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THE DEVELOPMENT OF PROCESSING SYSTEMS FOR MANITOBA WILD RICE

BY

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A dissertation submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

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The Development of Processing Systems for Manitoba Wild Rice

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TO THE MEMORY OF MY FATHER,

WHO INSTILLED IN ME AN OVERWHELMING DESIRE

TO STUDY, AND

TO MY MOTHER,

WHO ENCOURAGED AND SUPPORTED ME THROUGHOUT

MY ACADEMIC ENDEAVORS.

ABSTRACT

Color, cleanliness and degree of breakage are the main quality criteria for acceptable wild rice. These characteristics can change drastically because of wide variations in processing procedures. Processing has not been standardized, and uniform quality standards do not exist for the industry. This study was designed to improve upon the existing processing methods and aimed at standardizing the procedures needed to produce a more uniform final product that best accords to consumer preference. The flavor characteristics of wild rice were also investigated using 18 characteristics.

Results indicated that good quality wild rice was obtained when low temperature curing, controlled humidity and controlled high temperature parching during processing were used. As curing progressed, color development increased under favorable conditions. Well controlled parching and curing systems will not affect total yield and thus ensure optimum yields.

The consumer survey conducted indicated that dark colored, whole and clean wild rice was more acceptable. However, present high prices generally limit the use of wild rice to gourmet cooking only.

Results from the flavor analysis showed that wild rice with dark brown color, straight and split kernels, bland aroma, grainy taste and slight chewiness was of good quality and was considered to be highly acceptable.

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INTRODUCTION

Wild rice, (Zizania aquatica) has long been the staple food crop of the Indians in the Northern Great Lakes Region. This crop was not cultivated but allowed to grow naturally and then harvested in large quantities from its habitat in the shallow lakes and streams of the area. Today, due to its limited supply and unique flavor and color characteristics, wild rice is considered a delicacy by most North Americans. Even with its high price, $6.00/lb in 1972 (41) as compared to 10¢/lb in 1918 (37), there appears to be a growing demand for this grain. This demand has encouraged cultivation of wild rice in paddies, along with the use of mechanical harvesting and processing techniques. Since 1968, the increase in production of paddy wild rice has been dramatic, especially in the United States. For instance, in Minnesota, it increased forty fold in five years (12, 15, 41). However in Canada, natural stand harvest supplies the largest quantity of rice with the production from paddies being very limited.

When compared to other cereal grains, (Table 1) wild rice is a nutritious food. It is relatively high in protein and low in fat content (6, 26, 38). The analysis of wild rice indicates that it contains 14.10g protein, 6.2mg niacin and 353 calories per 100g of raw parched product. Other researchers have stated that it is also rich in the B vitamins, especially thiamine, riboflavin and nicotinic acid, while being low in Vitamin A and some minerals.

Today, wild rice, although no longer used as a staple food by most of the Indians, still remains as a major supplementary food and a source of much needed income for the native people (38, 41). Due to the high price, most consumers cannot afford to use it as often as they would like to. Yet, despite the high cost, the white man has introduced successful, numerous recipes for the preparation of wild rice. Now it is used in game-bird stuffings, desserts and in various other ways. The basic method of preparation of wild

TABLE 1*. Composition of Wild Rice and Comparisons With Other Grains.

Grain Wild Rice	Water	Protein	Fat	Carbon	Ash	Calories Fuel Value per lb
Whole Grain	9.5	12.9	1.0	75.2	1.4	1,625
Ground	13.0	10.9	0.8	74.0	1.3	1,740
Parched Whole Grain	11.2	14.6	0.7	72.3	1.2	1,620
Parched & Ground	9.5	11.5	0.8	76.9	1.3	1,800
Rice, polished	12.3	8.0	0.3	79.0	0.4	1,630
Barley, pearled	11.5	8.5	1.1	77.8	1.1	1,650
Wheat, cracked	10.1	11.1	1.7	75.5	1.6	1,685
Oats, rolled	7.7	16.7	7.3	66.2	2.1	1,850
Cornmeal, unbolted	11.6	8.4	4.7	74.0	1.3	1,730
Hominy	11.8	8.3	0.6	79.0	0.3	1,650
Kafir Corn	16.8	6.6	3.8	70.6	2.2	1,595
Buckwheat Flour	13.6	6.4	1.2	77.9	0.9	1,620

*Adapted from - "Wild Rice" - Indian Food and a Modern Delicacy", by Taylor A. Steeves, Economic Botany. 1952.

rice is by boiling it in water until the rice becomes tender to one's taste. At the present time, quality standards have not been established for the final product. Consumers have therefore had to contend with whatever is available in the market regardless of its quality.

The major problems in the processing of wild rice are 1) - the industry has not become equipped for large scale operations and 2) - much of the understanding of the processing operations is based on art and not on scientific technology. This study was therefore carried out 1) - to study the effect of the curing system on wild rice quality, by varying a) temperature, b) humidity and c) storage time. 2) - to study the effect of the parching system on wild rice quality by varying (a) temperature and (b) time. 3) - to evaluate the quality of the final product obtained in (1) and (2) above by color analysis, yield analysis, sensory evaluation and consumer preference.

2. LITERATURE REVIEW

Wild rice has served the Indians both as food and revenue for many years. However, no information was ever written concerning their processing techniques until 3-5 hundred years ago (6, 7, 18, 38). Such information became available only after the white man migrated to the wild rice regions in the 18th century (19, 38). At that time, the white man was dependent on this grain as a staple and winter food. The Indians harvested the rice, processed it by hand and sold it to the white man until recent years when he began to manage the production of this grain.

Rapid growth of this new industry has resulted in the need for improved cultivation and processing techniques. The first commercial paddies were developed in Minnesota in 1964, and since then, (tables 2 & 3), commercial wild rice production and processing has expanded rapidly into Wisconsin, Manitoba, Northwestern Ontario, Saskatchewan, Alberta, and Michigan.

2.1 The Wild Rice Plant

The wild rice plant that grows in the upper Great Lakes region is known scientifically as Zizania aquatica. It is found throughout the eastern and northern United States and southern Canada (19, 38). It is also known by several other names such as Indian rice, menomen, water oats and marsh oats (8, 19, 38).

Wild rice is an annual aquatic grass. It matures indeterminately, shatters and therefore the seed has to be harvested in the immature green stage (8, 19, 25, 38).

2.2 The Wild Rice Kernel

A kernel of wild rice will range from 1-3 cm long and 2-4 mm in diameter. It is almost cylindrical with a slight indentation along the length of the kernel and tapered ends (25, 26, 35). The outer

TABLE 2. The Production of Wild Rice in Minnesota from 1973-75.

Year	Acres Natural Stands	Unprocessed Grain (lb)
1973	-	1,000,000
1974	-	550,000
1975	-	100,000
	Cultivated Fields (Paddy)	
1973	18,000	3,000,000
1974	13,000	2,700,000
1975	13,000	3,200,000

Courtesy of University of Minnesota, Department of Agronomy and Plant Genetics. April, 1976.

TABLE 3*. The Price and Supply of Green Wild Rice in Manitoba from 1966-74.

Year	Green Rice Natural Stand (kg)		Approximate price to Harvestor (kg)	
	(lb)	(kg)	(lb)	(kg)
1966	(119,126)	54,036	$ (1.10)	$ 2.43
1967	(593,000)	268,984	(1.45)	3.20
1968	(230,000)	104,328	(.64)	1.41
1969	(160,000)	72,576	(.75)	1.65
1970	(145,000)	65,772	(.70)	1.54
1971	(470,000)	213,192	(.45)	.99
1972	(678,000)	307,540	(.45)	.99
1973	(624,000)	283,046	(.50)	1.10
1974 (est.)	(102,000)	46,267	-	-

*Adapted from Wild Rice Production in Manitoba by D. Punter et. al. No. 527. 1975.

coat of the kernel is a thin, pigmented layer known as the pericarp (Figure 1). Covering the whole kernel is a thin outer sheath called the hull. One end of the hull tapers to a bristly hair-like point called the beard which is usually about as long as the kernel. The hull clings tightly to the kernel but must be removed during processing. Freshly harvested grain contains about 35-40% moisture (22, 41, 42) and has a pliable kernel that is dark-brown to black in color when fully mature. After processing, the kernel contains 7-11% moisture and the endosperm is hard and translucent due to the gelatinization of the starch.

2.3 Early Methods of Processing Wild Rice

A detailed description of the methods used by the Great Lakes Indians in processing wild rice has been reviewed thoroughly by Chung, 1975 (10).

The traditional harvesting method involved two individuals in a canoe, one maneuvering the canoe through the rice stand and the other bending wild rice stalks over the canoe and striking them with a stick, causing the mature seeds to fall into the canoe (8, 19, 38, 41). This technique is still in use today by native people but is gradually being replaced (15, 33, 41).

After harvesting rice was cured (dried) by one of three methods: (1) - rice was spread in a thin layer and exposed to the sun for several days: (2) - rice was placed on grass mats hung 3 to 4 feet above a slow-burning smokey fire for 1 to 3 days: (3) - a few pounds of rice was put into a kettle and heated at a high temperature for 15-30 minutes with constant stirring (8, 19, 28, 41). The latter method was called "parching" and produced rice with the best flavor (3, 8, 19, 38, 41). Often times rice was sun-dried for a few days and then parched.

After curing, rice kernels became hard and hulls were brittle. This permitted the hulls to be removed by a rubbing action, which was accomplished in one of three ways: (a) - putting the rice into a shallow hole and having

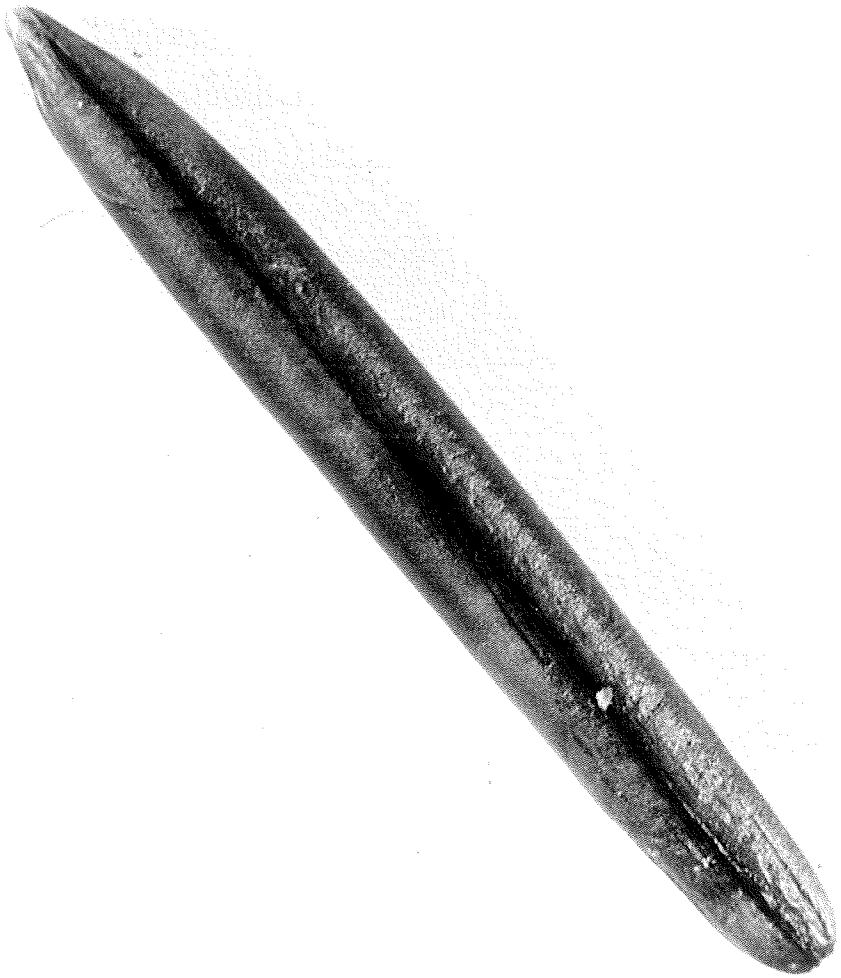


FIGURE 1. The Wild Rice Kernel.

a man tread on it; (b) - putting rice into a shallow hole and pounding it with a pole; or (c) - putting rice in a bag or on a blanket and beating it with sticks. After dehulling, chaff and kernels were separated by winnowing (19, 38). Following this operation, rice was ready for storage or to be cooked and consumed.

2.4 Modern Processing Methods

Modern wild rice processing accomplishes the same purposes as traditional methods but involves a higher degree of mechanization. Processing techniques and equipment designs vary among processes although they are similar in all respects. The basic steps of processing are: harvesting, storage (curing), parching, hulling, winnowing (cleaning), grading (size separation) and packaging (8, 10, 13, 38, 41, 42). Special machines called speedheads have been adapted to harvest natural stand wild rice (Figure 2), (13, 38). Paddy rice is harvested by rice combines after draining of the paddies (41, 42). The harvested rice is packed into cloth or plastic bags and transported by truck to the processing plant (41, 42).

The rice is usually stored (cured) from 1-5 weeks either outdoors or in sheds. The purpose for this is twofold: (a) - to mature the green rice and (b) - for storage since the equipment used in the subsequent steps is not of a size sufficient to handle the large bulk of material very quickly. The basis for this is economics, i.e. the rice harvesting season is only 4-6 weeks while the processing season has been extended to 12-14 weeks. Even under these conditions the plant and equipment lie idle for the rest of the year (8, 13, 14, 32, 38, 41, 42).

