4 the value
5	Chalky grain	8	12	1/8 the value
6	Red grain	6	10	1/4 the value
7	Unpolished grain	10	15	1/8 the value
8	Moisture content	14	15	Full payment

Source: NS (2049)

According to the decision of NFC in the 1432nd meeting dated on 2062/9/4, the following standards are established for the quality of *Aruwa Mansuli* and *Sona Mansuli* varieties of rice.

a. Regarding the quality standard assessment for the rice, the physical properties have also to be identified along with the identification of former standards parameter for the free sale ability of rice.
b. The admixture of other varieties of grains can be identified by estimating following physical parameters. These values lying beyond the standard below will indicate the admixture of foreign variety.
c. The broken in *Sona Mansuli* variety is to be reduced from 25% to 20%. (NFC, 2062).

Table 2.8 Standard for *Mansuli* rice

Parameters	Values
1000 kernel weight (gm)	12.0-13.0
$^L/_B$ Ratio	2.5-2.7
Length (mm)	5.0-6.0
Breadth (mm)	2.0-2.2

Source: NFC (2062)

The millers and other agencies are also involved in rice marketing employing their own grade known as miller's grades. According to them the classification of rice is done as superfine, fine, medium and coarse varieties based on size, shape, palatability, admixture of foreign grains, red grains and translucence. Most of the fine qualities are very slender. The palatability characteristics (appearance, cohesiveness, tenderness and aroma) have an important bearing on the exiting quality grading, therefore aromatic and slender varieties like *Basmati* and *Kukurjali* fetch a higher market price. Red and foreign grains are objectionable in the present grading system (Karki, 1976).

2.6 Physical characteristics of grain

2.6.1 Size, shape and weight

The measurement of physical characteristics of paddy as well as milled rice gives the rice varieties which affect the milling, cooking and eating qualities (Arraullow *et al.*, 1976).

Pokharel (1991) found that the local varieties '*Chaite-4*' and '*Laxmi*' were long. '*Remni'* was short grain type where as others (*Kalchini, Sutna, Chaite-2, Kalma, Bindeswori*) etc. were medium types. The study among some local varieties showed that the longest variety was '*Anapachi'*. Shortest one was '*Jhuppi'* and others (*Katkomal, Lal dhan, Mansuli, Kalanamak)* etc were medium types (Limbu, 1987).

In Nepal, local varieties *Durga, Kanchan, Janaki, Mansuli, Himali, Bindeshwari, Sabitri* and *Laxmi* etc. all are slender (Shah, 1985). It has also been found that varieties *IR-10787* and *DR-31* were slender as well as *BW-288* and *IR-2095* were medium. The paddy variety '*Boya*' has a minimum 1000 kernels weight (18.5 gm) and '*Chaite-4*' have a maximum (24.5 gm) were recorded on the study of different local varieties of paddy (Pokharel, 1991).

2.6.2 Appearance/colour

The grain appearance is largely determined by endosperm opacity, the amount of chalkiness, either on the dorsal side of the grain (white belly) or on the centre (white centre) and the condition of the 'eye' (Kanda *et al.*, 1969).

In some varieties, grain tends to break more frequently at the eye or pit left by the embryo when it is milled. Rice samples having damaged eyes have poor appearance and low market value. Similarly, greater the chalkiness, lower the market acceptability (Kanda *et al.*, 1969).

The starch granules in the chalky areas are less densely packed than those in translucent areas and there is air space between starch granules. Therefore, chalky areas are not as hard as translucent areas and the grain with chalkiness are more sensitive to breakage during milling. Chalkiness has no direct effect on cooking and eating quality. But negative influence on milling quality and market quality (Juliano, 1982).

2.7 Grain quality

The term grain quality to a large extent determines market price and acceptance by consumers. Next 'yield' grain quality is the most important factor concluded by rice breeders. If the consumers do not care for taste, texture, aroma or appearance of newly developed rice variety, then other outstanding characteristics may be worthless (Limbu, 1987).

Grain quality takes even greater importance as developing nations become more prosperous and as producing countries achieves self sufficiency in rice, for both of these conditions discriminating consumers. Quality characteristics of rice grain are related to the complex of physiochemical properties, dimensions, shape and weight, dormancy, pigmentation, hardness and other milling properties, chemical composition of the endosperm, aroma and nutritive value. Rice quality is usually evaluated according to its stability for a specific end use by particular consumer, whose preference may vary (Kaul *et al.,* 1982).

Since rice is processed and consumed mainly in whole kernel form, the physical attributes of the intact endosperm are always important (Pillaiyer, 1988).

Rice quality may be studied into four broad and interrelated quality characteristics. They are milling quality; market quality; nutritional quality; cooking, eating and processing quality (Bhattarcharya *et al.*, 1971).

2.7.1 Milling quality

Milling quality is directly related to milling yield or milling recovery. Milling yield of rough rice is the estimate of the quantity of the head rice and of total yield of milled rice that can be produced from unit of rough rice (Karki, 1969)

From a given sample of rough rice about 70% milled rice is obtained, 20% broken whereas 50% head rice is reported. The head rice recovery may vary from as low as 25% to as high as 65%. Environmental factors such as temperature and humidity during ripening and post harvest handling are known to influence grain breakage during milling. Head rice recovery is also dependent upon the grain size, shape and appearance. In general, varieties and breeding lines with long or long bold grains and those having chalky grains give lower head rice yields. Varieties having medium, long, slender, translucent grains give the best head rice yield (Pilliyer, 1988).

Among IR varieties, IR-8 and IR-S, which have bold and chalky grains, give lower head rice yields, where as IR-20, IR-26, IR-36 and IR-42 give very high head rice yields (IRRI, 1979).

According to Karki (1969) good milling quality consists of high rice yield with minimum breakage during shelling or polishing. And percentage breakage increased non-linearly with milling time, whereas breakage varied linearly with degree of polishing. The head rice yield is positively correlated to hardness. The type and design of machineries influence the milling results. Accordingly, the huller mill gives a lower yield of rice as well as considerable higher breakage as compared to sheller-polisher mills. The rubber roller sheller gives much lesser breakage compared to other sheller. Proper adjustment and maintenance of mills are equally important for optimum performance (Bhattacharya, 1989).

Rice breakage is also related to milling conditions; particularly the prevailing relative humidity should be same as equilibrium R H of rice being milled. Low humidity increases breakage. The temperature of the mill room had no effect as long as the rice entering the mill is also at the same temperature (Bhattacharya, 1989).

Milling breakage of properly parboiled paddy doesn't exceed 1-2% (Bhattacharya & Indudhara swamy, 1967). It has been established that cracks, incomplete grain fillings and chalkiness are completely removed during the parboiling process due to starch gelatinization i.e. parboiling toughens the grain and reduces breakage (Poudyal, 1994).

In Nepal, Acharya (1991) found that the brown rice, milled rice, head rice, bran and husk percentage varied from 75.1-82.0%, 66.7-75.9%, 21.4-66.8%, 2.5-13.5% and 18.0-24.9% in the 36 varieties of paddy respectively.

Pokharel (1991) observed that percentage head rice were maximum (87.33) in '*Remni*' and minimum (59.54) for '*Kalchini*', local variety.

2.7.2 Market quality

Market quality or marketability largely depends upon the physical characteristics of the grain. In general long grains are preferred in the India sub-continent but in south East Asia, demand is for medium to medium long rice. There is a strong demand for long grain rice in the international market (IRRI, 1979).

The market quality of the rice can be defined as the composite of those characteristics that differentiate individual lots and have significance in determining the degree of consumer acceptability of each one. The chalkiness and whiteness are two of the most conspicuous factors determining the commercial value of milled rice along with the proportion of broken grains, discolored grains, immature grains, damaged grains and so on. In every standard grade of rice there is specific range of percentage of chalky grains permissible to each class of quality grades (Kanda *et al.,* 1969).

Chalkiness disappears upon cooking and had no direct effect on cooking and eating quality, but it influences consumer preference and affect milling recovery. In a test with *japonica* variety, the fraction of rice with white belly from a sample of brown rice had a lower milling recovery than the fraction without the white belly (Kanda *et al.*, 1969).

The formation of starch is very much influenced by environmental factors, particularly those that interrupt normal grain filling, such as infestation by insect and through stress during ripening. But there is strong evidence that this character is under genetic control and selection for less chalky grain is effective. Therefore, in the breeding programme there is a routine evaluation system for the degree of chalkiness (IRRI, 1979).

Rating the degree of chalkiness by sight (visual method) is the common procedure used in any breeding work or in grading for marketing value. The percentage of chalky area of grain is determined visually as is given in the standard evaluation system for rice. Where 0 for none; 1

for small (<10%); 5 for medium (10-20%); and 9 for large (>20%) chalky area. Simple as well as optical instruments can also be used for measuring the degree of chalkiness (IRRI, 1975).

2.7.3 Nutritional quality

Rice provides more calories than any other cereal grains. Its nutritive value is highest among cereals and other grains. Protein content of rice is less than that of wheat. The true protein digestibility and biological value of rice protein are the highest among wheat and other cereals. Among, it has a comparatively high content of essential amino acids. The biological value is directly related to the concentration of the first limiting amino acid, 'lysine' (Eggum, 1979).

Eggum *et al* (1975) showed that tannin has a severe negative influence on protein digestibility. Similarly, crude fibre has a negative effect on both the digestibility of protein and energy. Rice has a very low content of crude fibre and tannin which may explain the high digestibility of rice protein and perhaps the high energy digestibility as well (Eggum, 1979).

Among rice eating people, the general level of health is low in comparison with western standard, resulting in high mortality rate, short expectation of life, the prevalence of disease, poor physical development and working capacity. FAO (1965) reported that husked, hand pounded and parboiled rice contains about 358 calories per 100 gm and milled white rice 360 calories per 100 gm while G. Evans (n.d.) states that lightly milled rice has a vitamin B_1 content of 0.7 mg/1000 non fat calories compared with only 0.18 mg/1000 non fat calories in high milled product. In a typical 2,500 calorie diet with rice as the staple food, 2,000 or more calories are provided by the rice while the remaining 500 calories, drawn from other foods, are unlikely to carry with them more than 0.4 mg of vitamin B_1. Highly milled rice will not provide the additional 0.5 mg which is necessary if the danger of beri-beri is to be avoided. Only rice providing 0.5 mg or more per 1000 non fat calories could act as an adequate safeguard against the occurrence of beri-beri under these conditions. Such a level is only found when rice is lightly milled, parboiled or 'fortified' (Grist, 1975).

The proteins are rich in arginine but, like other cereals, poor in lysine and threonine. Pecora & Hundley (1951) have shown that a diet containing 90% milled rice is markedly improved by the addition of lysine and threonine. Kik (1957) showed that by replacing part of protein in milled rice by equivalent amount of fish (perch), the body weight of the animal is markedly increased, indicating that the perch has better nutritive value than milled rice at the level of protein intake.

In some cereals, the presence of phytic acid (inositol hexaphosphoric acid) retards mineral absorption by forming insoluble compounds with them. The effect of phytic acid can be overcome by adding calcium carbonate or vitamin D. Phytates in animal diet markedly decreases the availability of zinc (Zn) forming zinc phosphate complex in gastrointestinal tract. Absorption of zinc bound by phytic acid is increased by autoclaving or vitamin D addition. Phytase, the enzyme which hydrolyses phytate is stable in dry heat 100^oC to 110^oC for 16 hrs, whereas autoclaving for 1 hr reduces the phytase activity by 50%. Boiling water inactivates phytase activity completely. Eggum (1979) observed that total digestibility and net protein utilization were positively correlated with lysine content of the rice protein.

According to Juliano (1972) the quality of the protein (albumin) of the outer layer is superior to that of protein in endosperm. The flour milled from the outer portion of the grain has twice the protein content, higher the fat, B vitamins and minerals than milled rice. Protein content dropped slightly during parboiling probably due to leaching out of non-protein nitrogen. It is considered that a greater intake is desirable of protein derived from food other than rice. The amount of fat eaten in rice consuming countries is low and in view of the fact that the fat facilitates the absorption of certain vitamins and spares thiamine. An increase in consumption of fat is desirable (IRRI, 1979).