During curing, the green rice is spread out on the ground and piled up to a height of 1-3 feet (15). The rice is stirred and turned over every day and then watered when necessary, throughout the curing period (10, 15, 41). The purpose of this practice is to prevent any excess heat

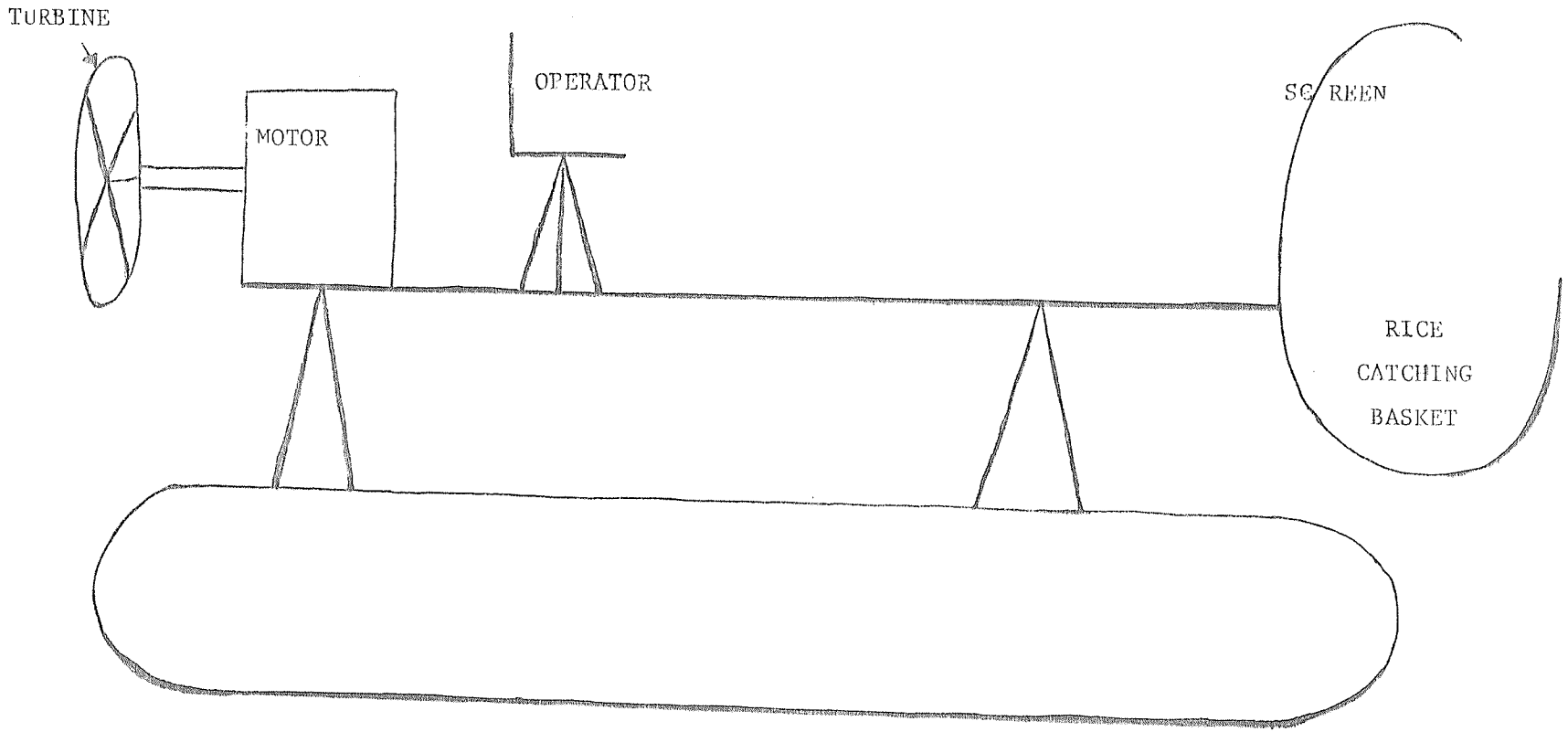


FIGURE 2. A Diagram of Wild Rice Harvester. (A home-made pontoon machine driven by an air turbine and powered by a Volkswagon 1500 motor. It is used by the Dubois Wild Rice CO., Lac du Bois, Manitoba).

accumulation in the rice pile, dissipate moisture, and retard mycelial growth (15, 20). Under these conditions of storage, a combined enzymatic and microbial fermentation occurs, resulting in several important changes in the rice, namely: (a) - development of a darker color in the kernels; (b) - development of acceptable flavor; (c) - easy removal of the hull after parching; and (d) - a decrease in the final yield of finished rice (10, 15, 41). These factors will be discussed in more detail in the next section.

Parching is generally carried out in mechanically rotated, horizontal steel cylinders that are heated by gas. Inside these drums are steel paddles for stirring the rice to prevent scorching (15, 22). Parching may also be done in stationary barrels with paddles rotated mechanically to mix the rice. This method does not dry or prevent scorching of rice as efficiently as does the rotating drum method (15, 22).

After wild rice is dried to contain about 10% moisture, it is hulled, usually in a rice huller equipped with two rollers that rotate at different speeds (7, 15, 35, 38). The hull is stripped from the kernel when the rice grain passes between the rollers. This is a critical processing phase due to the fact that the kernels' long thin shape makes them easily susceptible to breakage. How successfully and efficiently rice is hulled depends largely on the uniformity of the grain, storage and curing treatment and parching conditions (10, 15, 35).

Modern cleaning (winnowing) of wild rice is accomplished by using commercial seed-cleaning aspirators (15, 22). After cleaning, the wild rice is size-graded into whole, cracked and unhulled fractions using gravity tables or sizing screens (15, 22, 41). The finished rice is packaged and stored in a similar manner as done for other dried grains.

2.5 Curing (Fermentation) of Green Wild Rice

As mentioned above, the wild rice processor must store most of the freshly harvested grain that arrives at his plant, due to the short harvesting period and high cost of processing equipment (7, 15, 35, 38). The rice is therefore stored in piles up to 3 feet deep either outdoors or in sheds. It is then turned over and watered daily for a period of 2-6 weeks while the kernels mature, i.e., develop a darker color (10). The immature kernels that must change color are those which have a green to light brown pericarp at the time of harvest. During the curing process, this green to light-brown color changes to dark brown or black if curing conditions are favorable (10, 15, 20, 22). The curing process is thus necessary to ensure a more uniform dark colored product, since after harvesting, any lot of rice usually would contain a mixture of dark mature and green immature kernels.

This color change probably results from a continuation and completion of the ripening process during curing (10, 15, 22, 41, 42). However, if the harvested kernel is not near maturity, ripening enzymes are not yet present and the color change does not occur (10, 15).

The ease of hulling is also regarded as an important factor in the curing process. Since kernels that are not hulled in one pass through the huller must be passed through the huller again, easily hulled rice means a more efficient operation, results in less breakage and hence, better yield (10, 15, 41, 42). The increase in hulling efficiency, at the present time can only be attributed to cellulolytic enzyme action in the hull during the curing period (23).

The development of acceptable flavor in wild rice is also achieved during the curing process (10, 41, 42). Uncured wild rice normally has a bland grassy unacceptable flavor (10, 15, 22, 41, 42). However, an

acceptable grainy, nutty and slightly earthy flavor is developed under favorable curing conditions, giving wild rice its unique "gamey" flavor characteristics (15). Microorganisms could be important in the development of wild rice flavor, since curing conditions are generally conducive to their growth (15, 20). Molds could also be important in the development of the fermented flavor of wild rice since they thrive during curing (35).

Unfortunately, the presence of mold mycelia in curing wild rice has been associated with and attributed to undesirable and unacceptable moldy flavors in the finished rice plus possible development of aflotoxins (10, 15, 23).

Another result of curing is a decrease in rice solids towards the end of a lengthy curing period (10, 15, 41, 42). This is caused primarily by respiration activities in the grains and partly by the growth of microorganisms (15). The significance of microorganisms in causing a loss in rice yield was reported in Logan's M.Sc. thesis research.

2.6 Cooking Studies and Kernel Fragility

Consumer acceptance and preference, with respect to eating and cooking qualities are important in judging rice, since they vary from person to person (37). Most consumers prefer rice grain that cooks dry and fluffy with kernels that retain their conformation and remain separate after cooking. Others prefer rice that cooks moist and chewy with the grains tending to cling together (37). Since different groups of people prefer various cooked textures, there is a demand for all types in the market (37). Taste panel works conducted by Chung (1975) and University of Wisconsin (40, 41) have indicated that processing techniques affect the cooking properties and acceptability of cooked wild rice.

Therefore this study was carried out to determine the effects of parching temperatures on the quality of cooked wild rice.

2.7 Sensory Evaluation

Every food processor is interested in product quality as influenced by processing techniques. This applies as well to the wild rice industry. However, no well established quality standards exist for wild rice. At the present time, numerous processing methods produce finished rice with great variations in appearance and taste (41, 42).

Pfaffmann (1961) has noted that the senses of taste and smell have one unique property: they can and do instigate strong acceptance or rejection responses (1, 30, 31). Hence the evaluation of wild rice by means of these attributes is undoubtedly appropriate. Wild rice flavor is one of the major factors in judging the quality of the finished product (41, 42).

The first flavor profile for wild rice was through taste panel studies in 1970 by the University of Wisconsin. This group reported that the flavor of wild rice included the following characteristics: bland, grassy, tea-like, moldy, earthy, swampy, bitter, toasted, raw, starchy, grainy and uncooked. In 1975 Chung developed the second wild rice profile. This was modeled after the Wisconsin system, and consisted of 24 parameters. Both the Wisconsin group and Chung have reported that, acceptable flavor in finished wild rice is affected by processing techniques; especially curing time and temperature, as well as parching temperatures. These studies also indicated that mature wild rice kernels have a more acceptable flavor than immature kernels.

Therefore, the objective of this sensory evaluation was to determine a final and precise flavor profile that best describes good quality finished wild rice, and which could be related to consumer preference.

2.8 Consumer Survey

One of the first needs of a developing industry is to determine consumers preference for quality and grade. With such knowledge, it will be possible to control production and processing to adapt the desired product to market demands.

Consumer reactions are difficult to measure (18, 29) but the necessity for such studies will continue to grow as competition for the consumer food dollar increases. Consumer reactions may be measured in two ways: (a) - by consumer preference studies and (b) - by consumer practice studies. This is because, those who prefer may not be those who buy (1). Preference studies are designed to determine consumer's subjective reactions to external phenomena, and their reasons for having them. Practice studies are designed to determine what consumers actually do under given circumstances, such as the amount of whole grain or broken grain rice purchased when the cost of each type is quite different. Acceptance of a food varies with standard of living and cultural background; whereas preference refers to selection when presented with a choice (1, 17, 31). In addition to the quality of a food, preferences are frequently influenced by prejudice, group conformance, "status value", snobbery etc.

Many complex factors combine to influence the public's acceptance and selection of food (1, 40) (Table 4). The major factors however, are appearance, flavor and cost.

Appearance probably has the greatest initial influence since visual properties significantly control selection of the item from many others that may be displayed (1).

Flavor is mentioned by a large number of consumers as the reason for overall preference and continued use of a product. Once the food has been tasted, color and texture become secondary to flavor (1).

TABLE 4*. Factors Influencing Acceptance and Preference.

Attributes of the Food Product	Attributes of the Consumer
1. Availability	1. Regional preferences
2. Utility	2. Nationality, race
3. Convenience	3. Age and sex
4. Price	4. Religion
5. Uniformity and dependability	5. Education, socio-economics
6. Stability, storage requirements	6. Psychological motivation (a) Symbolism of food (b) Advertising
7. Safety and nutritional value	7. Physiological motivation (a) Thirst (b) Hunger (c) Deficiencies (d) Pathological conditions
8. Sensory properties (a) Appearance (b) Aroma and taste (c) Texture, consistency (d) Temperature (e) Pain	

*Adapted from "Principles of Sensory Evaluation of Food" by Amerine et. al. 1965.

Price is an important limitation to the freedom with which the consumer selects foods. Consumer buying behavior for a canned product indicated that 68% of 179 families selected a certain brand on the basis of flavor, whereas 59% of the 128 families who selected a minor brand did so on the basis of a lower price (1, 17, 29, 31). The price of wild rice in 1972 was $6.00/lb (41) as opposed to $2.54/5 lbs of polished white rice in the same year. Whether consumers will purchase wild rice at a rate commensurate with the supply and at a price high enough to ensure a continuous flow of the rice into the market, should be of concern to every wild rice processor.

Other factors influencing consumer reactions to foods are: interest, motivation, discrimination, regional preferences, age, sex, "status value" etc. (1, 31).

At the present time no information or standards exist with respect to consumer preference of wild rice. Hence, this survey was conducted to determine consumer preferences and practices for finished wild rice.

3. Materials and Methods

The department purchased 91.0 kg lots of green lake rice from each of the following lakes: Eileen, Harrop, Shallow and Lac la Ronge; and 91.0 kg of green paddy rice from Sprague in September, 1974. These lots were put in frozen storage at -40°C, and processed in early 1975. In September, 1975 the Department purchased another 45.5 kg of green rice from Crowduck Lake; 22.8 kg from Booster Lake and 91.0 kg green paddy rice from Sprague. This lot of rice was also processed after three months storage at -40°C.