2.7.4 Cooking and eating quality of rice

There are different aspects of the evaluation of quality of rice, such as yield, response to fertilizers, disease resistance etc. which are criteria for the determination of agronomic quality. From the point of view of post harvest technology, the important quality characteristics of rice are its milling, cooking and processing characteristics (Bhattacharya, 1971).

Cooking quality of rice is an exclusive factor determined by subjective preference. However stickiness or cohesiveness of the cooked grains is generally accepted as the most important characteristic determining cooking quality. Milled rice that has a high protein content or high gelatinization temperature requires more water and longer time to be cooked than rice with lower values (Juliano *et al.*, 1965).

Low G T rice such as *japonica* varieties start to swell at a lower temperature during cooking than intermediate or high G T rice. However, these properties may affect the eating quality. Rice that has high protein or high G.T. tends to be undercooked when boiled at the same rice: water ratio than rice with lower values. However, the method of cooking is less important than varietal differences in determining the relative eating qualities of milled rice (Batcher *et al.,* 1956).

Water absorption and volume expansion during cooking are positively correlated with amylose content (Rao *et al.*, 1952). Waxy rice expands the least during cooking and its boiled grain has the heaviest bulk density. Soaked milled rice of *Basmati*, D-24-4 and certain Iranian varieties show extreme grain elongation during cooking. This property is not confined to long grain rices. In fact, the highest elongation ratio was obtained with the medium grain Burmese variety, D25-4 which has intermediate amylose content and low G T (IRRI, 1967).

A darker tan colour in the raw and cooked rice of variety may be related to high protein content but varietal differences also exist. BPI-76 has a grain that is more characteristically tan-colored than that of waste other varieties with the same protein level. Aromatic varieties are preferred in many countries but the preferred aroma may differ from region to region. The exact nature of aroma has not been studied but varieties differ in the character of the aroma. Climatic factors have marked effect on the intensity of aroma which is volatile (IRRI, 1984).

Many countries have shown a keen interest to evaluate the cooking quality of rice such as Central Food Technology Research Institute (CFTRI) of India and International Rice Research Institute (IRRI) of Philippines. Several physicochemical quality parameters have been used to determine the cooking quality of rice. These include water uptake ratio, alkali scores, starch iodine blue value, kernel elongation ratio, hardness etc. However, none of these parameters seem to give unfailing indication of the cooking behaviors of rice in isolation because the cooking quality of rice is a subjective criterion. The ultimate tests of cooking quality of rice appear to be the sensory evaluation (Juliano, 1985).

2.7.4.1 Cooking time

Steinbarger (1932) found that quality was inversely related to cooking time and directly related to loss of starch in the cooking water. Parthasarathi and Nath (1953) found that cooking time varied inversely and exponentially with temperature. According to Mahadevappa *et al* (1968), the time required for cooking to the same degree of softness of was greater for parboiled than for raw rice samples. According to Batcher *et al* (1956), the long grain varieties of rice required more water than medium and short grain varieties. The optimum cooking time ranged from 26 to 30 minutes.

El-Hissewy *et al* (1991) states that the cooking time varied with the rice: water ratio. With 1:1 ratio the cooking time ranged between 19 min. (Reiho) and 33 min. (IR28) and from 21 min. to 32 min. for Gz 2175-5-6 and IR28, respectively with 1:1.5 ratios. While with 1:2 ratio, IR28 also had the highest (25 min) and Giza 171 the lowest (19 min) cooking time.

2.7.4.2 Amylose content

It is well known that starch is composed of branched fraction amylopecin and a linear fraction amylose. The major linkage is α-(1→4) D-glucopyranosidic but amylopectin contains in addition the α-(1→6) D-glucopyranosidic linkage at branched points. Amylopectin is the major fraction of rice starch. In waxy rice amylose content range between 1 & 2 percent only. Amylose content of non-waxy milled rice is classified as low 10-20%, intermediate 20-25% or high (more than 25%) usually determined by iodine colorimetry and amylopetin can be calculated indirectly because starch and protein constitute 98% of total dry matter of milled rice (Juliano *et al.*, 1964). Amylose: Amylopectin ratio is the single most important factor determining the eating quality or texture of cooked milled rice. Amylose content varies directly with combine temperature during grain development particularly in low amylose rice. The texture of freshly boiled rice is not affected by difference in G T of the starch which tends to harden faster on storage, due to the higher molecular weight of their amylopectin. High amylose content rice (i*ndica* varieties) is related with high G T, low alkali score, more hydration and non sticky and vice-versa in low amylose content rice (*japonica* Varieties) (Juliano, 1966).

It is generally acknowledged that amylose content is the important factor influencing eating quality, higher amylose content being associated with a firmer, less sticky cooked grain. Amylose content is directly measured quantitatively. Sometime starch iodine blue (optical density) value has been taken as the indirect quantification of amylose content. Waxy starch (rice) stains reddish brown with iodine and non waxy starch (rice) stains purple blue with iodine (Arroullow *et al.*, 1972).

Amylose content is the one which exert the major influence on eating quality. It correlated negatively with taste panel for cohesiveness, tenderness and gloss of cooked rice regardless of water rice ratio (Juliano, 1968).

The wide range of amylose content of non waxy rice is grown in thirty countries. Although *japonica* varieties have low amylose, some have intermediate levels, particularly in cool climatic area such as in Australia and South Korea. Low amylose rice is preferred in Japan for its stickiness, tenderness, gloss and taste. It is more sensitive to overcooking than rice that have higher percent amylose and its cooked grains disintegrate when soaked overnight. Most *japonica* varieties have low G T. Most *indica* varieties have intermediate, moderately high or high amylose content. Philippine and Indonesians prefer intermediate amylose rice. They prefer cooked rice that remains soft ever when stored overnight. This kind of rice has less than 25 percent amylose (Juliano *et al*., 1964).

Moderately high amylose rice has the flakiness than high amylose rice but when cooked it is not as hard as cooked high amylose rice. This type of rice is preferred in Thailand and Malaysia to high amylose varieties as shown from recent analysis of samples by the simplified amylose assay. Even in the Philippines where the people like partial to intermediate amylose rice, IR-20 (moderately high amylose) is preferred for its soft textures to IR–22 (high amylose). Such amylose difference of about 2% points was difficult to detect with the old amylose assay but was consistently obtained with the new simplified amylose technique (IRRI, 1972).

The late maturing is varieties Texas, Patna and Rexoro are considered moderately high amylose varieties but these have been replaced by intermediate amylose earlier maturing long grained rice. This moderately high amylose rice has lower amylograph set back viscosity (400 Barbender units) than high amylose rice (Halick and Kelly, 1959).

High amylose rice cooks dry and fluffy and has a dull appearance and a hard texture. Most varieties in South Vietnam and Ceylon are of this type. High amylose rice is also common in most rice producing countries, including Indonesia and Philippines. Cooked high amylose rice also hardens fast on storage. In Sri Lanka where all varieties have high amylose content, small and short grain varieties are preferred to bold grain varieties because of their resistance to splitting during boiling (IRRI, 1971).

Such a high correlation between texture of cooked rice and amylose content limits the extent to which any one variety can universally meet the different eating quality preferences in various countries. Moderately high amylose rice may find greater acceptability in tropical Asia than an intermediate or high type. Protein content is a secondary affecting texture. It is important in countries where the amylose of the rice varieties is narrow. Protein is the major quality factor in Spain, although the preferred variety is higher in both protein and amylose than the other varieties. According to Kaul *et al* (1982) high amylose content (greater than 25%) may be more digestible than low amylose types. It has been observed that all the early maturing varieties (98-130 days) contain 21-27% amylose (IRRI, 1982).

2.7.4.3 Gelatinization temperature (GT)

The G.T. of rice starch has traditionally been defined in rice quality research as the temperature of which all the starch granules in a sample lose their birefringence. It is the temperature at which starch granules start to swell irreversibly in hot water with loss of crystallinity (Juliano, 1976).

Cooking involves hydration and gelatinization of starch. The starch in the rice however is gelatinized by adding water and by heating. When starch is steeped in water, it slowly becomes hydrated and finally reaches equilibrium of about 30% moisture. When this starch slurry is heated, the hydration gradually increases and finally the rate of hydration rises sharply while at the same time, the starch slurry suddenly becomes viscous and also more transparent. This change is called the gelatinization of starch and corresponding temperature is G T. To gelatinize the starch, the minimum moisture content is about 25% and temperature is about 70^{o}C. Final G.T ranges from 55-79^{o}C in rice starch and may vary by as much as 10^{o}C within a variety. Final G T may be low (below 70^{o}C), intermediate (70-74^{o}C) and high (above 74^{o}C). G.T. could be indexed by either alkali score or water uptakes ratio or soluble amylose ratio (Tani, 1987).

Although gelatinization and amylose content are in general independent properties of starch, it is interesting that no rice with both high amylose and high gelatinization or with no waxy or low amylose and intermediate gelatinization have been identified (Tani, 1987). Raw rice needs about 15-20 minutes to become fully cooked in boiling water (Antonio & Juliano, 1974).

Raw rice cooked beyond 20 minutes continues to absorb water but the grain loses their shape, become almost flat, burst along the ventral line of fusion and become pasty. Gelatinization and cooking characteristics are directly related to grain length. Short and medium grain rice show similar gelatinization temperature while long grain rice has typically 5-7^{o}C higher (Webb, 1975).

2.7.4.4 Water uptake ratio/swelling no.

It is termed as the ratio of the final to the initial volume or weight of the rice. As for the water uptake ratio of milled white rice, waxy rice registers a larger value than non-waxy rice, if the cooking temperature ranges from 65-75^{o}C. However, when the cooking temperature raised beyond 90^{o}C, non waxy rice shows a larger ratio than waxy rice. Hence waxy rice can be cooked with greater ease than non-waxy rice but boiled waxy rice is liable to be deformed (Ebata, 1987).

Studies have shown that water uptake is related to the surface area. Hence water uptake per gram at a definite time of cooking is always high for small and slender varieties because they have a relatively high surface area per gram, but is low for big sound varieties. For these reasons, small slender varieties need much less time to cook than big or sound varieties (Bhattacharya, 1971).

Milled rice that has a high G.T. absorbs less water and takes longer time to cook that rice with lower value. Rice that have low G.T. such as *japonica* varieties start to swell at a lower temperature during cooking than that rice having intermediate or high G.T. According to Juliano higher the cooking time, higher will be the starch final G.T. There is also the positive correlation of cooking time with surface area per grain. Cooking time also depends upon grain, thickness, length, 1000 kernel weight and alkali spreading value. The cooking time, which is required to gelatinize the centre of grains, is proved correlated highly with the final G.T., thus the alkali spreading value and surface area per grain (Bhattacharya *et al.,* 1982).

According to Juliano (1979) the volume expansion, water absorption and solids in gruel seems to related mutuality and are determined on large scale by amylose content of rice. According to Rao *et al* (1952) rice varieties with good quality have a high swelling number (water uptake ratio) and vice versa. This test is excellent quality indicator of rice (Bhandari, 1978). Increase in volume expansion and water absorption during cooking results from aging of freshly harvested rice regardless of storage form rough, brown or milled rice (Bhattacharya, 1971).

2.7.4.5 Solid in gruel

Gruel loss of the cooked rice contains starch, protein and non starchy polysaccharides. Water soluble vitamin (thiamin, riboflavin and niacin) may be partially lost during washing of the milled rice before boiling and in the cooking process, starch; protein and non starchy polysaccharides are lost when gruel is discarded (Aroullow *et al.,* 1972). The loss of solid into gruel is greater in raw rice than in parboiled rice. It is reported that the total solid in residual cooking liquid of non waxy rice are small but these of waxy rice are larger and this is considered as one of the cause of the stickiness of the latter's cooked rice (Ebata, 1987).

All the varieties have poor cooking quality immediately after harvest, on cooking they are about to become pasty, fail to swell, properly lose more solids in solution and fragmentation, the grains are more cohesive and have a tendency to disintegrate. These characteristics become progressively less with age (Grist, 1975). The stored rice needs longer time for coking, the volume expansion and water absorption increases and total solids in cooking water decreases as compared to fresh rice (He, 1989).

2.7.4.6 Kernel elongation ratio

Subrahmanyan (1959) mentioned that old rice increases in length much more than new rice without disintegration during cooking. Cracked grains expand more in length without cooking than uncracked grains (Desikachar & Subrahmanyan, 1961).

Japonica rice tends to elongate more than the short grain *indica* rice. High expansion on cooking is still considered to be a good quality by poor people, who do not care whether the expansion is lengthwise, is lengthwise or crosswise. Wealthy people on the other hand prefer varieties that expand more in length than the breadth. *Basmati* rice of India or Pakistan, *Bahara* of Afghanistan, *Dumsian* of Iran, *Bashful* of Bangladesh and D25-4 from Burma elongate 100% upon cooking (Khush *et al.,* 1979).

According to Puspamma & Reddy (1979), the elongation property of *Basmati* type rice also improves during storage and accompanies in volume expansion and water absorption during cooking of milled rice (Juliano, 1985). The stored rice needs longer time for cooking, the volume expansion and water absorption increases and total solids in cooking water decreases as compared to the fresh rice (He, 1989).

Fine, long and slender varieties elongate more than coarse and medium varieties. Elongation ratio varied from 1.21 to 1.84 (Acharya, 1991). According to Ban (1988), kernel elongation ratio was 1.11- 1.52 in length and 1.14-1.55 in breadth.

2.7.4.7 Volume expansion ratio

Volume expansion ratio is measured as bulk volume or as displacement volume using a hydrophobic solvent such as xylene. The increase in the height of cooked rice in a container of known dimensions is the usual index of volume expansion, expressed as the ratio of volume of cooked rice to volume of raw rice (Juliano, 1982). Volume expansion values below boiling water temperature are also used in differentiating into gelatinization temperature types, as in the water uptake number. Only low GT samples are completely gelatinized at $80^{o}C$ (Juliano, 1985).

According to Poudyal (1994), volume expansion ratio of '*Bans mansuli'* rice was 4.25 in raw 5.00 in stored and 3.25 in parboiled. Observation shows maximum in stored and minimum in parboiled rice.

2.7.4.8 Pasting characteristics

The pasting characteristic of starch or flour is determined by the Barbeder viscograph. The special point to be noted are : the gelatinization temperature (the temperature of initial rice in viscosity), the temperature and the value of peak viscosity, the fall in viscosity on cooking for 20 minutes (the breakdown) and the rise in viscosity on cooking to $50^{o}C$ (set back value). The set back value is dependent on the amylose content, a high amylose starch gives a high set back value and vice versa, this is due to retrogradation (Bhattacharya, 1971).

Rice starch granules contains both the amorphous and crystalline portions and commonly show a type of X-ray diffraction pattern that is related to the chain length of the amylopectin. The crystallinity of rice starch is about 38% as measured by the X-ray diffraction, which disappears after the starch are gelatinized. Therefore presence or absence of the crytallinity have been used as an index of the starch gelatinization. Starch granules contains both amylose and amylopectin, only amylopectin contributes to crytallinity of starch. The starch has shown that the starch crytallinity is based on closely packed outer chains of amylopectin of 12-18 glucose units (Maningat and Juliano, 1979).

Raw rice starch can be digested by some amylases. The degradation rate is dependent on the affinity of the amylase to starch granules. It was observed that amylase digested starch granules with the preference of amylose or the long chain of amylopectin are more resistant to degradation (He, 1989).

In general, a moderately high gelatinization temperature, a low peak viscosity and a high set back value (high amylose content) of rice flour are associated with good cooking qualities of the rice (Bhattacharya, 1971).

2.7.4.9 Gel consistency

A gel consistency test is based on the tendency of cooked rice gel (100 mg flour in 2 ml 0.2 N KOH) to flow. The gel consistency is classified on the basis of the thickness of the gel.

a. Soft (thickness 61-100mm).
b. Medium (thickness 41-60mm).
c. Hard (thickness 26-40mm).

Gel consistency is a good measure of gel viscosity of milled rice obtained with a Wells-Brookfield cone plate micro viscometer. Rice with a hard consistency harden faster during cooking, shown a higher amylograph set back, a higher gel viscosity and has lower level of water soluble amylose at 100^{o}C (Juliano, 1976). It has been found that amylose content and gel consistency are inversely related. In most of Asian countries high amylose rice with a soft gel consistency is preferred (Juliano, 1976).

A major factor affecting the gel consistency of rice is the lipid content of the rice sample. All brown rice give hard gel consistency and all defatted brown rice have soft gel consistency. Thus, degree of milling is an important factor affecting gel consistency, mainly from its effect on the fat content of the sample (Perez, 1979).

2.7.4.10 Starch iodine blue value

This is a rough and indirect method of measuring the amylose content of the rice. For this test, fine rice powder is extracted with hot water (75-100^{o}C) after which the filtrate is mixed with iodine and the blue colour is measured at 590-600nm.

This test indicates the fraction of total amylose soluble in simple water. However, only low G T samples are completely gelatinized, and high G T samples give very poor absorbance (high transmittance) readings (Juliano, 1985). It has been reported that, in a test using an extraction temperature of 99.5^{o}C, the starch iodine blue test (75 mg flour in 30 ml of water) gave absorbance values that correlated with amylose content of US rice varieties. When the test was used on rice representing all amylose types, some high amylose (>25%) rice showed lower soluble amylose levels than expected. Since, the phenomenon is independent of the water rice ratio; the low values must reflect in situ retrogradation of amylose (Juliano, 1985).

Unfortunately, it has been found that this fraction varies appreciably from variety to variety by six percentage point, due to environmental factors, temperature during ripening, nitrogen fertilizer and degree of milling. Higher water soluble amylose is associated with higher values however this test does not give a true and clear picture of the amylose content of the variety (Bhattacharya, 1971).

2.7.4.11 Alkali spreading and clearing score

This test measures the chemical solubility of starch and is widely used in rice quality research (Bhattacharya, 1979). This test gives highly significant relationship between cohesiveness of cooked samples and the extent of spreading and clearing of rice grain immersed in dilute alkali. The extent of disintegration or swelling of rice kernels in a given alkali solution can be determined by measuring G.T. of rice. Six kernels of rice are immersed in a 10ml of 1.7% KOH in a specially designed plastic box for 23 hrs in a constant temperature room. The extent of spreading and clearing of kernels is then determined by means of seven point score-card. The score correlate inversely with the G T (Simpson *et al.,* 1965) and this was confirmed by Juliano (1972). In 1972, Bhattacharya and Sowbhagya also observed that reasonable variation in time and temperature of the reaction did not affect the score. They used six kernels of rice soaked in 1.4% KOH in a 7 cm diameters petriplates at room temperature and reaction was noted the next day. Maningat and Juliano (1979) stated that 1.7% KOH gave the widest spreads of results; 1.4% KOH did not distinguish between high G.T. and intermediate G.T. sample. They suggested that 1.15% KOH could be used for low G.T. and 1.85% KOH for very high G.T. varieties. But in the modern opinion, 1.4% KOH gives the greatest spreads of scores among different varieties (Bhattacharya, 1979).

Bhattacharya *et al* (1978) observed that the alkali degradation correlates quite well with the amylose content of rice and other properties of stickiness (very low, very high), consistency (very high, very low) etc. Thus, this test apart from indicating the G T also gives a kind of spot test for overall quality of rice and later it was confirmed that alkali reaction was inversely related to the amylose content of rice and apparent solubility (Bhattacharya, 1979). Low G T samples show higher scores (Juliano 1985). Low G T rice disintegrates completely where as rice with intermediate G T shows only partial disintegration. Rice with high G.T. remains largely unaffected in the alkali solution. Although the G T and cooking time of milled rice are positively correlated (Juliano, 1967). G.T. does not correlate with texture of cooked rice (Khush *et al.*, 1979).

2.8 Cooking qualities of Nepalese rice varieties

Various laboratory of the world have been doing enormous work in the determination of cooking quality or rice. In Nepal, cooking quality test has been done by food testing laboratory Hetauda. Bhandari (1978) studied alkali scores, water uptake ratio, kernel elongation ratio of 42 varieties of rice including some early rice also. Variya, N-10, N-12, Pakistani fine, *Basmati* fine, Nagina etc. being fine varieties their water uptake ratio and kernel elongation ratio were high while alkali spreading and clearing score was low. Alkali spreading and clearing score for IR-8 was very high showing gluteneous rice.

In 1974, only amylose and alkali digestibility of ten varieties of Nepalese rice was examined at IRRI (Mallick, 1981). Bhattarai and Sitaula (1984) studied the cooking quality of *katkomal* and *Mansuli* variety respectively. In 1984, Shrestha studied in terms of alkali scores, water uptake ratio, kernel elongation ratio for twenty variety of rice including early rice. In his study the alkali spreading value observed maximum for *laxmi* (7), *Bindeswori* (7) and minimum for *Kanchan* (3, 4, 5); similarly clearing score 7 for both *Laxmi* and *Bindeswori* and minimum for *Kanchan*, CH-45, *Mallika* (2; 2,3; 2,3) respectively. Water uptake ratio obtained at the rate of 1.36 (Parwanipur-1) and maximum for *Mansuli* (2.41). Kernel elongation ratio observed maximum for *Sabitri* (1.18) and lower for Parwanipur-1 (1.0).

Shah (1985) studied only water uptake ratio of twelve commercial varieties of rice including early rice. According to him better cooking quality was observed in *Sabitri*, *Mansuli* and *Mallika*.

Limbu (1987) studied specially the cooking quality of sixteen varieties of rice available in Eastern region of Nepal, including alkali scores, water uptake ratio, kernel elongation ratio, starch iodine blue value, gruel loss and organoleptic test in *Agahani* rice. Ban (1988) studied the cooking quality of *Agahani* rice varieties available in Far Western region of Nepal using the parameters as Limbu's without organoleptic test.

Acharya (1991) studied the cooking quality of rice including some early rice of 36 varieties. P1429-89, M-41-2M-5, *Chaite* -4, *Khumal* -4, NR15016, IR-32307-107-3-2-2 and *Barkhe-2* had better cooking performance. Raut (2006) observed the cooking quality of four varieties of rice using the same parameters as that of Limbu (1987) and Ban (1988).