Two controlled environment cabinets (P.M. Industries, ENCON. Division, Wpg.), a two-burner coffee roaster (Jabez Burns), and a small huller utilized in this study have been previously described by Chung (1975). The cabinets (1.65 m X 2.25 m X 2.4 m high) (Figure 3) were designed for humidity and temperature control and permitted air exchange (inside air replaced by outside air) at a rate of 1,270 cfm.

Each of the two units of the coffee roaster held a maximum of 454 g of cured rice. The units were heated by manually controlled gas jets; rotated at a speed of 55 rpm and were powered by a 1/6 hp electric motor (Figure 4).

The single roller huller (Figure 5) (designed by the Plant Science Department, University of Manitoba) was powered by a 1/6 hp electric motor. This unit consisted of a steel roller covered with rubber which rolled against a firm wall also covered with rubber. The gap between the roller and the wall could be spring adjusted according to the size of the product being hulled. The abrasive action encountered by the rice passing through the gap was sufficient to remove the hull. After passing the gap the rice kernels and the hulls encountered an air stream generated by a fan which was sufficient to separate the two fractions.

FIGURE 3. The Controlled Environment Cabinet.

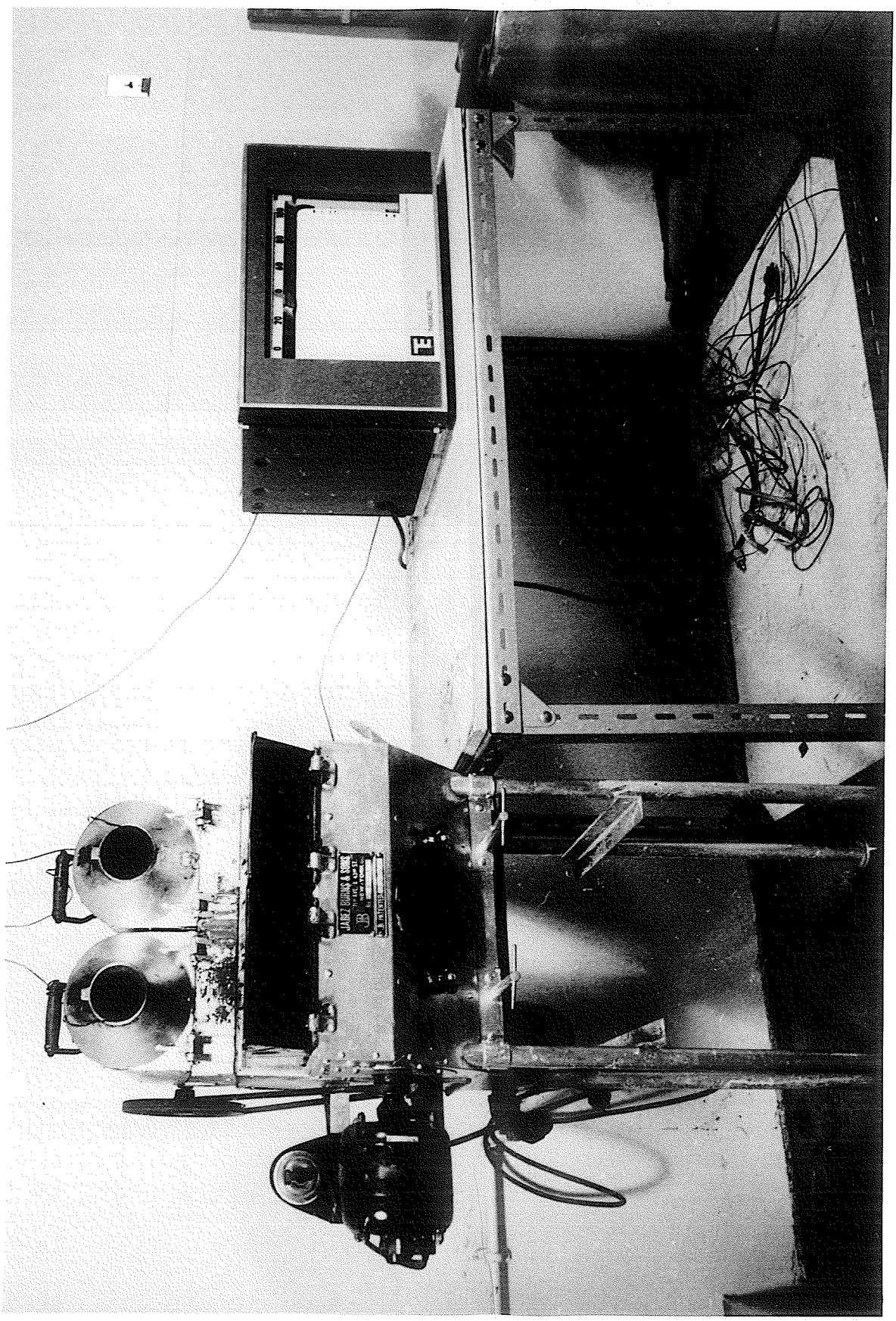


FIGURE 4. The Jabez-Burns Two-burner Coffee Roaster.

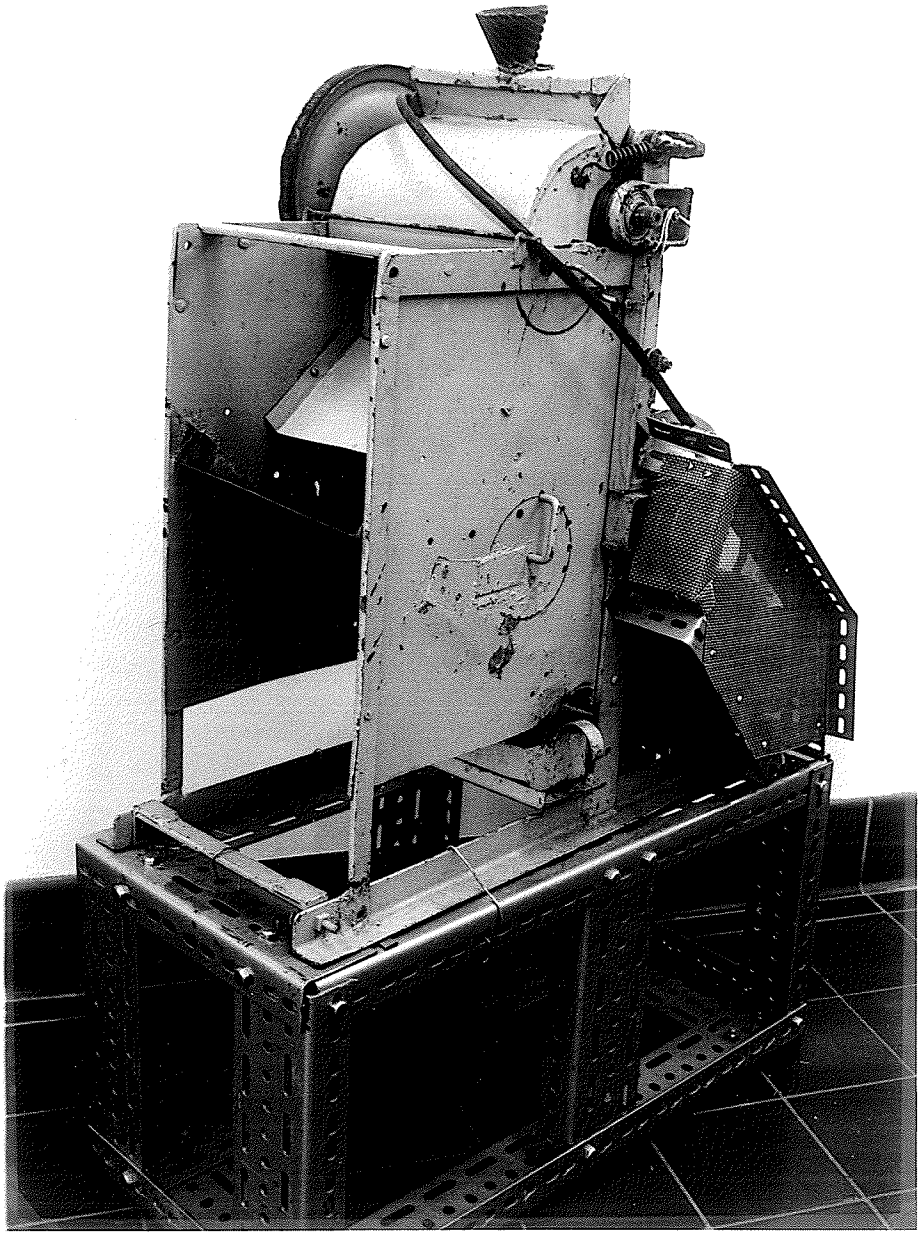


FIGURE 5. One Roller Wild Rice Huller.

3.1 Curing and Parching Studies

These experiments were designed to determine the optimum and most efficient systems for processing wild rice. Chung found that low curing temperatures were the most ideal for producing high quality rice. He also reported that parching temperature affected especially, yield and overall quality of finished wild rice. However, Chung did not study the interaction between curing temperature and humidity. His research also failed to establish an optimum parching condition (temperature) for wild rice. Therefore, the purpose of this research was to establish those conditions of curing and parching wild rice that would produce high quality finished rice.

The wild rice cured utilizing systems A, B, and C were parched by 1 and 2. The Lac la Ronge, Harrop Lake and paddy wild rice cured with system D were parched in the same manner. The Eileen and Shallow Lake wild rice cured by system D were parched by systems 3 to 9 inclusive. The wild rice cured by systems E and F were parched by system 6.

The purpose of using two different temperatures for parching was to facilitate comparison of results with the previous work carried out by Chung. The low temperature used was just above gelatinization temperature of wild rice and the high temperature was just below the maximum recommended parching temperature (41, 42). In addition, a series of temperatures, ranging from below the gelatinization temperature of wild rice to above the recommended maximum parching temperatures, were investigated in order to select the optimum parching temperature for wild rice.

3.1.1 Curing Studies

The variables studied in these experiments included temperature, humidity, storage time, and type of wild rice and were designed as follows:

System A.
Temperature 3°C
Relative Humidity 95%
Rice Type - Paddy wild rice, Lake wild rice from Eileen, Harrop, and Shallow Lakes and Lac la Ronge.
Storage Time - 9 weeks.

System B.
Temperature 5°C
Relative Humidity 95%
Rice Type - Paddy wild rice and Shallow Lake wild rice.
Storage Time - 7 weeks.

System C.
Temperature 38°C
Relative Humidity 95%
Rice Type - Paddy wild rice and Shallow Lake wild rice.
Storage Time - 6 days.

System D.
Temperature 15°C
Relative Humidity 95%
Rice Type - Paddy wild rice and Lake wild rice from Eileen, Harrop and Shallow Lakes and Lac la Ronge.
Storage Time - 4 weeks.

System E.
Temperature 10°C
Relative Humidity 75%
Rice Type - Paddy wild rice and Crowduck Lake wild rice.
Storage Time - 4 weeks.

System F.
Temperature 10°C
Relative Humidity 55%
Rice Type - Paddy wild rice and Crowduck Lake wild rice
Storage Time - 4 weeks.

The Crowduck and Paddy wild rice used for systems E and F had been separated by washing into mature and immature fractions based on specific gravity.

These conditions were selected because they represented the range encountered by wild rice processors (15° - 38°C and variable relative humidity) or were recommended by previous researchers (3, 5 and 10°C and high relative humidities) (10, 15, 41).

3.1.2 Parching Studies

Parching temperature, time, curing environment and the type of rice were the variables studies in these tests. The various parching systems were designed as follows:

System 1. Low Temperature Parching -
Rice at room temperature was gradually raised to 79°C and parched for 50 minutes in the coffee roaster.

System 2. High Temperature Parching -
Rice at room temperature was gradually raised to 135°C and parched for 25 minutes.

System 3. Rice at room temperature was gradually raised to 65°C and parched for 70 minutes.

System 4. Rice at room temperature was gradually raised to 79°C and parched for 55 minutes.

System 5. Rice at room temperature was gradually raised to 93°C and parched for 45 minutes.

System 6. Rice at room temperature was gradually raised to 107°C and parched for 40 minutes.

System 7. Rice at room temperature was gradually raised to 121°C and parched for 30 minutes.

System 8. Rice at room temperature was gradually raised to 135°C and parched for 25 minutes.

System 9. Rice at room temperature was gradually raised to 149°C and parched for 20 minutes.

3.2 Experimental Procedure

The wild rice purchased for these studies has been previously described in Section 3. When specific samples of rice were required, these were removed from frozen storage and thawed at room temperature, (usually about 10-24 hours) then thoroughly washed in cold water to remove gravel, worms, insects and plant debris.

3.2.1 Experimental Design for Curing

For specific trials, 24.0 kilograms (kg) of wild rice (for each rice type) were subdivided into 3 lots of 8.0 kg and placed into cylindrical metal containers (61.0 cm X 30.5 cm) to a depth of approximately 30.5 cm. The cylinders were perforated on the bottom with 16, 0.32 cm holes. All rice samples cured by systems A, B, C, and D were treated as above. Rice samples cured by systems E and F were handled as follows: each rice type was divided into two sub-samples. One sample was the unwashed control (mixed fraction), the other was washed in a cold water system in order to separate the rice into two fractions. (This research was part of Leung's M.Sc. thesis program (44). The heavier rice (mature fraction) sank while the lighter (immature) fraction floated and was removed. The weights of these fractions were recorded and will be utilized in Leung's thesis.

The unwashed control, mature and immature fractions were cured as described in Section 3.1.1 by Systems E and F.