Table 2.9 Physicochemical properties of different verities of rice in different country

Variety	Country	Amylose %	Alkali Spreading	Gel Consistency (mm)	Water Uptake	Kernel elongation ratio	Source
Basmati 370	Pakistan	21.9	4.8	42	-	-	IRRI (1983)
Sind Basmati	Pakistan	25.4	7	37	-	-	IRRI (1983)
Jayai 77	Pakistan	20.8	5.6	38	-	-	IRRI (1983)
Mehran 59 rice	Pakistan	29.5	7	34	-	-	IRRI (1983)
I R-8	Pakistan	28.4	7	30	-	-	IRRI (1983)
Basmati 1	-	22.76	6.7	70	119.1 ml	1.95	Sharp (1986)
Basmati 2	-	24.53	6.7	56	117.3 ml	1.97	Sharp (1986)
Della AR	-	22.7	4.1	45	80 ml	1.36	Sharp (1986)
Della LA	-	23.16	2.9	56	73.8 ml	1.42	Sharp (1986)
Jasmine	-	18.2	6.8	77	30.4 ml	1.39	Sharp
Starbonet	-	22.68	3.1	51	75.1 ml	1.37	(1986)
Sinchu waxy	Taiwan	1.9	7	100	-	-	IRRI (1983)
Taiwan waxy 46	Taiwan	1.5	6.4	100	-	-	IRRI (1983)
Hung-Cheh-Chu	China	1.6	4.6	88	-	-	IRRI (1983)
Wu-Ko-Chu	China	1.5	6.4	100	-	-	IRRI (1983)

Source: Ban (1991)

Table 2.10 Physicochemical properties of different varieties of rice in Nepal

Varieties	Alkali Scores		Water uptake ratio	Kernel elongation ratio	Source
	Spreading	Clearing			
IR 24	6	4,5	1.68	1.03	Shrestha (1984)
Mallika	4	2,3	1.82	1.02	Shrestha (1984)
CH 45	4	2,3	1.62	1.02	Shrestha (1984)
PP 1	4,5	4,5	1.36	1	Shrestha (1984)
Laxmi	7	7	2.02	1.16	Shrestha (1984)
Chandina	5,6	5	2.04	1.11	Shrestha (1984)
Bindeshwari	7	7	2	1.11	Shrestha (1984)
Mansuli	6	4,5	2.08	1.82	Shrestha (1984)
Bindeshwari	2,3	1,2	1.9	1.19	Bhandari (1978)
CH 45	2	1	1.41	1.23	Bhandari (1978)
Chandina	2,3	1,2	1.64	1.15	Bhandari (1978)
Bansmati 3	1,2	1	1.6	1.22	Bhandari (1978)
Durga	-	-	2.27	-	Bhandari (1978)
Mallika	-	-	2.87	-	Shaha (1987)
Chandina	-	-	2.31	-	Shaha (1987)
CH 45	-	-	2.17	-	-
Bindeshwari	-	-	1.71	-	-
Laxmi	-	-	2.09	-	-
IR 24	4	2,3	1.78	1.36	Acharya (1991)
Mallika	2,3	1,2	2.3	1.38	Acharya (1991)
Chandina	-	-	2.16	1.33	Acharya (1991)
Laxmi	7	5,6	2.1	1.41	Acharya (1991)
Bindeshwari	6	4,5	1.98	1.45	Acharya (1991)
Chaite 2	2,3	1,2	2.2	1.39	Acharya (1991)
Durga	4	2,3	2.18	1.33	Acharya (1991)
Chaite 4	2	1	2.58	1.21	Acharya (1991)
CH 45	2,3	1,2	2.02	1.37	Acharya (1991)
Mansuli	2	1	3.14	1.03	Bhandari (1979)

Source: Pokharel (1991).

2.9 *Mansuli* and *Sona Mansuli* rice:

2.9.1 *Mansuli* rice:

This is the first popular *japonica* and *indica* cross variety. The parent is Mayang Ebos 80/2 X Taichung 65. This matures in 145 to 165 days. Its plant height is 135-140 cm. This is good for the medium fertility soil. The grain is fine, so liked by the farmers. This has the best grain quality among all the recommended high yielding varieties of Nepal. The straw is also liked by cattle. Its thousand kernels weight is 17 gm. This can be planted also as a second crop in double rice crop area.

The variety was selected in Malaysia from the F2 crosses received in 1956 from CFTRI under international hybridization programme of the international rice commission. This variety was released in 1956 in Malaysia and in 1973 in Nepal. This variety has been developed at Rice Research Station, Bukit Merah in Malaysia (Mallik, 1981/1982).

2.9.2 *Sona Mansuli* rice:

The *Sona Mansuli* rice is a late maturing variety than *Mansuli* rice. But the yield of this variety is better than *Mansuli*. It is cultivated in the Eastern and Central Terai region of Nepal especially in Bara, Parsa, Jhapa and Morang districts. *Sona Mansuli* rice has been cultivated in these areas for 6/7 years and was introduced in Nepal from the different parts of India. The unique character of this variety shows that the leaves remain green even though the grain has already been matured & dried. The *Sona Mansuli* rice has not been released in Nepal till now (it's a non released variety) because Agric. Scientists are facing a great problem with this variety. The rice plant suffers from a disease named 'sheath blight'. And scientists are involving in different research to get rid of the disease (Kandel, 2007).

Part III

Materials and methods

3.1 Materials

The two varieties of rice namely *Mansuli* and *Sona mansuli* were collected from different areas of Eastern and Central Terai region of Nepal including godown of Nepal Food Corporation. The samples collected were of crop year 2063. i.e. new crop for the year.

3.2 Sampling procedure

For the collection of samples from different areas simple random sampling technique was followed and required amount of working sample was derived. Ten samples of each variety were purchased/collected; stored in polyethylene bag at room temperature of CCT, Hattisar, Dharan laboratory and hence, twenty samples in total were analyzed for the different parameters.

Sample coding was done as A, B, C, D, E, F, G, H, I, J for *Manuli* rice and N, O, P, Q, R, S, T, U, V, W for *Sona Mansuli* rice. The details of the samples are given in appendix B.

3.3 Methods

3.3.1 Physical measurements of rice

3.3.1.1 Appearance/colour

Colour of the rice samples were observed visually.

3.3.1.2 Moisture content

In this work, moisture content was determined by hot air oven method. Triplicate sample of rice was ground and 3 gm of each was taken. Then it was heated in hot air oven (Ambassador, Laboratory Electric oven, 220/230 volt, 600 watt) at $130^0C \pm 3^0C$ for one hour for all the samples. The sample was removed and placing it on desiccator for some time weight was taken and m. c. was calculated as followed by Sitaula, (1984).

3.3.1.3 Thousand kernels weight

Thousand kernels were counted from the sample and weight was determined using the electronic balance (MP series electronic balance, Shanghai Hengping Scientific Instrument co.

ltd., China; weighing capacity: 200gm; readability: 0.01 gm; repeatability $\leq \pm 0.01$ gm; linearity: $\leq \pm 0.02$ gm) and expressed in grams.

3.3.1.4 Bulk density

Bulk density was determined by using bushel weight tester (Seed Bureau Equipment company, 1022- W, Jackson BLDV, Chicago, 60607, 312738-700 ohaus) and expressed in Kg/Hl. The instrument gave direct weight per hectoliter.

3.3.1.5 Length breadth ratio

Length and breadth measurement was done by using a special device for the rice known as rice caliper or slide caliper. L/B ratio was then calculated by using data obtained.

3.3.2 Standardization and correction of data

Since, different samples of rice have different moisture content; the values of bulk density and thousand kernels weight were expressed at moisture content 12% (wb) i.e. 13.36% (db) using the following expression:

DM = (100-y) W/100………............................i

Z = (X.DM)/(100-X)……...............................…ii

Corrected wt. of rice = Z+DM

Where,

W = initial weight

X = %final moisture content

Y = %initial moisture content

DM = Dry matter

Z = water content in the sample at X as in the final moisture content.

3.3.3 Cooking quality of rice

3.3.3.1 Cooking time

Minimum cooking time was determined by method of Ranghino (1966). Starting after 10 min of cooking in boiling water at least 10 grains were pressed between two glass plates every minute. Cooking time was evaluated when 90% of the grains no longer showed an opaque centre. Then optimum cooking time was calculated as minimum cooking time plus 2 minutes.

3.3.3.2 Alkali spreading and clearing scores

Six kernels of each rice samples were spread in a petridish resting on a black surface containing 25 ml of 1.5% KOH solution and left undisturbed for 24 hours at room temperature. Then the sample was scored for spreading and clearing according to seven point scales as shown as follows (Bhattacharya, 1971).

Table 3.1 Alkali spreading scale card

Scale	Spreading	Clearing
1	Kernel not affected	Kernel Chalky
2	Kernel swollen	Kernel Chalky, collar powdery
3	Kernel swollen; collar incomplete or narrow	Kernel chalky; collar cottony and cloudy
4	Kernel swollen; collar complete and wide	Center cottony; collar cloudy
5	Kernel split or segmented; collar complete and wide	Center cotton; collar clearing
6	Kernel dispersed; merging with collar	Center cloudy; collar clearing
7	Kernel completely dispersed and intermingled	Center and collar cleared

3.3.3.3 Water uptake ratio or swelling no.

a. Water uptake at 80^{o}C

About 5g milled rice was poured into a test tube having internal dia. 2-3cm containing 28 ml water which was arranged in 80^{o}C serological water bath (Vinay Trading co., D. C. road, Ambala Cantt, India; temp. range:(30-110^{o}C) for 15 minutes. Then the cooked rice was immediately washed once with about 25 ml cooled distilled water stirring with bent wire to minimize over cooking. Then the liquor was drained into tarred crucible for the determination of gruel loss. The excess water remained in the cooked rice sample was reduced by gentle pressing with hand in between the filter paper. It was immediately weighed in electric balance (MP series electronic balance, Shanghai Hengping Scientific Instrument co. ltd., China; weighing capacity: 200gm; readability: 0.01 gm; repeatability $\leq \pm 0.01$ gm; linearity $\leq \pm 0.02$ gm) and then water uptake was determined as:

Water uptake at 80^{o}C = weight of cooked rice/weight of uncooked rice

b. Water uptake at 96^oC

The above same procedure was followed except the temperature of water 96^oC (boiling point at Dharan) instead of 80^oC.

Water uptake at 96^oC = weight of cooked rice / weight of raw (uncooked) rice

Water uptake ratio = water uptake at 80^oC/ water uptake at 96^oC.

3.3.3.4 Gruel loss or solid in gruel

The gruel liquor obtained during the experiment for water uptake was drained on tarred crucible and was placed into the hot air oven (Universal hot air oven, Navyug, India; temp. range: 30-250^oC) at 100°C for 24 hours. The weight of the residue was measured with the help of electronic balance (MP series electronic balance, Shanghai Hengping Scientific Instrument co. ltd., China; weighing capacity: 200gm; readability: 0.01 gm; repeatability ≤ ±0.01 gm; linearity: ≤ ±0.02 gm). Then the gruel loss (dry wt. basis) was determined and expressed the value after correction in %. The data correction was done as:

$$\%\ \text{gruel loss} = \frac{\text{Weight of the residue (dry)}}{\text{Dry weight of sample}} \times 100$$

Dry weight of sample = weight of sample taken - weight of moisture in the sample.

3.3.3.5 Starch iodine blue value (SIBV)

Ground rice sample was passed through a simple sieve and 1 gm powder was transferred to a 250 ml Erlenmeryer flask. 100 ml distilled water (dw) was added and the flask was immersed into serological water bath at 77°C for 15 minutes. The flask was removed from water bath and allowed to stand for 15 minutes at room temperature. It was filtered through whattman no 42 filter paper. First 30-40 ml of filtrate was discarded. 10 ml aliquot of the filtrate was pipetted into 100 ml volumetric flask containing 1 ml 30% HCL and 1 ml of iodine solution (prepared by dissolving 2 gm iodine in 1 litre solution of KI). Then 60 to 70 ml distilled water was added, shaken well and final volume was made up to the mark with distilled water. It was allowed to stand for 30 minutes at room temperature. The intensity of the blue colour was determined in spectrophotometer (Systronics spectrophotometer 105, range: 340-960 nm) at 620nm and optical density was recorded. In the instrument, the percentage of transmittance was set at 100 with blank (100 ml together with 1 ml HCL solution, 1 ml iodine solution and distilled water).

3.3.3.6 Kernel elongation ratio

Twenty kernels of each rice sample were taken and their length and breadth was measured with the help of rice calipers and poured into a test tube having (2-3) cm internal diameter containing 25 ml of distilled boiling water. It was then placed in water bath (Vinay Trading co., D. C. road, Ambala Cantt, India; temp. range: 30-110^{o}C) for 15 minutes.

The cooked kernels were taken out and placed on blotting paper with the help of bent wire to absorb excess water. The length and breadth of cooked kernels were measured by spacing on graph paper. The kernel elongation ratio was calculated as:

Lengthwise KER = length of cooked kernels/ length of raw kernels

Breadthwise KER = breadth of cooked rice/ breadth of raw kernels.

3.3.3.7 Volume expansion ratio

For the determination of volume expansion ratio, 10 ml hydrophobic solvent (xylene) was taken in a 100 ml graduated cylinder, 5 gm of rice sample was poured into it and the increase in the level of hydrophobic solvent in cylinder was recorded.

Hence, initial volume of rice sample = (final level of hydrophobic solvent - initial level of hydrophobic solvent) = x cc.