3.2.2 Experimental Design for Parching

For the purpose of determining the optimum curing time, samples were removed from the curing environment as described below and were parched as outlined in Section 3.1.2.

The parching study started at 0 time for each curing system and continued every 7 days for Systems A, B, and for some rice types in System D, E and F to the end of storage. Samples were removed every second day, starting at 0 time for System C. For System D, an optimum storage time was selected and the remaining types were parched at that one time. There was not sufficient sample for the immature fraction from Systems E and F to have continuous parching. This was parched at 0 time and at the end of storage while the mature and mixed fractions(unwashed control) were parched as described for Systems A and B. For each parching study the rice types were replicated as follows: rice was removed at random from the three containers, mixed, weighed into three 250 g sublots and parched.

3.3 Curing and Parching Techniques

Wild rice should be turned (stirred) and watered periodically to prevent heat build-up in the rice pile and to ensure even distribution of moisture in the rice pile (10, 15, 22, 41, 42). These are also techniques used in the industry.

3.3.1 Curing Techniques

The rice had uniform moisture distribution as a result of washing and therefore was watered only when it appeared to be dry. The rice

cured under Systems A and B were turned every second day for the purpose of increasing aeration, reducing bed temperature and helping to prevent mold growth. The rice cured with systems C, D, E and F systems were turned every day. The moisture content of the rice was determined at the beginning and at the end of curing. The temperature of the wild rice bed was monitored throughout all curing studies as follows: glass mercury thermometers were inserted into the center of the rice bed of each container and left until a constant reading was attained. This temperature was then recorded. The desired temperatures and humidities were set by control in the cabinets one week prior to use in order to equilibrate conditions and were monitored daily after the experiments were started.

3.3.2 Parching Technique

The temperature of the rice bed for each unit of the coffee roaster was monitored throughout the entire period of parching. Thermocouples, composed of copper and constantan were positioned in the center of the rotating unit and were coupled with a thermoelectric multipoint recorder. This system was standardized by means of a Thermoelectric Minimite with reference to a thermocouple temperature - millivolt table prior to experimental use. All parched samples were then treated as follows:

1. The moisture content was determined by the vacuum oven method (2).
2. The samples were weighed prior to and after hulling.
3. The hulled rice was cleaned and size graded with a clipper manufactured by A.T. Fernell and Co. Saginau, Michigan. The size of screens that were used were 0.31 cm X 1.875 cm (8/64 in. X 3/4 in.) and a No. 8 mesh for Lake rice while a 0.113 cm X 1.25 cm (1/22 in. X 1/2 in.) was used for paddy rice.

4. The Hunter Lab Model D25 Color Difference Meter was then used to evaluate the color of the finished rice.

3.4 Hulling Studies

All hulling was carried out within twenty four hours after parching. This is necessary with respect to ease of hulling and reduced kernel breakage (10, 22, 41).

The effect of the various curing and parching systems on the ease of hulling was evaluated by qualitative means. After cleaning (Section 3.3.2) the yield of rice for each treatment was calculated as follows:

$$\text{Percent yield of finished rice} = \frac{\text{weight of hulled rice}^*}{\text{weight of cured rice}^{**}} \times 100$$

*Weight of hulled rice was the combined weight of broken and whole kernels.

**This was always 250 g.

3.5 Color Analysis

In the wild rice industry, suitable color development has been designated as one of the primary quality factors which determine the market value of wild rice (22, 24, 41, 42). However, there is no standard method yet established for wild rice color measurement. The Hunter Lab Model D25 Color Difference Meter has been widely used for the measurement of color of grains. It has been used to measure the color of polished domestic rice in the rice industry (37), and has also been used for the determination of wheat class and grade (24, 34). A detailed description of color measurement has been presented in Chan and Gerbasi's theses (9, 16).

3.5.1 Procedure for Color Analysis

For color measurement of the wild rice in this study, three color values were used to calculate the total color difference of each rice

sample compared to a color standard. The overall (total) color difference (ΔE) indicates the difference in color between the specimen and the color standard. The larger the ΔE value, the larger is the color difference between the sample and the color standard.

3.5.2 Experimental Design for Color Analysis

A good finished wild rice should have a dark-brown to black color. Consequently, a white color standard plate was chosen as the reference, with the following value:

$$L = 93.8$$

$$aL = -1.1$$

$$bL = 2.3$$

The difference of each color component has a value of ΔL, ΔaL and ΔbL and ΔE is calculated from these values by means of the following equation:

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta aL)^2 + (\Delta bL)^2}.$$

3.5.3 Techniques for Color Analysis

All samples obtained from all processing systems in this study were analyzed for color as follows:

(a) Approximately 40.0 g of clean finished wild rice, from each sample, was placed in a clear glass container (especially designed for the Color Difference Meter).

(b) The color difference value of each sample was then recorded.

(c) The ΔE value was then calculated, for each sample, from the data obtained from (b) above.

3.6 Cooking Study and Kernel Fragility

The cooking properties of finished wild rice are important in the overall

acceptance of this grain. This study was conducted to determine which parching temperatures produce acceptable cooked rice. The effects of parching temperatures on kernel fragility were also investigated.

3.6.1 Cooking Study Procedure

All wild rice samples used in this study were processed by curing systems A and D and parching systems 3 to 9 inclusive, as described in Sections 3.3.1 and 3.3.2. Eileen Lake and Shallow Lake (1974) wild rice were selected as the rice types to be used. Following curing, parching and hulling, whole kernels were separated out from the whole samples and were treated as outlined below.

3.6.2 Experimental Design for Cooking

For each parching system, there were 3 replicates for each rice type and each curing system. The 3 replicates were mixed and then 2 sub-samples composed of 100 whole kernels each were drawn and weighed. Water amounting to 7 times the weight of each sub-sample was added and then the mixture was cooked (40). All sub-samples were cooked for 45 minutes (same cooking time as used for taste panel work).

3.6.3 Cooking Techniques

The sub-samples were cooked in a Corning gourmet double boiler as follows:

(a) Each sub-sample was washed three times with clean tap water.

(b) The amount of water required for each sub-sample was placed in the boiler and brought to a boil before the rice was added.

(c) During cooking, the water temperature was maintained just at boiling point.

(d) After 45 minutes of cooking time, any excess water was drained off by means of sieves.

(e) The cooked kernels were than grouped according to the following categories:

(i) whole and intact

(ii) whole and split

(iii) straight

(iv) curled

and then counted. These counts were then recorded.

3.6.4 Procedure for Kernel Fragility Study

All wild rice samples used in this study were the same as those used for the cooking study (as described in section 3.6.1).

3.6.5 Experimental Design for Kernel Fragility Study

There were 3 replicates obtained for each parching system and for each rice type and curing system (as described in Section 3.6.2). Four sub-samples of 50 whole kernels were randomly selected from the combined triplicate samples (as in Section 3.6.2) for each rice type. All sub-samples were then handled in the following manner.

3.6.6 Techniques for Kernel Fragility Study

Each sub-sample was held under fluorescent light in order to expose the stress points more clearly. These were vertical fissures in the kernel that were liable to break apart upon hulling or cooking. The number of kernels containing stress points were counted and recorded for each sub-sample.

3.7 Sensory Evaluation

The main objective of this study was to improve upon and finalize the characterization of the appearance, aroma, texture and flavor of (cooked) wild rice. This profile was used to evaluate the quality of finished wild rice that was obtained from the processing studies. It was anticipated that this profile would be a standard guideline for wild rice processors and consumers. A group of 8 trained panel members were asked to evaluate the rice samples according to the established profile guidelines.

3.7.1 Experimental Procedure and Panel Training

A total of 330 replicates were obtained from all rice types used in all the processing systems, and it was not possible to test all of these in the sensory studies. Of these, 87 replicates were used in the sensory evaluations and were selected on the basis of previous studies carried out on the flavor and acceptability of wild rice. These studies conducted by Chung (1975) and the University of Wisconsin (1973) indicated, for example, that wild rice cured at high temperatures eg 38°C, were highly unacceptable after an extended curing period. In addition, many replicates were considered to have received very similar treatments and therefore, a representative replicate was selected.

Eight students and staff from the Food Science Department who were trained in 1974 (for Chung's research) were retrained to identify the flavor characteristics of wild rice. In 1974, panel training sessions were held twice a week for 4 months. The panelists held a discussion period after each training session during which the various sensory characteristics were identified and discussed. Twenty-four descriptive words derived from these training sessions were utilized as the basis

for the format of the ballot used in the 1975 study by Chung. The 1975 ballot served as the basis for the ballot used in this study. The re-training sessions were conducted over a period of 2 weeks and were held once a day and 5 days a week. A ballot of 22, 7-point scales (Appendix 2) was constructed and represented the sensory characteristics of wild rice as established by the panel. These scales were classified under five categories, namely: appearance, aroma, taste, texture and after-taste. The overall acceptance of a wild rice sample was based on the evaluation of these categories.

3.7.2 Sampling Design and Techniques for Sensory Evaluation

The replicates selected for the sensory evaluations are presented in Table 5. There were three replicates for each curing time, each parching system and each rice type except for paddy rice which had only two replicates because of the very low yield of whole grain rice. Replicates were randomly selected and were prepared as follows:

1. Four samples of 40.0 g each were weighed out for each taste panel session.

2. For 40.0 g of rice, 280.0 ml of water were used for cooking (40).

3. Each sample was washed thoroughly with clean tap water before cooking.

4. The 280.0 ml of water was measured into a Corning gourmet double boiler and brought to a boil before the rice was added.

5. During cooking, the temperature of the water was maintained just at the boiling point.

6. After 45 minutes of cooking time, any excess water was drained off by means of sieves.

TABLE 5. Samples Used for Sensory Evaluation of Finished Wild Rice. (These were common for both Lake and Paddy rice and for parching systems 1 and 2.

Curing Temperature °C	Length of Curing Period in Weeks									
3°	[0]	[1]	2	[3]	4	[5]	6	[7]	8	[9]
5°	[0]	[1]	2	[3]	4	[5]	6	[7]		
10°	[0]	[1]	2	[3]	[4]					
15°	[0]	[1]	2	3	[4]					
	Length of Curing Period in Days									
38°	[0]	1	[2]	3	4	5	[6]			
	Parching Systems									
3°	[3]	[4]	[5]	[6]	[7]	[8]	[9]			
15°	[3]	[4]	[5]	[6]	[7]	[8]	[9]			

[ ] Samples used in the taste panel work.

7. A tablespoonful of cooked rice from each sample was placed in a 60 ml lily cup and was served immediately to ensure that the rice was still warm while being tasted.

8. One 240 ml cup of water was provided for each panelist for the purpose of rinsing his/her mouth between and after samples.

For tasting, 4 samples were presented at the same time to each judge for evaluation at each taste panel session. Panelists were required to follow directions as described in Appendix 1 and evaluate each sample according to the descriptions on the ballot (Appendix 2).

Eight judges were used throughout the sensory evaluation panels and 6 were utilized at each session. All the panel results were analyzed statistically by the randomized block design (1) and computer analysis.

3.8 Consumer Survey

To date, wild rice processors have relied on the "good name" of wild rice, (as being a good grain with unique flavor for special gourmet dishes) in selling their products. As a result, no attention has yet been paid to consumer preferences and/or practices for wild rice. In view of the fact that no information and data exists now on consumer reactions to wild rice, this survey was conducted to a) determine how often wild rice is used by those who purchase it, b) how the rice is purchased (ie shopping habits), and c) how it is cooked and served.

3.8.1 Procedure for Survey

All respondents were chosen from the city of Winnipeg, because it was anticipated that since Manitoba has one of the largest wild rice producing areas in North America, the people in this province would be

more knowledgeable in the use of this grain. All respondents were contacted by telephone and were told that this was a survey, (on the use of wild rice), conducted by a graduate student from the University of Manitoba. Those respondents who were willing to participate were asked a series of questions to ensure that they met at least 2 of the following criteria:

1. that the respondent did most of the shopping for wild rice in the household.
2. that the respondent served wild rice at least once a year, and
3. that the respondent prepared or cooked the wild rice meal him/her-self.

A total of 70 respondents were obtained this way and interviewed. The characteristics of respondents are described in Appendix 3 and illustrates the distribution of participants by employment, education, age and family size.

3.8.2 Design for Consumer Survey

A 17 point questionnaire was used to determine consumer purchasing habits for wild rice (Appendix 4). The questionnaire was designed also to obtain information on cooking habits, frequency of use and general knowledge of the grain.

The first 4 questions were designed to select respondents. The next section dealt with the description of wild rice shopping habits, namely frequency of purchasing and criteria for selection; cooking methods and source of information on cooking wild rice was also investigated. The next section dealt with preferences with respect to color, cleanliness, and general knowledge of good grain wild rice. The last part of the questionnaire dealt with the biodemographics of the respondents.

3.8.3 Techniques Employed for Consumer Survey

All interviews were conducted by 1 person, over a period of 4 weeks (between the months of Jan. and Feb. 1976). Each inteview required approximately 1 hour (ie including the telephone conversation). All respondents were shown samples of finished wild rice (processed in this study) at one point in the interview. Hence it was necessary to meet each respondent in person, usually in their home, in order to obtain the required information. One paddy rice and three lake rice samples were used for all interviews. All answers given by respondents were noted down by the interviewer. All the interview data were analyzed by counting the various descriptive characteristics of the population under investigation. For the consumer preference study, statistical analyses consisted of finding a Chi Square relationship between rice types and the dimensions (ie color, size etc) in question as judged by the consumer.

4. Results and Discussion

The studies on the processing of wild rice were carried out between Jan. 1974 and Feb. 1976. The main objectives of this research, as stated before, were to investigate the effects of curing systems on wild rice quality by varying: 1. temperature, 2. humidity, and 3. storage time. The effects of parching systems on wild rice quality were also investigated. The quality of the finished product was then evaluated by yield analysis, color analysis, sensory evaluation and consumer preference tests. It was also possible to compare the effects of the various processing systems on the quality of the rice from different locations (lakes and paddy).

4.1 Observations of the Curing Systems

During the curing process, various changes occurred in the wild rice which were observed visually and were detected by instrumental analysis.

At the much cooler temperatures utilized in systems A and B, curing was a success. The physical appearance and odor were acceptable to the end of seven weeks curing although color changes were slow and minimal in all rice types. Germination was observed in both lake and paddy wild rice at the end of 7 weeks curing period. This phenomenon indicated that both the lake and paddy rice were still physiologically active at the later stages of curing.

Wild rice cured by system C showed rapid color and odor changes. Physical deterioration apparently was accelerated by the high temperature environment (system C). Rice cured by system D showed no physical deterioration at the end of the curing period. There was no detectable odor at the end of the curing period, whereas a strong objectionable odor was evident within three days of curing by system C.

Wild rice cured by systems E and F also showed no detectable unpleasant odor throughout storage. The physical appearance and color were acceptable throughout the curing period. No sprouting was observed but molds were seen to be growing in all samples. Hence, curing was terminated, when they were detected, for both paddy and lake rice at the end of 4 weeks curing.

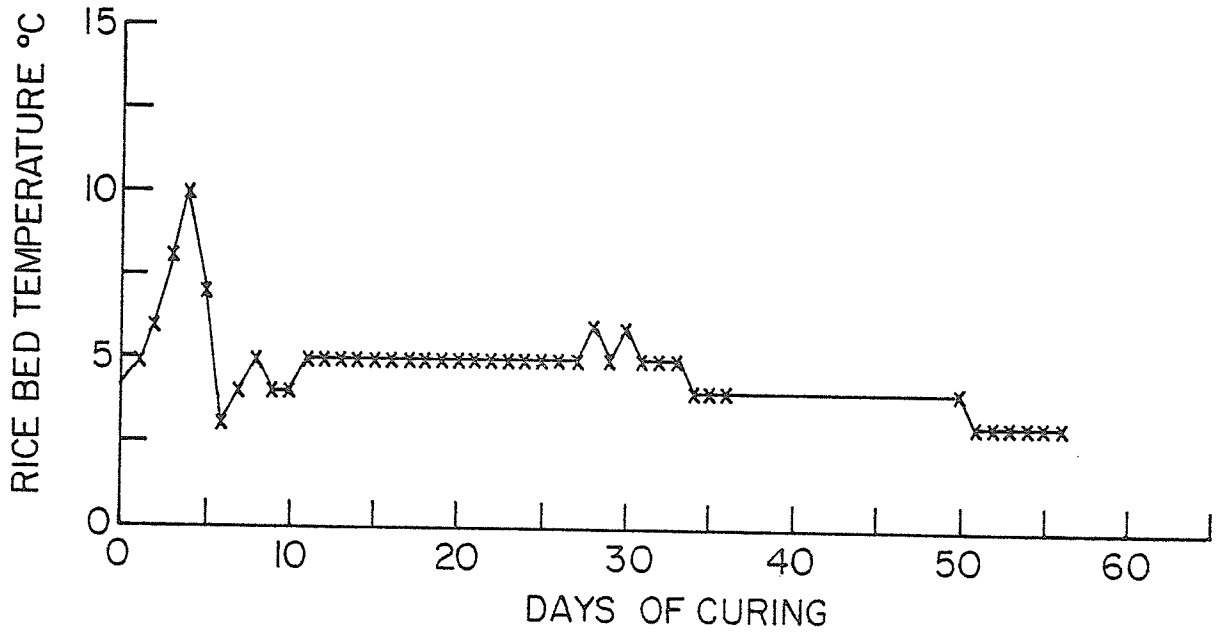
The development of acceptable color in all rice types was as follows: Shallow Lake, Eileen Lake, Harrop Lake, Crowduck Lake, Lac la Ronge and Paddy rice, in descending order. Rice lots from Shallow Lake, Eileen Lake, Harrop Lake and Crowduck Lake appeared to be well matured and had nearly dark-brown color prior to curing; whereas the Lac la Ronge and Paddy rice appeared very green initially.

Factors which caused the termination of a curing study for all rice types were noted as follows: soft milky kernels (ie physical deterioration of kernels), color fading, sprouting or germination and reduced volume (yield) of rice. These factors were evident at the end of 9 weeks and 7 weeks of curing by systems A and B respectively. Slimy texture, dirty appearance and strong swampy odor were the undesirable factors that caused termination of curing by System C. Mold growth in the rice pile was the determining factor for terminating curing by systems D, E and F. Reduced volume (yield) although insignificant was noted in all rice types towards the end of all curing periods (except lake rice cured by systems E and F).

4.1.1 Rice Bed Temperature

The bed temperature of the rice cured by systems A and B showed very little fluctuation from the control temperatures throughout the entire curing period (Figs. 6-10). The temperature rose to 14°C for lake rice (Figs. 6, 8, 10) and 16°C for Paddy rice (Figs. 7 and 9) in the first

FIGURE 6. Rice Bed Temperature of Lake Wild Rice Cured at 3°C and 95% Relative Humidity (Lac La Ronge).



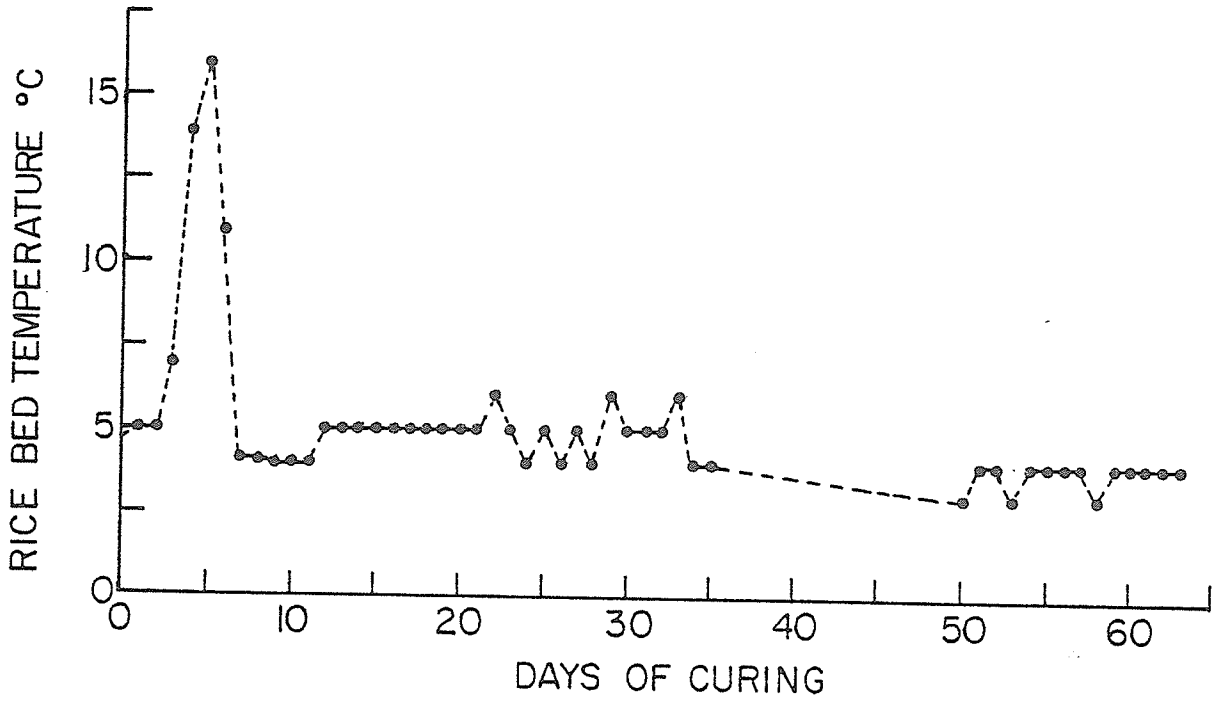
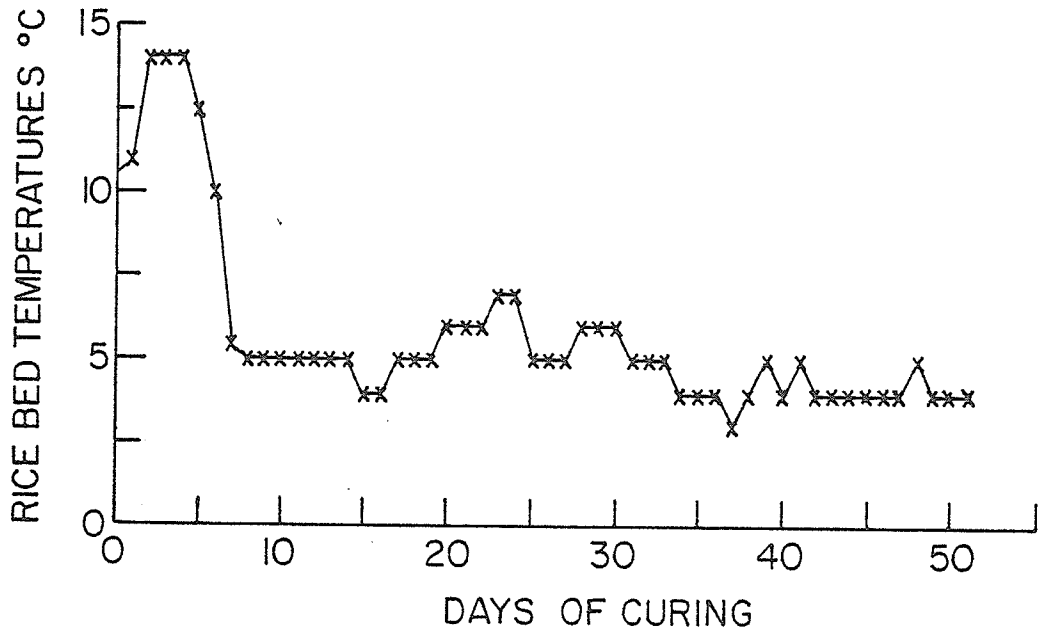


FIGURE 7. Rice Bed Temperature of Paddy Wild Rice Cured at 3°C and 95% Relative Humidity.

FIGURE 8. Rice Bed Temperature of Lake Rice Cured at 5°C and 95% Relative Humidity (Shallow Lake).



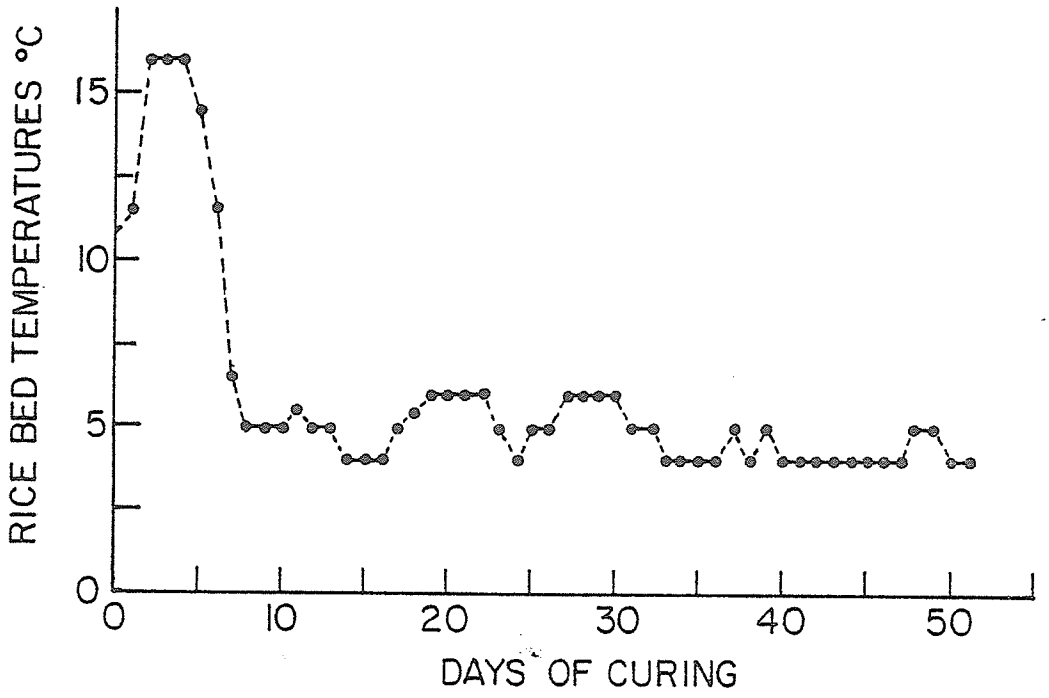
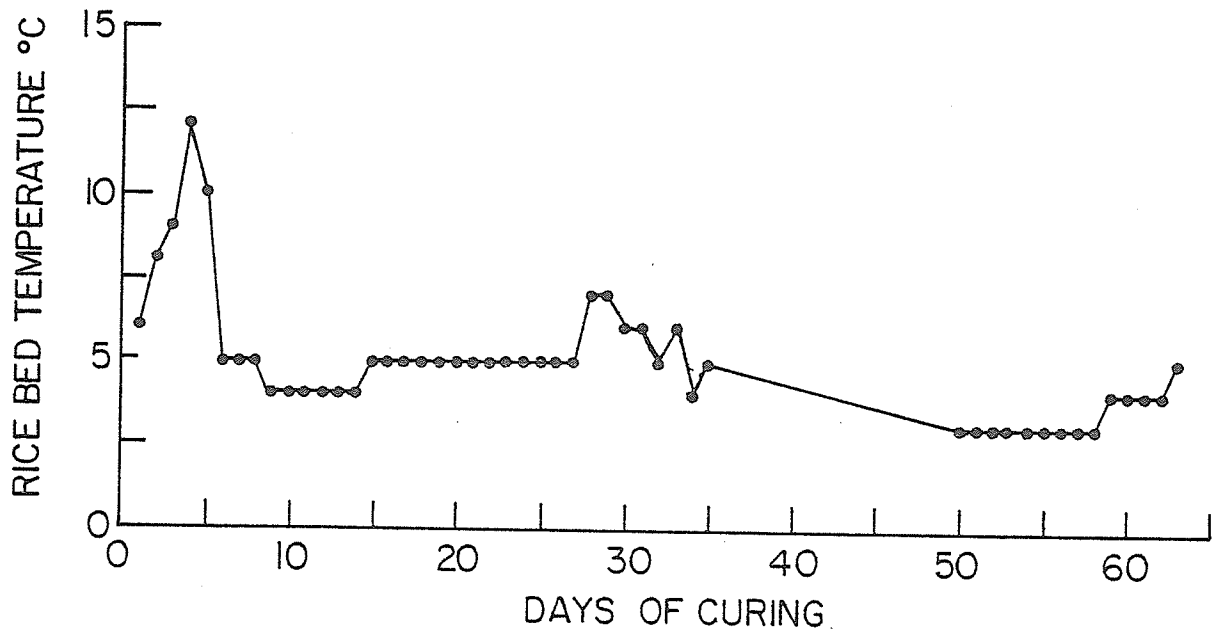