Same procedure was repeated for the cooked sample and the volume of cooked rice sample was noted.

Volume of cooked sample = (final level of hydrophobic solvent - initial level of hydrophobic solvent) = y cc.

Thus, Volume expansion ratio = Vol. of cooked sample of rice (y) /vol. of raw sample of rice(x).

3.3.4 Data analysis

The experimental data were analyzed with the help of computer's inbuilt Excel program by using the t- test. That is the test statistic for comparing means from two independent lots in case of small sample (n<30) at 5 % level of significance.

Part IV

Results and discussion

4.1 Physical characteristics of rice

All the samples were analyzed to evaluate the physical characteristics such as appearance, moisture content, thousand kernels weight, bulk density, L/B ratio. The results obtained are presented in the Table A.1 and A.2, Appendix A.

4.1.1 Appearance/colour

The colour of both *Mansuli* and *Sona Mansuli* rice was clear white translucent. The colour of *Mansuli* rice matched with the observation of Sitaula (1984), Limbu (1987), Ban (1988) and Poudel (1998). And no any distinct difference was observed visually between the colour of two variety of rice samples.

4.1.2 Moisture content

Moisture content (wet basis) of the *Mansuli* rice was found to be (12.18±0.68) % in an average. Similarly, in case of *Sona Mansuli* rice the average moisture content (wet basis) was found to be (13.04±0.52) %. The moisture content was higher for *Sona Mansuli* rice than that of *Mansuli* rice (fig no.4.1).

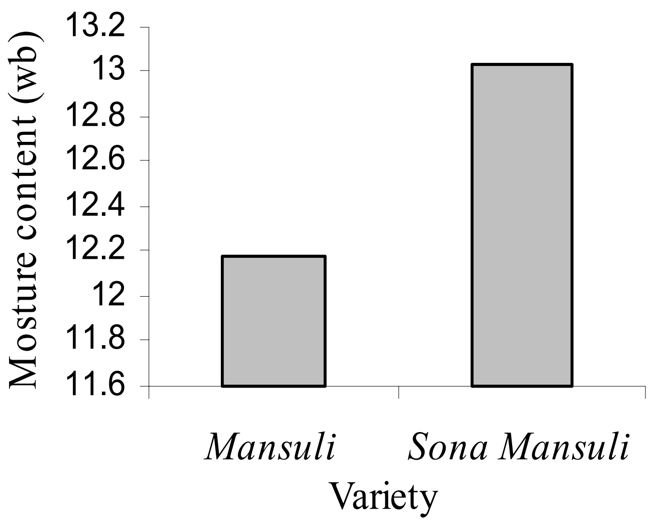

Fig 4.1 Moisture content of two varieties of rice

Moisture content of *Mansuli* rice is slightly lower than the observation of Sitaula (1984) and Limbu (1987); slightly higher than that of Ban (1988) and Poudel (1998).

The statistical analysis showed that there is significance difference between the moisture content of the two varieties of rice at 5% level of significance (Table C.5, Appendix C).

The maximum tolerable limit for moisture content in case of rice is 14% (Nepal Standard no. 282-2049; Nepal Food Corporation, 2062). The growth of microorganisms gets retarded and then spoilage is minimized at low moisture content. The lower the moisture content, the better the storability of rice (Pillayer, 1988).

Here, moisture content of both varieties was found to be within the standard of NFC and Nepal Bureau of Standard and Metrology (NBSM).

4.1.3 Thousand kernels weight

The average thousand kernels weight after standardization to 12% moisture content (wet basis), for the *Mansuli* rice was (13.09±0.51) gm. Similarly it was found to be (14.68±0.53) gm for *Sona Mansuli.*

Thousand kernels weight of *Mansuli* rice was slightly lower than the observation of Limbu (1987); slightly higher than that of Poudel (1998), Sitaula (1984) and Ban (1988). The slight variation in the result may be due to different factors such as agronomy characteristics, moisture content, maturity days, fertilizer used etc.

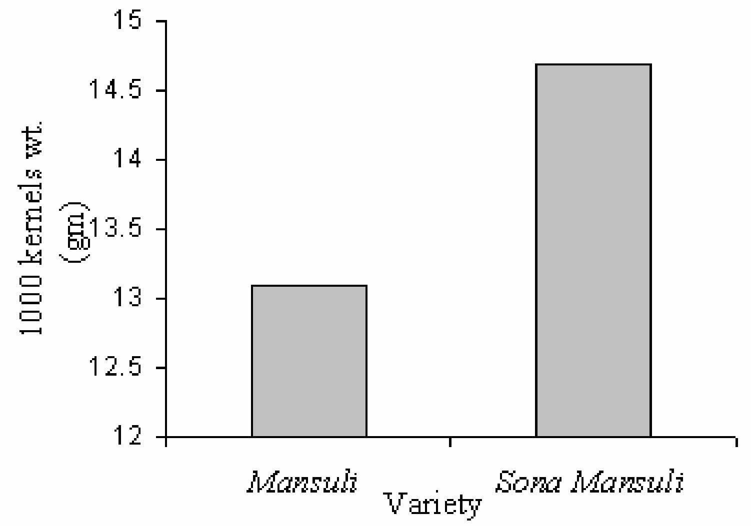

Fig 4.2 1000 kernels weight of the rice samples

For *Sona Mansuli* it was found to be slightly higher than *Mansuli* (Fig 4.2). Statistical analysis showed that there is significant difference between the thousand kernels weight of these two varieties at 5% level of significance (Table C.6 Appendix C).

The result indicated that both of these varieties fall on the moderately heavy class according to FAO (1972).

4.1.4 Bulk density

The bulk density after standardization to 12% moisture content (wet basis) was (78.88±1.42) Kg/Hl and (77.91±1.47) Kg/Hl for *Mansuli* and *Sona Mansuli* rice respectively.

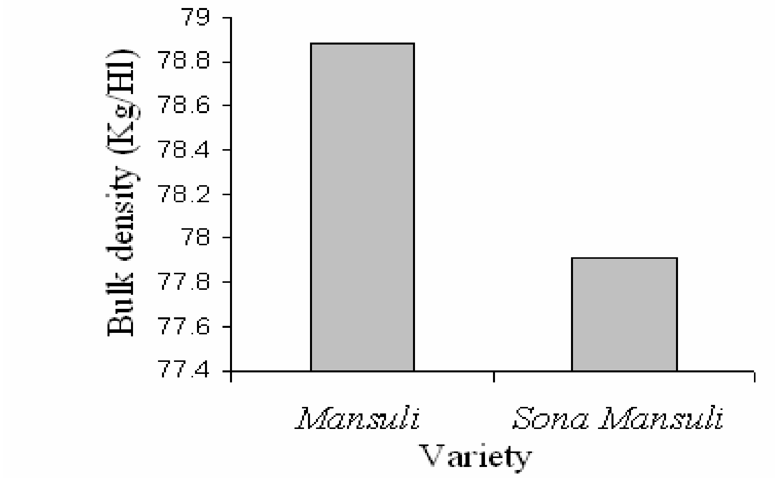

Fig 4.3 Bulk density of the two variety of rice

The bulk density for *Mansuli* rice is lower than the observation of Sitaula (1984), slightly higher than that of Limbu (1987) and meets the observation of Ban (1988) and Poudel (1998).

The bulk density value for *Sona Mansuli* is lower than that of *Mansuli* rice (fig 4.3).This may be due to the shape of the *Sona Mansuli* rice kernel because it has more elongated dimension than *Mansuli* rice kernels. Other factors may be the variety, chemical composition, and the structure of the starch granules in the grain. Statistical analysis showed that there is not significant difference between these two varieties at 5% level of significance (Table C.7, Appendix C).

4.1.5 Size

Average length of *Manuli* rice was found as (5.21±0.061) mm. In case of average breadth it was found as (2.02±0.047) mm. For *Sona Mansuli* rice, average length was found to be (5.34±0.065) mm and average breadth was (2.05±0.042) mm.

Average thickness was (1.49±0.041) mm for *Mansuli* and (1.55±0.029) mm for *Sona Mansuli* rice. On the basis of NFC standard (2062) the length and breadth of *Mansuli* rice should be in the range of 5.0-6.0 mm and 2.0-2.2mm respectively. The length and breadth of analyzed *Mansuli* rice sample was according to the NFC standard.

According to United States Department of Agricultural workers scale and FAO, the *Mansuli* and *Sona Mansuli* both fell on the medium class.

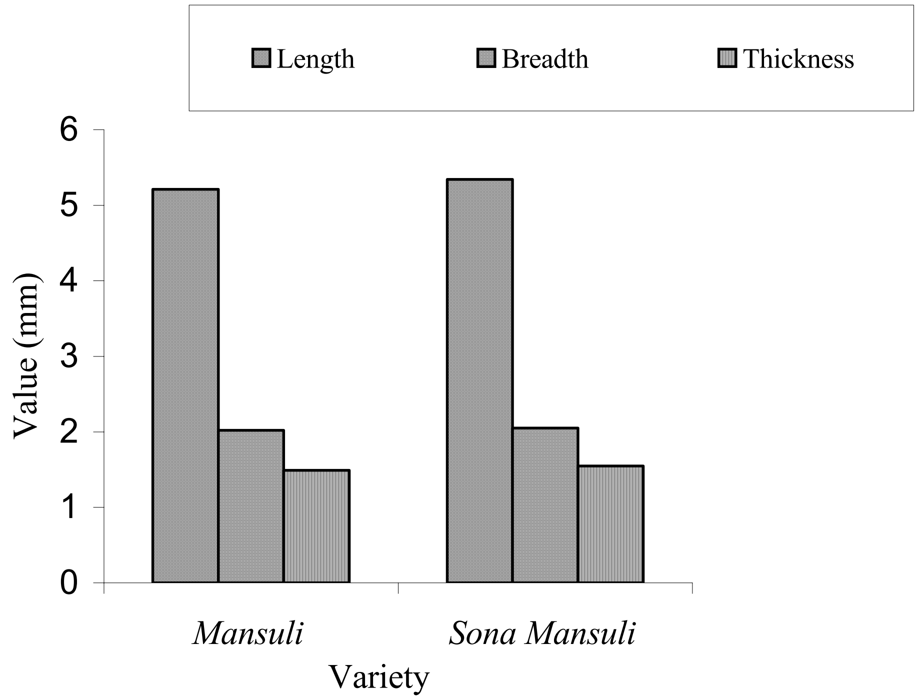

Fig 4.4 Length, breadth and thickness of the rice kernels of the two varieties

The average thickness of *Mansuli* rice was lower than *Sona Mansuli* rice (fig 4.4). The statistical analysis showed that there is significant difference between length and thickness of both varieties at 5% level of significance. But there is no such difference in case of breadth (Table C.1, C.2, C.3, Appendix C).

4.1.6 Shape

The L/B ratio of the *Mansuli* rice was (2.58±0.056) which is lower than the value for *Sona Mansuli* rice i.e. (2.60±0.041) (fig.4.5). Both of these varieties fell upon the medium grain variety. The observation for *Mansuli* rice also meets the classification of NFC (2062).

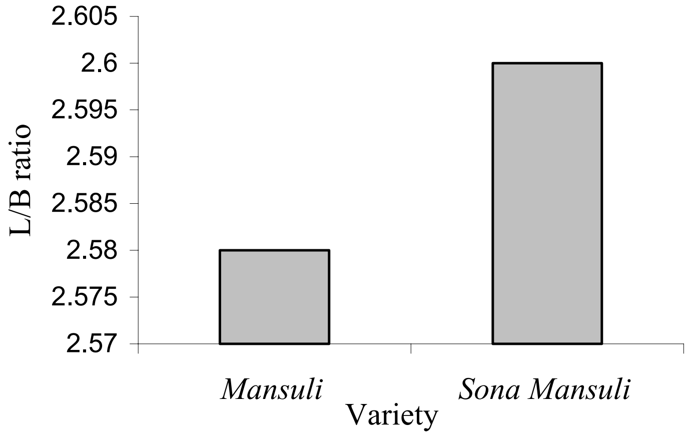

Fig 4.5 Length breadth ratio of the two variety of rice

Statistical analysis showed that there is no significant difference at 5%level of significance between these two varieties in terms of L/B ratio. Size and shape are important in grain marketing including milling, transportation and storage. Normally it is assumed that higher the L/B ratio better will be the quality of rice (Pokharel, 1991).