FIGURE 9. Rice Bed Temperature of Paddy Wild Rice Cured at 5°C and 95% Relative Humidity.

FIGURE 10. Rice Bed Temperature of Lake Wild Rice Cured at 3°C and 95% Relative Humidity (Harrop Lake).



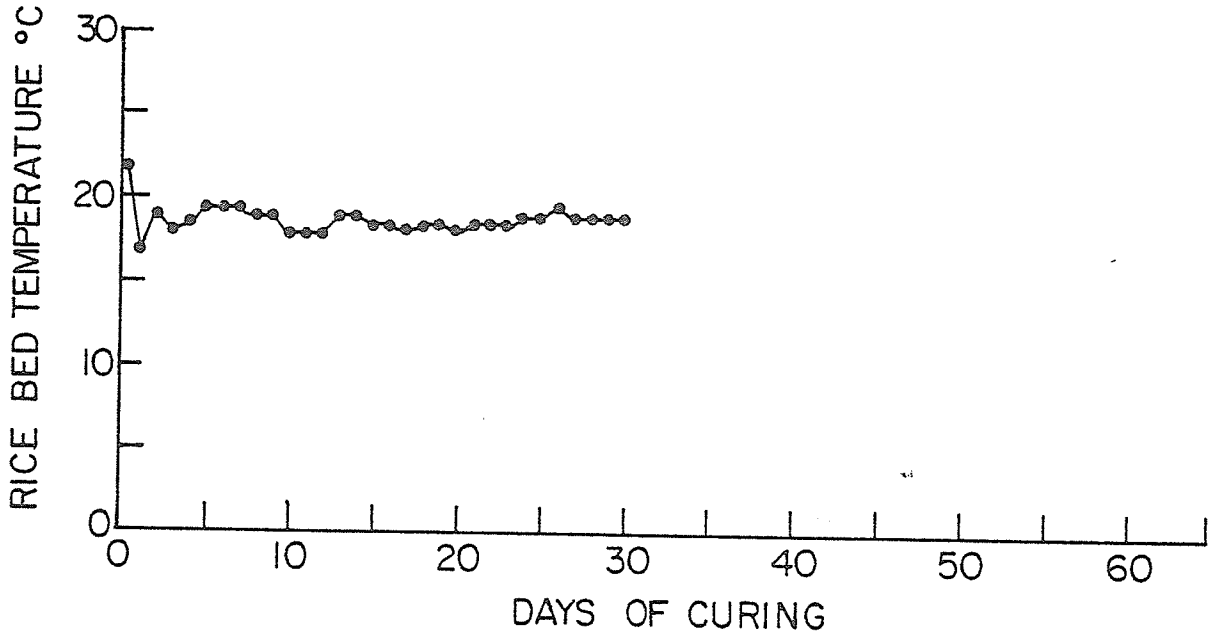


FIGURE 11. Rice Bed Temperature of Lake Wild Rice Cured at 15°C and 95% Relative Humidity (Harrop Lake).

five days and then fell to the control temperatures and remained fairly constant (around 3°-5°C) throughout the curing period.

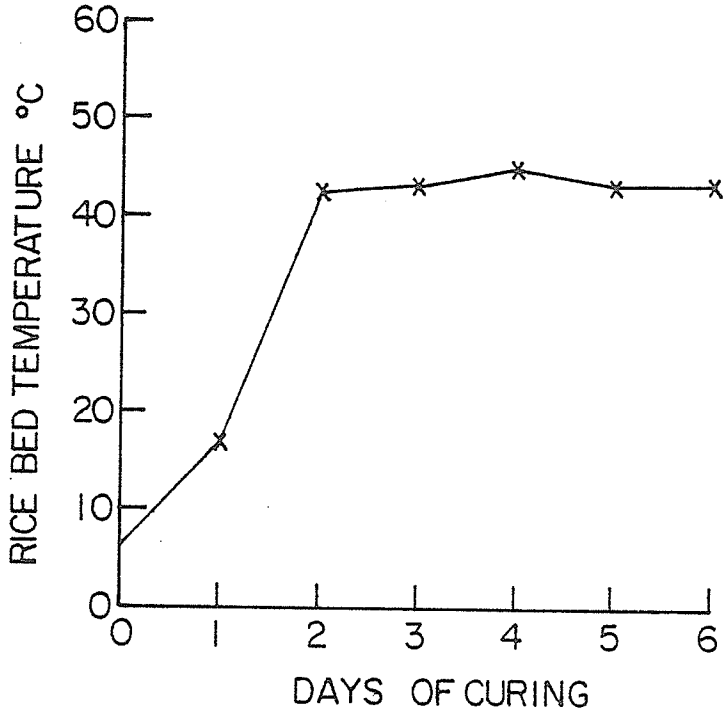
When systems C and D were used a higher bed temperature was recorded for both Lake and Paddy wild rice (Figs. 11-15). Under system C, bed temperature ranged from 17°C to 45°C for Lake rice (Fig. 12) and 19°C to 50°C for Paddy rice (Fig. 13). For system D, the temperature ranged from 14°C to 19°C for Lake rice (Fig. 11) and 17°C to 20°C for Paddy rice (Fig. 15).

The bed temperature of rice cured by systems E and F (Fig. 16-19) showed no significant fluctuation from the control temperature during curing, although a slight increase in bed temperature was observed during the last week of curing. The temperature ranged from 9° to 13°C for Lake rice (Figs. 16 and 17) and 9°C to 15°C for Paddy rice (Figs. 18 and 19). It appeared that the mature fraction for both Lake and Paddy rice maintained a slightly higher bed temperature than the mixed and immature fractions (Fig. 16, 17, 18, 19).

4.1.2 Effects of Relative Humidity

The relative humidities evaluated in this study were 95% (Chung 1975), 75% and 55%, while the temperature was kept constant at 10°C. Changes in bed temperature when rice was held at 10°C and 95% relative humidity (Chung 1975) appeared similar to those observed in rice cured at 5°C and 95% relative humidity (System B) for all rice types. While under 95% relative humidity, undesirable factors such as slimy texture, dirty appearance, soft milky kernels, decreased volume (yield) and swampy odor were detected in the last stages of storage; none of these factors were observed when 75% and 55% relative humidity were utilized. As mentioned before, termination of curing at the lower humidity levels was caused by the

FIGURE 12. Rice Bed Temperature of Lake Rice Cured at 38°C and 95% Relative Humidity (Shallow Lake).



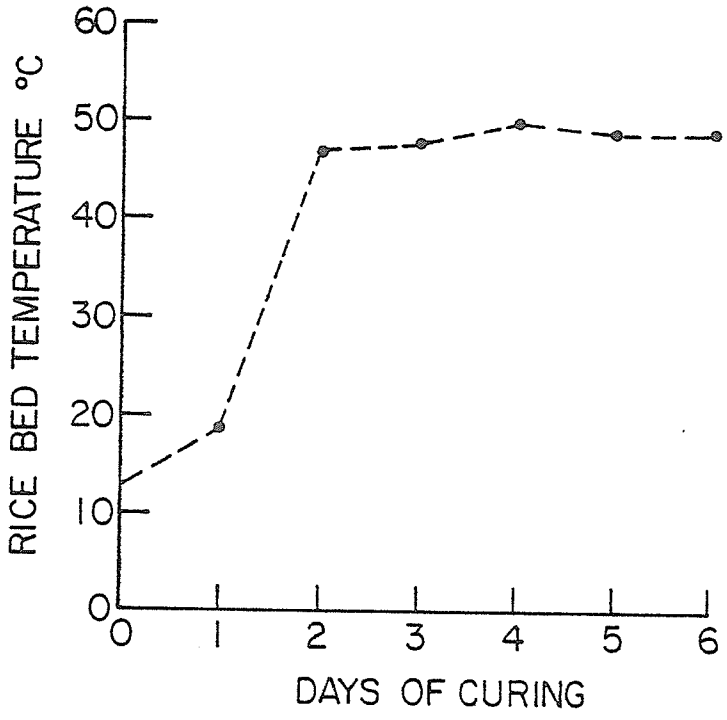
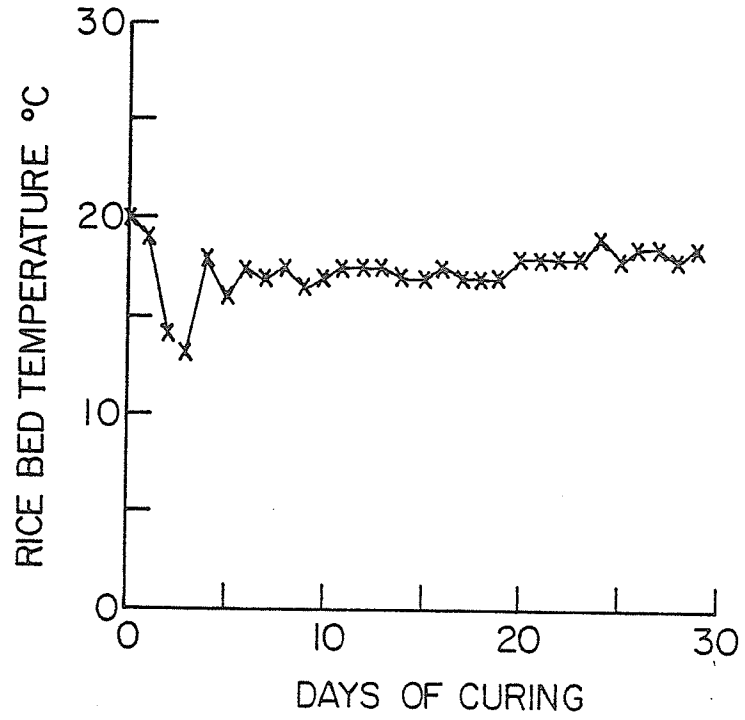


FIGURE 13. Rice Bed Temperature of Paddy Wild Rice Cured at 38°C and 95% Relative Humidity.

FIGURE 14. Rice Bed Temperature of Lake Rice Cured at 15°C and 95% Relative Humidity (Lac La Ronge).