4.2 Physicochemical characteristic of rice

The physicochemical characteristics of rice are mainly related to the cooking quality. The important cooking quality parameters examined were cooking time, alkali digestion characters, water uptake ratio, gruel loss, starch iodine blue value, kernel elongation ratio and volume expansion ratio. The results obtained are given in Table A.3 and A.4, Appendix A.

4.2.1 Cooking time

The optimum cooking time for the *Mansuli* rice was (15.47±0.66) minutes in an average. Similarly, for *Sona Mansuli* rice, it was (13.68±0.71) minutes.

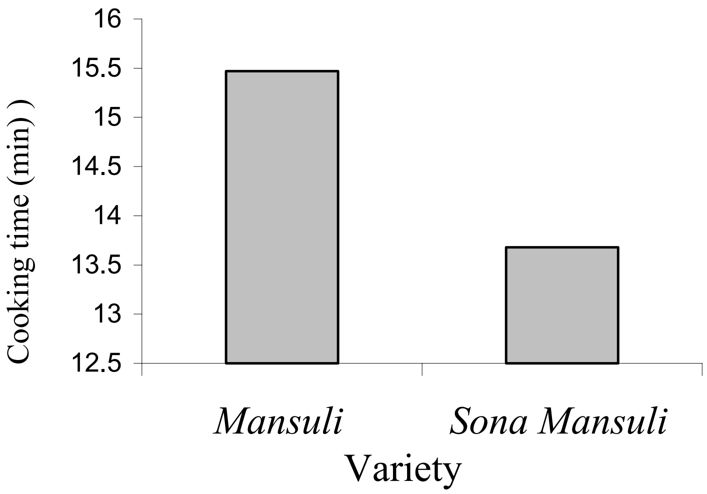

Fig 4.6 Optimum cooking time for the two varieties of rice

The cooking time determined was higher for *Mansuli* rice than that of *Sona Mansuli* rice (fig 4.6). Statistical analysis showed that there is significance difference between the cooking time of the two varieties at 5% level of significance (Table C.8, Appendix C).

It is correlated as lower the cooking time higher will be the cooking quality. According to Juliano, higher the cooking time higher will be the final starch gelatinization temperature (GT). There is also a positive correlation of cooking time with surface area per grain.

Cooking time depends upon age of rice, the materials, methods used during experiment, because the heat source and heat transformation from the glass wares, quantity of rice, dimensions of tubes etc. differs the result (Sitaula, 1984).

4.2.2 Alkali spreading and clearing scores

The alkali spreading and clearing score were found to be 2, 3 and 2 respectively for all the *Mansuli* and *Sona Mansuli* rice samples.

The observation on alkali spreading and clearing score shows that there is no any distinct difference between the *Mansuli* and *Sona Mansuli* rice because same type of result were obtained on both samples.

The alkali digestion values have been employed as an estimate of gelatinization temperature. Generally, alkali spreading and clearing values are negatively correlated with GT (Bhandari, 1979).

According to Bhattacharya (1971) high amylose content is usually associated with non sticky (integral type) cooking characteristics and vice versa.

4.2.3 Water uptake ratio or swelling no.

The average water uptake ratio for *Mansuli* rice sample was (0.49±0.023). For *Sona Mansuli* rice it was (0.55±0.0.26).

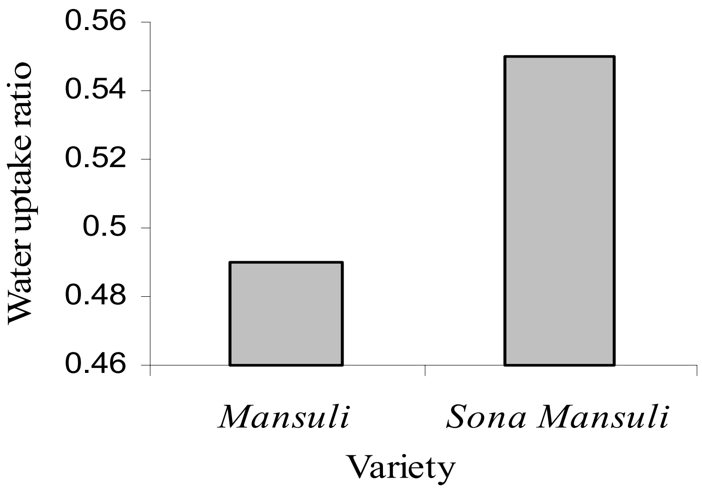

Fig 4.7 Water uptake ratio of the two varieties of rice

The water uptake ratio determined was found to be lower for *Mansuli* rice than that of *Sona Mansuli* rice (fig 4.7). Statistical analysis showed that there is significant difference between the water uptake ratio of these two varieties of rice at 5% level of significance (Table C.9, Appendix C).

The water uptake ratio obtained for *Mansuli* rice is lower than the value observed by Ban (1988) and meets the observation of Poudyal (1994) for *Bans Mansuli*. The lower value obtained here may be due to the new crop used which couldn't absorb more water during cooking.

According to Bhattacharya and Sowbhagya, variation in water uptake may be caused by different extraneous factors such as surface area, chalkiness, cracked kernels and protein content (Pokharel, 1991).

Water uptake ratio depends upon duration of storage of paddy and genetic characteristics e.g. amylose/amylopectin ratio of particular variety (Shah, 1987).

Generally it is assumed that higher the water uptake ratio better will be the quality of rice. Here, it is found to be higher in case of *Sona Mansuli* rice.

4.2.4 Gruel loss or solid in gruel

The percentage solid in gruel or gruel loss was (3.05±0.62) % and (3.22±1.04) % for *Mansuli* and *Sona Mansuli* rice respectively.

Gruel loss was found to be higher for *Sona Mansuli* rice as compared to the value obtained for *Mansuli* rice (fig 4.8). Statistical analysis showed that there is no significant difference between the percentage gruel loss at 5% level of significance (Table C.13, Appendix C..).

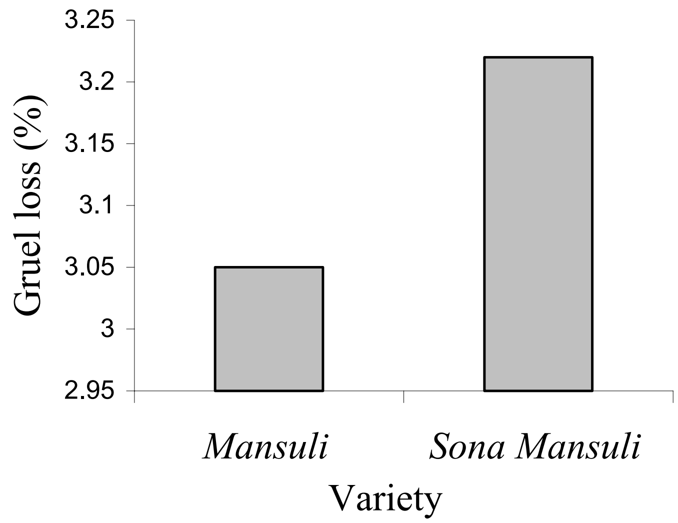

Fig 4.8 Gruel loss (%) for the two variety of rice

Higher loss of gruel is associated with poor cooking quality. The total solid in residual cooking liquid of *indica* rice (non pasty) is small but those of *japonica* rice (pasty) is large and it is considered as one of the stickiness of the latter's cooked rice. Nepalese people consider the quality of rice to be good if the loss of gruel is minimum (Ban, 1988). In this case lower values obtained for *Mansuli* rice indicates the better quality for *Mansuli* rice when compared to *Sona Mansuli* rice.

4.2.5 Starch iodine blue value (SIBV)

Starch Iodine Blue value expressed as optical density at 620 nm was observed as (0.28±0.028) for *Mansuli* rice in an average. For *Sona Mansuli* rice it was (0.46±0.029).

Fig 4.9 Starch iodine blue value (expressed as O.D.) for the two varieties of rice

In this study, SIBV was found to be higher for *Sona Mansuli* rice when compared to *Mansuli* rice (fig 4.9). The data obtained for *Mansuli* rice matches the observation of Ban (1988), slightly higher than that of Limbu (1987) and slightly lower than that of Sitaula (1984).

The statistical analysis showed that there is significant difference at 5% level of significance between the two varieties of rice (Table C.14, AppendixC).

The SIBV reflects the water soluble amylose content as a percentage of total amylose (Limbu, 1987). It is a rough and indirect method of measuring the amylose content of rice. Amylose is more soluble in hot water than amylopectin (Juliano, 1979).

4.2.6 Kernel elongation ratio

The lengthwise KER for *Mansuli* rice samples in an average was (1.53±0.09). Similarly, the average breadthwise KER was (1.38±0.06).

For *Sona Mansuli* rice, lengthwise KER was (1.51±0.08) and breadthwise KER was (1.45±0.06). Lengthwise KER was higher for *Mansuli* rice when compared to *Sona Mansuli* rice. Similarly, breadthwise KER was higher for *Sona Mansuli* rice in comparison to *Mansuli* rice (Fig 4.10).

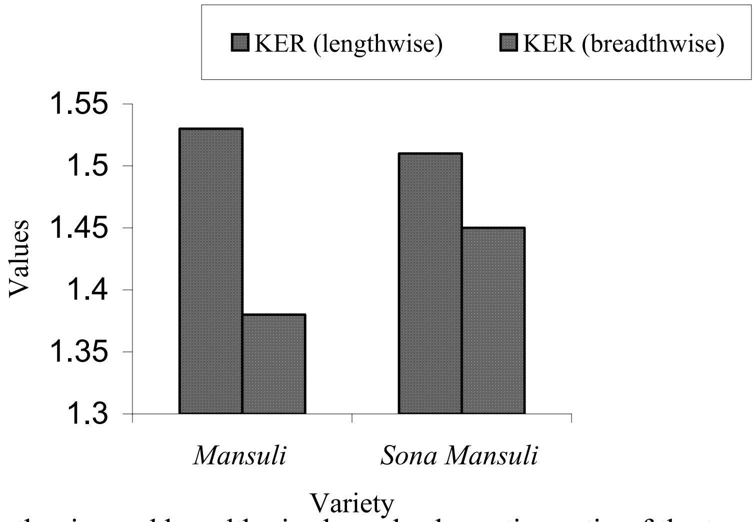

Fig 4.10 Length wise and breadthwise kernels elongation ratio of the two varieties of rice

Statistical analysis showed that there is no any significant difference at 5% level of significance between these two varieties in terms of both lengthwise and breadthwise KER (Table C.10 and C.11, Appendix C).

Nepalese people considered the quality of rice to be better if the KER is high. This is also found directly related to good cooking quality of rice in many part of the world (Pokharel, 1991).

4.2.7 Volume expansion ratio

The average VER obtained for the *Mansuli* rice sample was (3.60±0.27). Similarly, for *Sona Mansuli* rice it was (3.17±0.19). The VER was found to be higher for *Mansuli* rice than *Sona Mansuli* rice (fig 4.11).

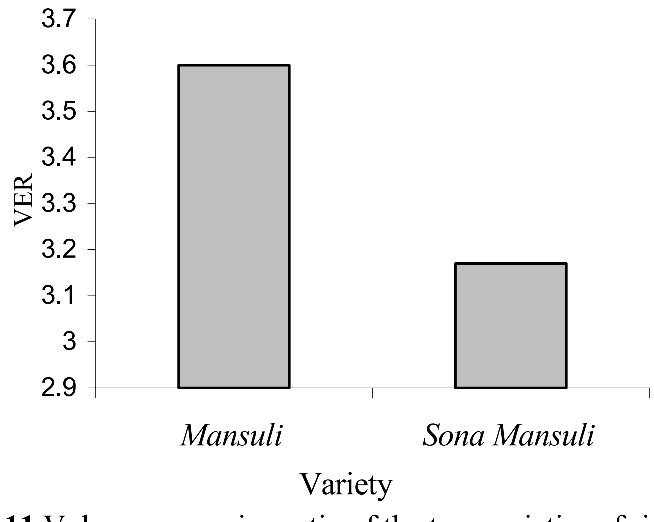

Fig 4.11 Volume expansion ratio of the two varieties of rice

The statistical analysis showed that there is significant difference between VER of these varieties of rice at 5% level of significance (Table C.12, Appendix C).

In the same way as water uptake ratio, VER is also a vital tool for differentiating the rice varieties into GT types. Higher the VER higher will be the cooking quality. The aromatic type of rice exhibits the good cooking characteristics such as grain elongation and VER during cooking (Juliano, 1979).

In this work, the higher VER for *Mansuli* rice indicates its better cooking quality as compared to *Sona Mansuli* rice.

Part V

Conclusions and recommendations

5.1 Conclusions

On the basis of work conducted the following conclusions can be deduced:

1. According to FAO (1972) size classification *Mansuli* and *Sona Mansuli* rice both fall on under the medium class. According to FAO (1972), based on the thousand kernels weight, both of these varieties fall on the moderately heavy class.
2. *Sona Mansuli* requires less time for cooking than *Mansuli* rice and lower alkali digestion values obtained for both varieties, concludes to be their higher gelatinization temperature.
3. *Sona Mansuli* rice has higher water uptake ratio, gruel loss and starch iodine blue value (SIBV), but lower kernel elongation ratio (KER) and volume expansion ratio (VER) than *Mansuli* rice.
4. The two varieties *Mansuli* and *Sona Mansuli* rice significantly differ from each other in terms of thousand kernels weight (13.09 & 14.68), length (5.21 &5.34 mm), thickness (1.49 & 1.55mm) of kernels respectively but don't differ significantly in terms of appearance, bulk density, breadth of kernels and L/B ratio.
5. Regarding the different cooking quality parameters there is significant difference between *Mansuli* and *Sona Mansuli* rice in case of cooking time (15.47 &13.68 min), water uptake ratio (0.49 & 0.55), starch iodine blue value (0.28 & 0.46) and volume expansion ratio (3.60 & 3.17) respectively but don't show significant difference in case of alkali digestion character, gruel loss and KER.

5.2 Recommendations

1. Nutritional and milling quality of two varieties could be studied.
2. Comparative study on the amylose content between the *Mansuli* and *Sona Mansuli* rice could be done.
3. Changes on the different quality parameters between *Mansuli* and *Sona Mansuli* rice during long term storage could be studied.

Part VI

Summary

Rice is the world's most important food crop. More than 90% of the world's rice is grown and consumed in Asia, where more than half of the world's population live and where nearly 80% of the world's poor are concentrated. Hence, the quality of rice plays vital role for the healthy life of a lot of people in the world and same is important for the large population of Nepal.

Mansuli variety of rice is popular among the people of Nepal due to its different quality parameters. At the same time, *Sona Mansuli*, which is similar in many quality parameters with *Mansuli*, is available in market with some lower price than *Mansuli*. Hence, present work is concerned with the comparative study of these two varieties regarding the cooking characteristics.

For the study, samples of the two varieties were collected from different parts of Eastern and Central Terai region of Nepal. Simple random sampling technique was followed for the collection of new crop of each rice sample. All the sample were analyzed separately taking the different quality parameters into consideration such as color, moisture content, thousand kernels weight, bulk density, L/B ratio, cooking time, alkali digestion character, water uptake ratio, gruel loss, starch iodine blue value (SIBV), kernel elongation ratio(KER) and volume expansion ratio (VER).

On the basis of physical parameters, both varieties have same white color and *Mansuli* rice has higher bulk density than *Sona Mansuli* rice. In case of cooking quality parameters, *Mansuli* rice has higher cooking time, lengthwise KER and VER than *Sona Mansuli* rice. And *Sona Mansuli* rice has higher value for the rest of the parameters studied.

From the work carried out it was observed that there is significant difference between these two varieties regarding the quality parameters such as thousand kernels weight, length, thickness of kernels, cooking time, water uptake ratio, SIBV & VER. But, in the same case *Mansuli* and *Sona Mansuli* rice don't differ significantly from each other on the basis of color, bulk density, L/B ratio, alkali digestion character, gruel loss & kernel elongation ratio.

Hence, by keeping in mind about these above mentioned parameters we can have a proper identification between these two varieties of rice.

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APPENDICES

Appendix A

Table A.1 Physical parameters for *Mansuli* rice

Sample	Length (mm)	Breadth (mm)	Thickness (mm)	L/B ratio	M.C. (wb)	Corr.1,000 kernels wt.	Corr. Bulk density (Kg/Hl)
A	5.18	2.01	1.52	2.613	11.36	12.751	79.449
B	5.18	2.03	1.53	2.554	12.20	13.109	78.776
C	5.24	2.01	1.43	2.60	11.16	12.416	81.142
D	5.18	2.10	1.48	2.47	12.30	14.311	77.534
E	5.16	2.02	1.52	2.552	12.62	12.938	78.364
F	5.33	2.10	1.54	2.542	12.19	13.730	79.647
G	5.15	1.93	1.44	2.674	11.73	12.799	78.901
H	5.20	2.03	1.52	2.561	11.77	12.973	81.071
I	5.30	2.01	1.52	2.655	13.02	13.175	77.224
J	5.17	1.98	1.43	2.605	13.51	12.776	76.720
Mean ± s.d.	5.21 ± 0.06	2.02 ± 0.04	1.49 ± 0.04	2.58 ± 0.05	12.18 ± 0.68	13.09 ± 0.51	78.88 ± 1.42

Table A.2 Physical parameters for *Sona Mansuli* rice

Sample	Length (mm)	Breadth (mm)	Thickness (mm)	L/B ratio	M.C.(wb)	Corr.1,000 kernels wt.	Corr. Bulk density (Kg/Hl)
N	5.23	1.99	1.55	2.626	12.97	14.370	77.537
O	5.36	2.06	1.59	2.60	13.00	14.730	77.115
P	5.32	2.04	1.52	2.607	13.07	14.382	77.110
Q	5.35	2.02	1.54	2.648	13.16	14.732	77.657
R	5.33	2.07	1.58	2.578	13.59	14.629	76.743
S	5.43	2.05	1.52	2.649	12.68	14.745	78.816
T	5.42	2.16	1.59	2.507	12.64	15.843	78.852
U	5.23	2.03	1.57	2.57	12.10	13.583	81.662
V	5.38	2.04	1.59	2.637	13.01	14.956	77.460
W	5.38	2.05	1.52	2.622	14.16	14.885	76.241
Mean ± s.d.	5.34 ± 0.06	2.05 ± 0.04	1.55 ± 0.02	2.60 ± 0.04	13.04 ± 0.52	14.68 ± 0.53	77.91 ± 1.47

Note: Every value is the means of at least three observations

Table A.3 Cooking quality parameters for *Mansuli* rice

Sample	Optimum Cooking time(Min.)	Water uptake ratio	KER		VER	Gruel loss (%)	SIBV (as O.D.)	Alkali Scores	
			(lenghthwise)	(bredthwise)				Spreading	Clearing
A	16.00	0.4687	1.4498	1.4120	3.50	3.38	0.32	2	2
B	15.00	0.4678	1.5115	1.4088	4.00	2.96	0.31	2	3
C	15.83	0.5294	1.5954	1.2835	4.00	2.02	0.33	2	2
D	15.36	0.5194	1.6930	1.4523	3.50	2.73	0.26	3	3
E	16.00	0.4814	1.6434	1.3912	4.00	2.51	0.28	2,3	2
F	16.38	0.4848	1.4727	1.2904	3.25	3.87	0.26	3	2
G	15.83	0.4610	1.5320	1.5336	3.50	3.39	0.24	3	2
H	15.58	0.5000	1.6346	1.3842	3.50	2.26	0.26	2,3	2
I	14.71	0.5200	1.4135	1.3830	3.25	3.44	0.27	2,3	2
J	14.06	0.4836	1.4139	1.3484	3.50	3.93	0.29	2,3	2
Mean ± s.d.	15.47 ± 0.66	0.49 ± 0.02	1.53 ± 0.09	1.38 ± 0.06	3.60 ± 0.27	3.05 ± 0.62	0.28 ± 0.028	2,3	2

Note: Every value is the means of at least three observations

Table A.4 Cooking quality parameters for *Sona Mansuli* rice

Sample	Optimum Cooking time(Min.)	Water uptake ratio	KER		VER	Gruel loss (%)	SIBV (as O.D.)	Alkali Scores	
			(lenghthwise)	(bredthwise)				spreading	clearing
N	14.25	0.5000	1.5411	1.4924	3.25	2.52	0.46	2,3	2
O	14.69	0.5517	1.5690	1.4902	3.00	1.60	0.50	2,3	2
P	13.61	0.5342	1.6522	1.5049	3.50	3.22	0.44	2,3	2
Q	13.45	0.5766	1.5962	1.4554	3.50	2.99	0.47	2,3	2
R	12.21	0.5500	1.5572	1.4879	3.25	4.16	0.40	2,3	2
S	14.65	0.5833	1.4088	1.2585	3.00	2.97	0.44	2,3	2
T	13.40	0.5324	1.4557	1.4351	3.25	4.57	0.48	2,3	2
U	14.16	0.5877	1.5315	1.4975	3.00	1.59	0.45	2,3	2
V	13.33	0.5757	1.4349	1.4950	3.00	4.59	0.50	2,3	2
W	13.16	0.5481	1.3903	1.4390	3.00	3.96	0.48	2,3	2
Mean ± s.d.	13.68 ± 0.71	0.55 ± 0.02	1.51 ± 0.08	1.45 ± 0.06	3.17 ± 0.19	3.22 ± 1.04	0.46 ± 0.029	2,3	2

Note: Every value is the means of at least three observations

Appendix B

Table B.1 Details of *Mansuli* rice samples

Code	Details	
A	Production Area	Morang/Sunsari
	Crop year	2063 B.S.
	Sample drawn	From NFC, Thapathali, Ktm.
B	Production Area	Saptari (Lahan)
	Crop year	2063 B.S.
	Sample drawn	From NFC, Thapathali, Ktm.
C	Production Area	Gauriganj, Jhapa
	Crop year	2063 B.S.
	Sample drawn	From market
	Brand Name	Hulas Premium Brand
	Dhiraj chamal udyog pvt. ltd., Gauriganj, Jhapa	
D	Production Area	Kalaiya, Bara
	Crop year	2063 B.S.
	Sample drawn	From market
	New Janaki rice mill, Kalaiya, Bara	
E	Production Area	Khanar, Sunsari
	Crop year	2063 B.S.
	Sample drawn	From market
	Brand Name	Saraswati Brand,
F	Production Area	Biratnagar, Morang
	Crop year	2063 B.S.
	Sample drawn	From Biratnagar, Morang
	Chandra Shiva rice and oil mill Pvt. Ltd. Biratnagar.	
G	Production Area	Itahari, Sunsari
	Crop year	2063 B.S.
	Sample drawn	From Itahari, Sunsari
	Goyal Gharelu Udyog, Itahari, sunsari.	
H	Production Area	Duhabi, Sunsari
	Crop year	2063 B.S.
	Sample drawn	From Duhabi, Sunsari
	Jitendra Chamal Laghu Udyog, Duhabi, Sunsari	
I	Production Area	Damak, Jhapa
	Crop year	2063 B.S.
	Sample drawn	From Damak, Jhapa
	Bipin Sheller mill, Damak-1, Jhapa	
J	Production Area	Damak, Jhapa
	Crop year	2063 B.S.
	Sample drawn	From Damak, Jhapa
	Nutan Sheller mill, Damak-11, Jhapa	