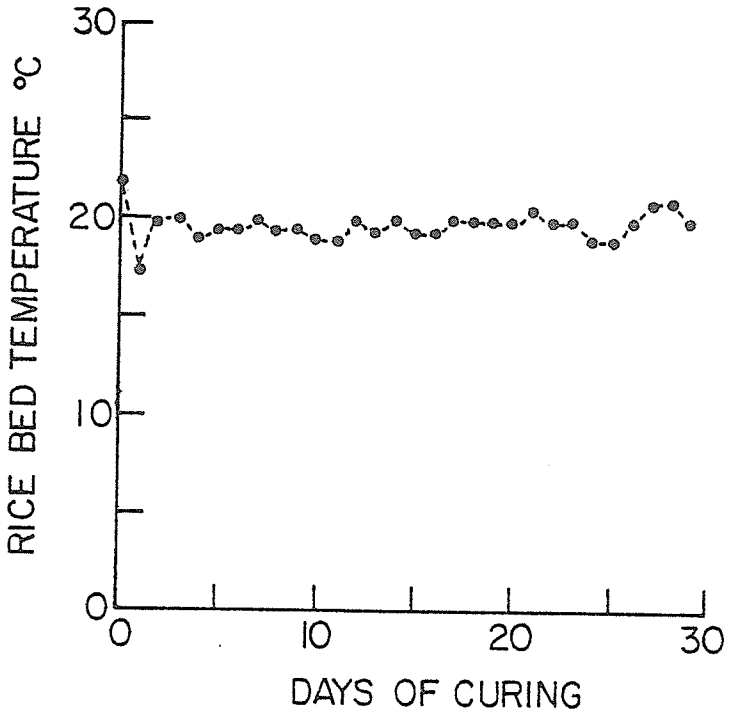
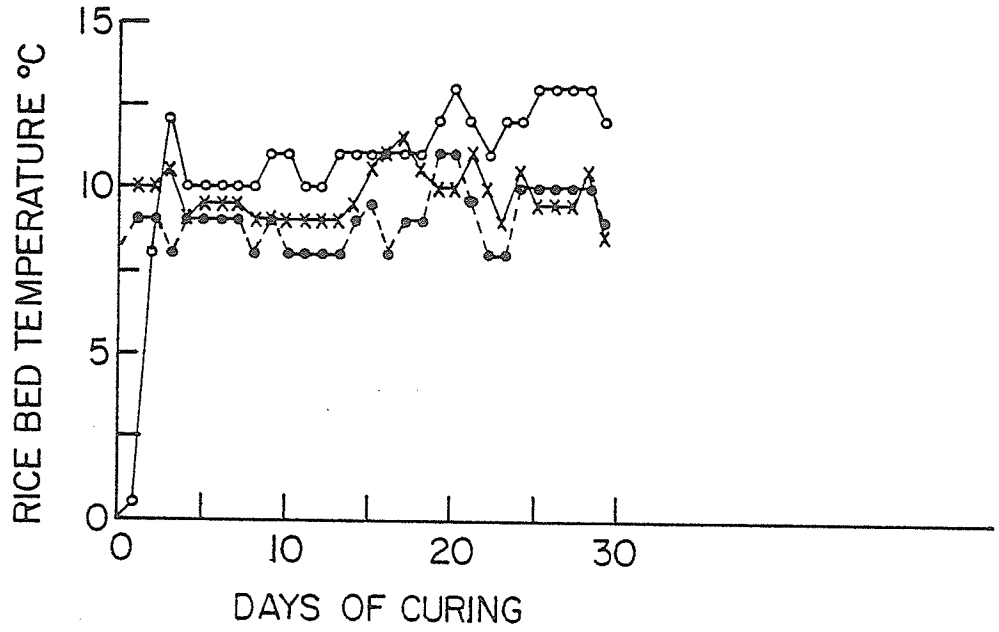


FIGURE 15. Rice Bed Temperature of Paddy Wild Rice Cured at 15°C and 95% Relative Humidity.

FIGURE 16: Rice Bed Temperature of Lake Rice Cured at 10°C and 75% Relative Humidity (Crowduck Lake).



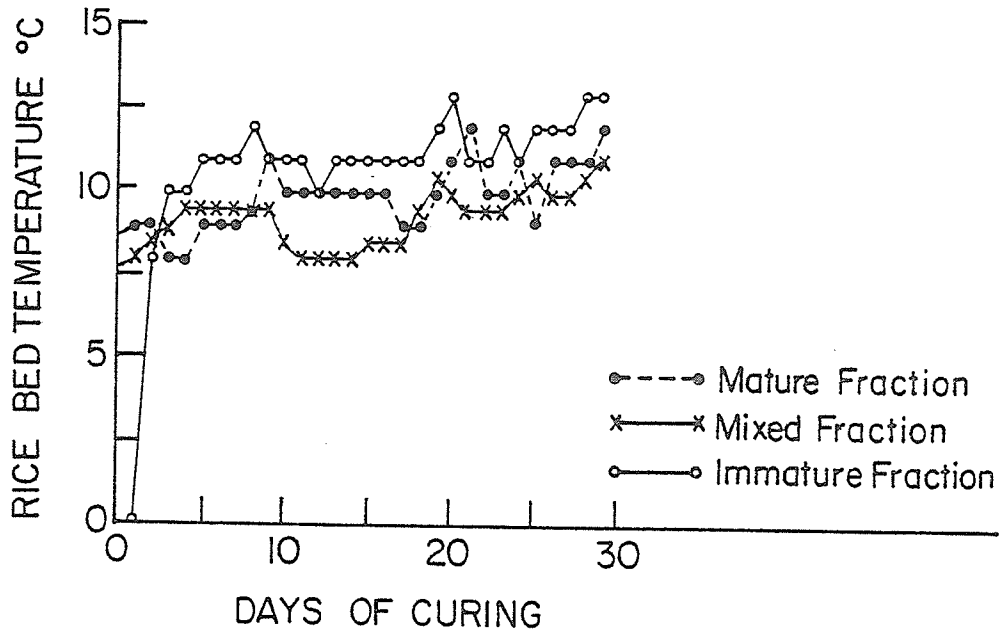
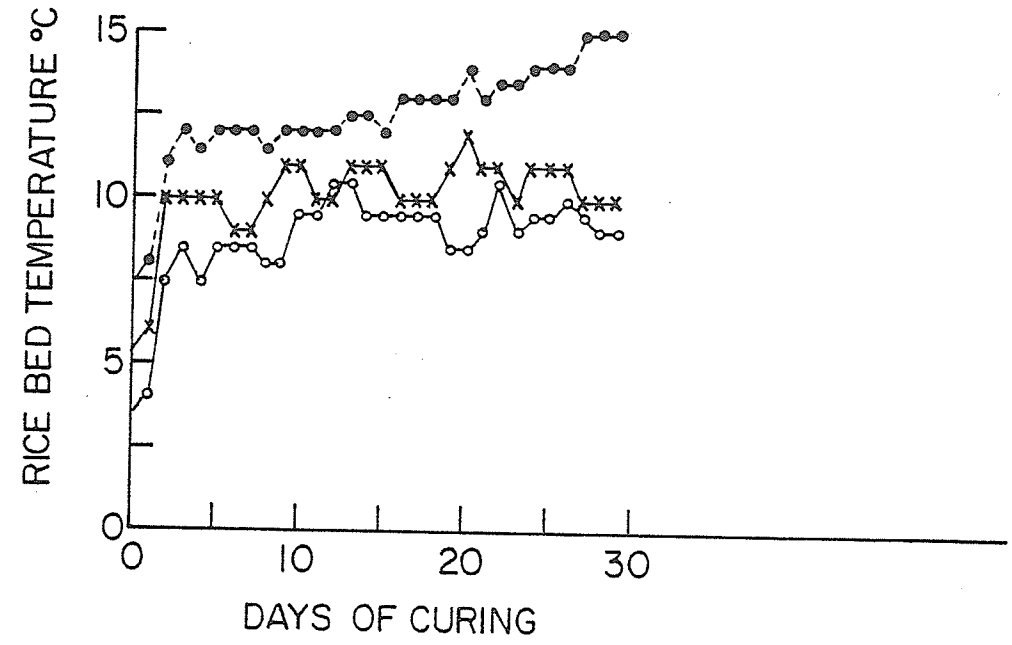


FIGURE 17: Rice Bed Temperature of Lake Wild Rice Cured at 10°C and 55% Relative Humidity (Crowduck Lake).

FIGURE 18: Rice Bed Temperature of Paddy Wild Rice Cured at 10°C and 75% Relative Humidity.



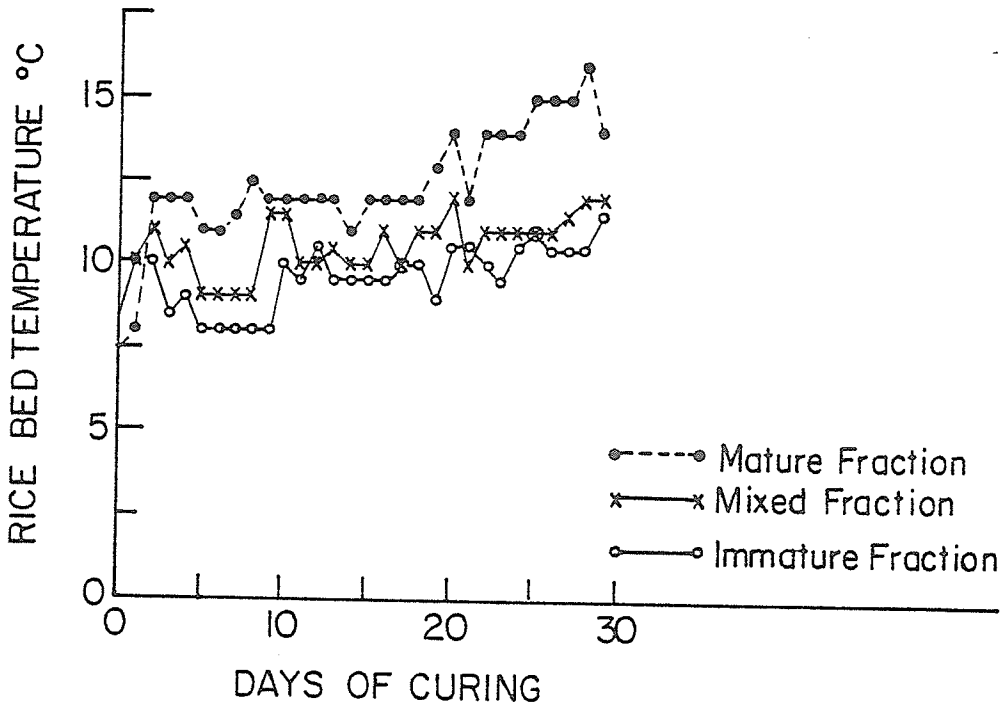


FIGURE 19. Rice Bed Temperature of Paddy Wild Rice Cured at 10°C and 55% Relative Humidity.

detection of mold growth in the rice piles. Also very high moisture content was observed in rice types cured by 95% humidity. On the other hand, moisture content of rice remained fairly constant in Lake rice when 75% and 55% were used (Tables 6 & 7). The moisture content of Paddy rice cured by 75% and 55% humidity decreased by approximately 6% as curing progressed. The moisture content of Crowduck Lake rice cured at 55% remained less than 40% (38.6%) throughout storage and as such caused "white centers" in this batch of rice. The factors causing white centers will be discussed later.

Wild rice must be well handled during curing to give a good quality finished product. Rice bed temperature was an important indication of good control during the curing period. The primary factors that contributed to changes in bed temperature included: 1. type of rice, ie Lake, Paddy; 2. specific genotype of rice, "maturity of rice, kernel size; 3. curing environment: method of handling during curing, ie turning and watering. Some of these factors were not controlled in some of the studies, are not controlled by commercial processors and were therefore accepted as part of the experimental error.

The curing environment appeared to play a major role in developing the temperature in the curing bed of rice. It was apparent that the lower the temperature of the curing environment, the easier it was to control the temperature of the rice bed (Figs. 6-19). Typical changes observed in rice bed temperature, odor and color were common for all Lake rice types except Lac la Ronge rice. This rice together with Paddy wild rice showed virtually no color improvement throughout the testing program.

In general, Paddy rice had a higher bed temperature than Lake rice in all the curing studies (Figs. 6-19). This might have been due to the fact that Paddy rice was smaller with less air spaces between the grains, thus resulting in more heat accumulation in the rice pile. In addition,

TABLE 6. Increase in Moisture Content of Wild Rice Cured at 10°C and 75% RH.

	% Moisture Content Before Parching			
	Weeks of Curing			
Rice Type	0	1	3	4
Paddy	66.3	61.5	59.1	60.1
Crowduck	38.6	41.1	41.2	41.5

TABLE 7. Increase in Moisture Content of Wild Rice Cured at 10°C and 55% RH.

	% Moisture Content Before Parching			
	Weeks of Curing			
Rice Type	0	1	3	4
Paddy	66.3	60.3	60.1	60.4
Crowduck	38.6	38.8	38.7	38.8

respiration activity may contribute to the higher temperatures observed in curing Paddy rice as compared to curing Lake rice. The Lake rice was already dark brown and well matured at time of receiving, whereas the Paddy rice was immature and very green. Lac la Ronge rice was green (like Paddy rice) although the kernels appeared much larger and longer in size. There were no significant differences in bed temperature among the various Lake rice types.

In summary, rice was easier to handle when cured at low temperatures and utilizing relative humidities of 75% and above (eg curing systems A, B, D and E).

4.2 Parching Study

Parching (drying) in wild rice processing is a major deciding factor with regard to the quality of the finished product. Parching of wild rice serves several purposes: 1. it conditions the rice for hulling; 2. it reduces the moisture content of rice for quality stability during storage; 3. it produces an acceptable toasted flavor and 4. it gelatinizes the starch in the kernels. There are numerous methods of parching which will accomplish these purposes, but they are not all equally desirable since the parching process may adversely affect the quality of the finished rice.

4.2.1 Effects of Moisture Content on Parching

The initial moisture content of wild rice is a contributing factor to the quality of the final product. Extensive investigations by the University of Wisconsin have shown that "white centers", an undesirable defect in finished wild rice, occur in wild rice when the moisture content of rice prior to parching is less than 40% (Table 8). (White centers

TABLE 8. *Relationship Between Initial Moisture Content and Proportion of Parched Wild Rice Kernels With White Centers.

Initial Moisture Content	Percentage of Whole Wild Rice Kernels With White Centers When Dried at 121°C
% wb.	%
5	41
25	28
30	3
35	2

*Adapted from "Drying and Hulling Characteristics of Wild Rice", University of Wisconsin, March 1975. Vol. 20, No. 3.

TABLE 9. Relationship Between Initial Moisture Content and Proportion of Parched Rice Kernels With White Centers.