Table B.2 Details of *Sona Mansuli* rice samples

Code		Details
N	Production Area	Birgung
	Crop year	2063 B.S.
	Sample drawn	From NFC, Thapathali, Ktm.
O	Production Area	Biratnagar, Morang
	Crop year	2063 B.S.
	Sample drawn	From market
	Brand name	Krishna Brand
	Radha Krishna Rice mill, Biratnagar, Morang	
P	Production Area	Birgunj, Parsa
	Crop year	2063 B.S.
	Sample drawn	From market
	Brand Name	Himal Brand,
	Chandan rice mill, Ram Gadhwa, Parsa, Birgunj.	
Q	Production Area	Dipendranagar, Chitawan
	Crop year	2063 B.S.
	Sample drawn	From market
	Brand Name	Swastik Brand,
R	Production Area	Kalaiya, Bara
	Crop year	2063 B.S.
	Sample drawn	From market
	Brand Name	Sikka Brand,
	New Janaki rice mill, Kalaiya, Bara	
S	Production Area	Katahari, Biratnagar, Morang
	Crop year	2063 B.S.
	Sample drawn	From Katahari, Biratnagar
	Bakrangi Food Industries, Katahari, Biranagar	
T	Production Area	Pokharia, Biratnagar, Morang
	Crop year	2063 B.S.
	Sample drawn	From Pokharia, Biratnagar
	Chandra Shiva rice & oil mill, Pokharia, Biratnagar	
U	Production Area	Duhabi, Sunsari
	Crop year	2063 B.S.
	Sample drawn	From Duhabi, Sunsari
	Jitendra Chamal Laghu Udyog, Duhabi, Sunsari	
V	Production Area	Damak, Jhapa
	Crop year	2063 B.S.
	Sample drawn	From Damak, Jhapa
	Bipin Sheller mill, Damak-1, Jhapa	
W	Production Area	Damak, Jhapa
	Crop year	2063 B.S.
	Sample drawn	From Damak, Jhapa
	Nutan Sheller mill, Damak-11, Jhapa	

Appendix C

t-Test for the comparison of the different quality parameters:

Table C.1 t-Test for length :two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	5.209	5.343
Variance	0.003765556	0.004756667
Observations	10	10
Pooled Variance	0.004261111	
Hypothesized Mean Difference	0	
df	18	
t Stat	-4.590165782	
t Critical two-tail	2.100923666	

Significantly different at 5% level of significance

Table C.2 t-Test for breadth : two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	2.022	2.051
Variance	0.002551111	0.001965556
Observations	10	10
Pooled Variance	0.002258333	
Hypothesized Mean Difference	0	
df	18	
t Stat	-1.364548504	
t Critical two-tail	2.100923666	

Not significantly different at 5% level of significance

Table C.3 t-Test for thickness: two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	1.493	1.557
Variance	0.001934444	0.000934444
Observations	10	10
Pooled Variance	0.001434444	
Hypothesized Mean Difference	0	
df	18	
t Stat	-3.778532045	
t Critical two-tail	2.100923666	

Significantly different at 5% level of significance

Table C.4 t-Test for L/B ratio: two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	2.5826	2.6044
Variance	0.003541378	0.001902489
Observations	10	10
Pooled Variance	0.002721933	
Hypothesized Mean Difference	0	
df	18	
t Stat	-0.934335293	
t Critical two-tail	2.100923666	

Not significantly different at 5% level of significance

Table C.5 t-Test for Moisture content(wb): two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	12.186	13.038
Variance	0.52956	0.305862222
Observations	10	10
Pooled Variance	0.417711111	
Hypothesized Mean Difference	0	
df	18	
t Stat	-2.94772241	
t Critical two-tail	2.100923666	

Significantly different at 5% level of significance

Table C.6 t-Test for 1000 kernels weight: two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	13.0978	14.6855
Variance	0.299631733	0.318978944
Observations	10	10
Pooled Variance	0.309305339	
Hypothesized Mean Difference	0	
df	18	
t Stat	-6.383512877	
t Critical two-tail	2.100923666	

Significantly different at 5% level of significance

Table C.7 t-Test for corr. bulk density: two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	78.8828	77.9193
Variance	2.258473511	2.401105789
Observations	10	10
Pooled Variance	2.32978965	
Hypothesized Mean Difference	0	
df	18	
t Stat	1.411491819	
t Critical two-tail	2.100923666	

Not significantly different at 5% level of significance

Table C.8 t-Test For Cooking time: two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	15.475	13.691
Variance	0.495516667	0.578343333
Observations	10	10
Pooled Variance	0.53693	
Hypothesized Mean Difference	0	
df	18	
t Stat	5.44403636	
t Critical two-tail	2.100922037	

Significantly different at 5% level of significance

Table C.9 t-Test for water uptake ratio: two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	0.49161	0.55397
Variance	0.000591143	0.00075628
Observations	10	10
Pooled Variance	0.000673712	
Hypothesized Mean Difference	0	
df	18	
t Stat	-5.372223529	
t Critical two-tail	2.100922037	

Significantly different at 5% level of significance

Table C.10 t-Test for KER lengthwise: Two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	1.53598	1.51369
Variance	0.010155813	0.007534605
Observations	10	10
Pooled Variance	0.008845209	
Hypothesized Mean Difference	0	
df	18	
t Stat	0.529957469	
t Critical two-tail	2.100922037	

Not significantly different at 5% level of significance

Table C.11 t-Test for KER breadth wise: Two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	1.38874	1.45559
Variance	0.005377874	0.005430823
Observations	10	10
Pooled Variance	0.005404348	
Hypothesized Mean Difference	0	
df	18	
t Stat	-2.033362175	
t Critical two-tail	2.100922037	

Not significantly different at 5% level of significance

Table C.12 t-Test For VER: Two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	3.6	3.175
Variance	0.086111111	0.042361111
Observations	10	10
Pooled Variance	0.064236111	
Hypothesized Mean Difference	0	
df	18	
t Stat	3.749594573	
t Critical two-tail	2.100922037	

Significantly different at 5% level of significance

Table C.13 t-Test for Gruel loss: Two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	3.049	3.217
Variance	0.434498889	1.224134444
Observations	10	10
Pooled Variance	0.829316667	
Hypothesized Mean Difference	0	
df	18	
t Stat	-0.412509626	
t Critical two-tail	2.100922037	

Not significantly different at 5% level of significance

Table C.14 t-Test for SIBV (as O. D.): Two-Sample Assuming Equal Variances

	Mansuli rice	*Sona Mansuli rice*
Mean	0.282	0.462
Variance	0.000884444	0.000951111
Observations	10	10
Pooled Variance	0.000917778	
Hypothesized Mean Difference	0	
df	18	
t Stat	-13.28583145	
t Critical two-tail	2.100922037	

Significantly different at 5% level of significance

Appendix D

Table D.1 Paddy out put in Major Rice Producing Countries

	2005	2006	2007 (forecast)
		(million tonnes)	
World	**632.9**	**628.7**	**632.8**
China	182.1	182.2	184.4
India	137.7	136.6	137.0
Indonesia	54.2	54.4	53.1
Bangladesh	39.8	39.2	40.5
Viet Nam	35.8	35.8	36.0
Thailand	30.3	29.4	30.2
Myanmar	25.1	25.2	25.2
Philippines	15.1	15.4	15.8
Brazil	13.2	11.6	11.3
Japan	11.3	10.7	10.4
USA	10.1	8.8	8.5
Pakistan	8.3	8.1	8.4

Table D.2 Paddy output by Regions

	2005	2006	2007 (forecast)
		(million tonnes)	
World	**632.9**	**628.7**	**632.8**
Developing countries	607.0	604.0	609.6
Developed countries	25.8	24.7	23.2
ASIA	572.2	569.2	574.3
AFRICA	20.4	21.6	21.7
NORTH AMERICA	10.1	8.8	8.5
CENTRAL AMERICA	2.3	2.4	2.5
SOUTH AMERICA	24.1	22.2	22.1
EUROPE	3.4	3.4	3.5
OCEANIA	0.3	1.1	0.1

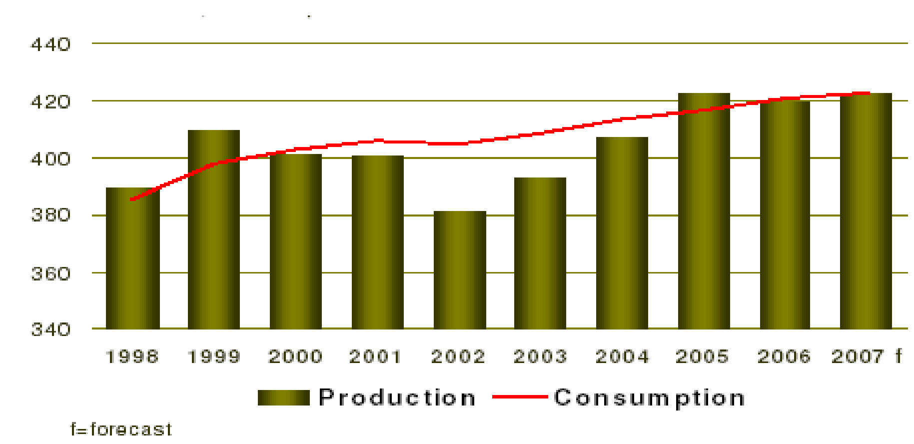

Fig D.1 Global rice production and Consumption (million tones)

Table D.3 Area, Production and yield of paddy in Nepal (2005/06)

District	Area (ha.)	Production(M T)	Yield (Kg/ha)
Jhapa	96,800	3,11,690	3,220
Morang	98,070	3,05,740	3,118
Sunsari	61,140	1,89,530	3,100
Saptari	68,000	1,57,500	2,316
Siraha	67,972	1,89,435	2,787
Eastern Terai region	3,91,982	11,53,895	2,944
Eastern region	5,08,122	14,21,046	2,797
Dhanusa	61,260	1,50,825	2,462
Mahottari	44,050	98,165	2,228
Sarlahi	40,974	95,417	2,329
Rautahat	48,500	1,12,805	2,326
Bara	54,500	2,00,230	3,674
Parsa	44,200	1,60,500	3,631
Chitawan	32,972	78,280	2,374
Central Terai region	3,26,456	8,96,222	2,745
Central region	4,32,740	12,25,238	2,831

Source: MOAC, (2005/06)

Table D.4 Released and registered rice varieties in Nepal (1960-2004)

Name of released variety	Year of release	Origin	Yield potential (MT/ha)	Maturity (days)	Recommended Domain
Barkhe-2	1987	Indonesia	4.3	148	Terai, Inner terai
Bindeshwori	1981	India	4.0	128	Terai, Inner terai
CH-45	1966	IRRI	3.5	118	Terai, Inner terai
Chaite-2	1987	IRRI	4.8	125	Terai, Inner terai
Chaite-4	1987	IRRI	4.5	118	Terai, Inner terai
Chaite-6	1991	IRRI	4.8	123	Terai, Inner terai
Chandina	1978	IRRI	3.8	128	Terai, Inner terai
Hardinath-1	2004	Srilanka	5.0	110	Terai, Inner terai
IR-20	1972	IRRI	4.0	153	Terai
IR-24	1975	IRRI	3.8	135	Terai, Inner terai
Janaki	1979	Srilanka	4.5	135	Terai, Inner terai
Jaya	1973	India	4.3	130	Terai, Inner terai
Laxmi	1979	IRRI	4.5	135	Terai, Inner terai
Makwanpur-1	1987	Srilanka	4.8	150	Terai, Inner terai
Mallika	1982	Bangladesh	4.0	128	Terai, Inner terai
Masuli	1973	Malaysia	3.5	155	Terai, Inner terai
Parwanipur-1	1973	IRRI	4.0	135	Terai, Inner terai
Radha-11	1994	IRRI	4.0	148	Central terai
Radha-12	1994	IRRI	4.6	155	Eastern terai
Rampur Mansuli	1999	Nepal	5.7	135	Terai and foot hills
Sabitri	1979	IRRI	4.0	140	Terai, Inner terai

Source: MOAC, (2005/06)