Rice Type	Storage Time Weeks	Curing Temperature °C	Curing Relative Humidity (%)	Initial Moisture Content (%)	% Kernels of Rice With White Centers When Dried at 107°C
Crowduck L. (1975)	0	-	-	38.6	17
	4	10°	75	41.5	0
	4	10°	55	38.8	14
Paddy (1975)	0	-	-	66.3	0
	4	10°	75	60.1	0
	4	10°	55	60.4	0
Paddy (1974)	0	-	-	63.4	0
	4	3°	95	68.9	0
Shallow L. (1974)	0	-	-	48.2	0
	4	3°	95	54.1	0
Eileen L. (1974)	0	-	-	45.9	0
	4	3°	95	48.2	0

indicate the presence of ungelatinized starch granules, and both the high temperature and moisture are necessary for gelatinizing the starch). Our results indicate the lower the moisture content of rice before parching the higher the percentage of rice kernels with white centers (Table 9).

The data obtained in this study (Appendices 5-8) indicated that the moisture content of rice prior to parching ranged from 38-59% for Lake rice and 55-70% for Paddy rice. When curing system A was used, the initial moisture content of rice before parching ranged from 45% at the beginning of curing to 59% at the end of 9 weeks curing for Lake rice. During the same period and under the same curing conditions the moisture content ranged from 63% at start to 70% at the end of storage of Paddy rice. Thus all rice types showed significant increases in moisture content at the end of curing by system A. For instance, increase in moisture content during storage was 14% for Harrop Lake rice, 13% for Lac la Ronge rice, 6% for Shallow Lake, 2% for Eileen Lake, and 7% for Paddy rice (Appendices 4-8). It must be noted that Shallow Lake and Eileen Lake rice were held for only 4 weeks under curing system A. Hence, the low percent gain of moisture in rice before parching.

For curing system B, the increase in moisture content of rice prior to parching was 8% for Shallow Lake rice (48% to 56%) and 7% for Paddy rice (63% to 70%) at the end of storage (Appendix 5). There was little difference in moisture uptake by all rice types when cured by system A as compared to system B.

As a result of the very high moisture content before parching, none of the rice cured by systems A and B were seen to have contained any kernels with white centers. Lake and Paddy rice cured under System C increased in moisture content also, thus no kernels with white centers were detected after parching.

Similar observations were made in rice cured by System D (Appendix 7 & 8).

In System E, it was found that the moisture content of Paddy rice decreased as curing progressed, (66% at start to 60% at end of storage) (Appendix 6 & 7). This was not the case with the Crowduck Lake rice in which a slight increase in moisture content was observed (Appendix 6). (38.6% at start to 42% at end of storage). As a result of the very low moisture content of the Lake rice before curing started, white centers were also detected in rice parched at this point (Table 9). White centers were no longer detected in this rice after 1 week of curing when the moisture content rose to 41% (Appendix 6). White centers were also detected in Lake rice cured by System F (ie the rice had less than 40% moisture content (Appendix 7) (Table 9). However, the Lake rice failed to gain any extra moisture and kernels with white centers were found in all parched rice throughout the curing period. The Paddy rice did lose moisture but the initial moisture content was much higher (60%). Hence, no occurrence of white centers was detected at any time.

In general, Paddy rice had a higher initial moisture content in all curing systems than the Lake rice types and no white centers were detected in Paddy rice. Among the Lake rice types the level of increase in moisture content were Harrop Lake, Lac la Ronge, Shallow Lake, Eileen Lake and Crowduck Lake in descending order.

The low initial moisture content of the Lake rice cured by System F, could be attributed to the low humidity environment level (55%). Rice cured under higher humidity levels (75% to 95%) did not show any kernels with white centers after equilibration.

The Wisconsin study also indicated that white centers were quite evident when rice with low moisture content ($\leq$ 40%) was parched at temperatures below the gelatinization temperature of wild rice (60°C to 65°C).

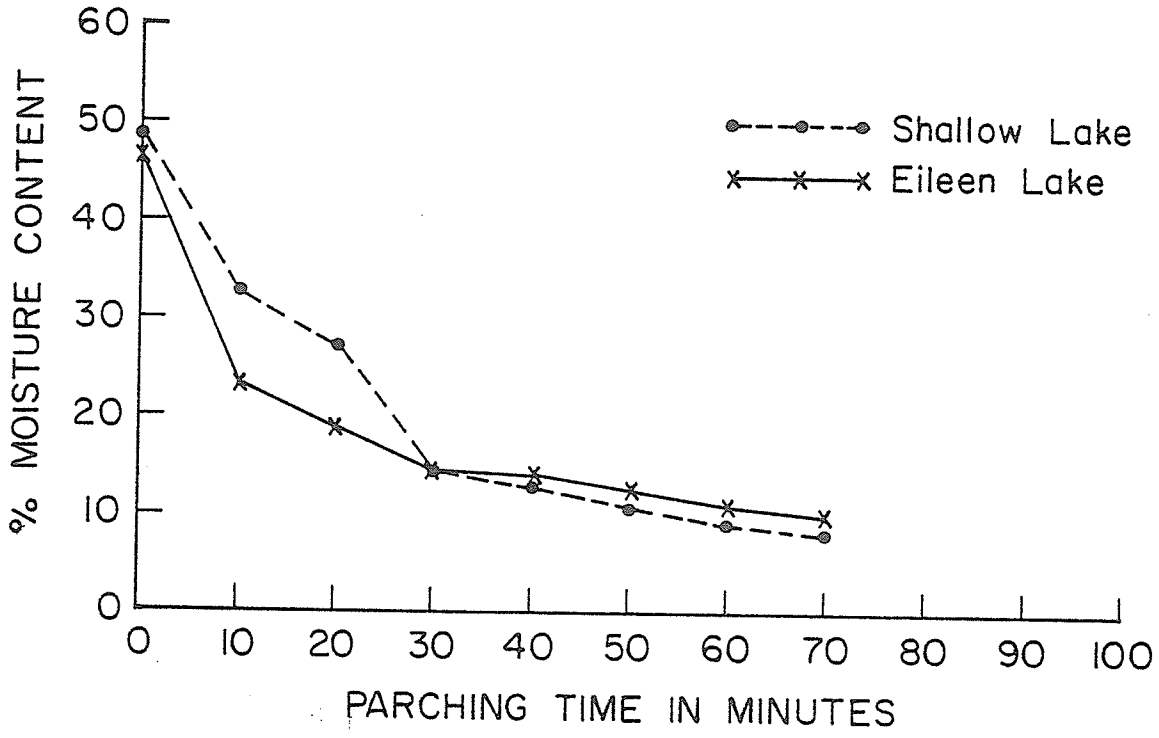
This phenomenon was not evident in any of the rice parched by Systems 1 and 3 in this study. This was because the initial moisture content of rice before parching was well over 40% in all rice types. (Crowduck Lake rice which showed white centers was cured by System F and parched by System 6). Consequently, an initial moisture content of not less than 40% and parching temperature of more than 65°C are essential in order to prevent white centers. Furthermore, an initial moisture content of less than 30% in the rice was found to induce excessive mold growth, thereby producing an undesirable moldy flavor in the finished rice (4, 15, 22).

Chung reported in 1975 that the moisture content of the parched rice, if maintained above 11% resulted in difficulties in hulling; and that rice with final moisture content below 7% was fragile and susceptible to breakage during hulling. Consequently all parching was timed such that the finished product would contain a moisture level of 7-11%.

The parching studies undertaken here (data presented in Figs. 20-26) indicated that the lower the parching temperature, the longer it took to reduce the moisture content to the required level of 7-11%. Also the higher the initial moisture content, the longer it took to reduce it to 7-11%. For instance, at a parching temperature of 65°C (System 3) it required 70 minutes to reach the moisture range of 7-11% (Fig. 20). Whereas, at 149°C only 15 minutes were needed to reach the same moisture level (Fig. 26).

In general, Paddy rice required longer parching times than lake rice since Paddy rice generally had a higher initial moisture content in all curing systems. When parching Systems 3 to 9 were used, Eileen Lake rice tended to dry faster than Shallow Lake rice due to the differences in initial moisture content (Figs. 20-26).

FIGURE 20. Drying Rate of Lake Wild Rice
65°C - Parching Temperature.



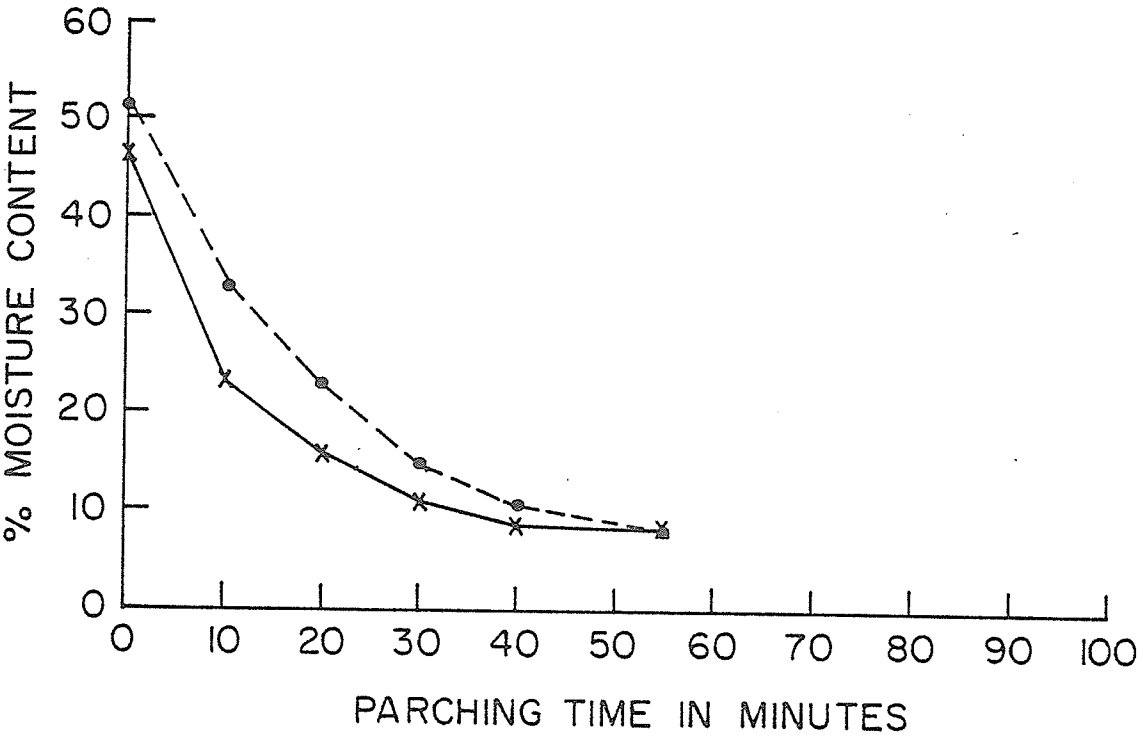
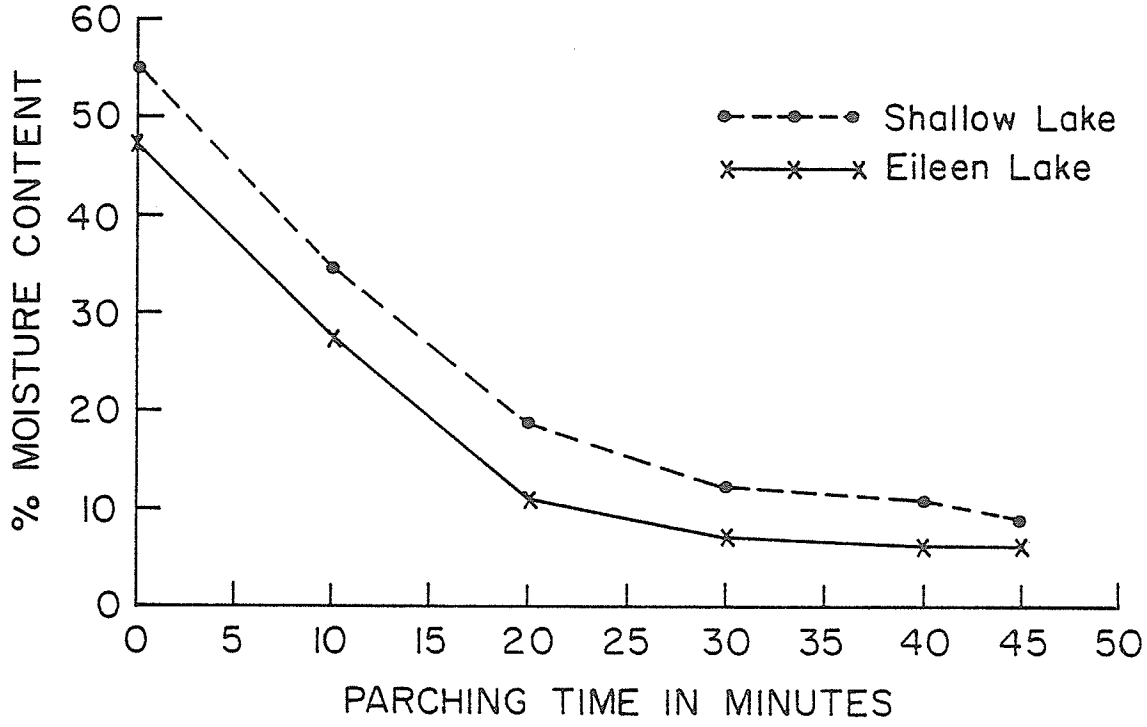


FIGURE 21. Drying Rate of Lake Wild Rice
79°C - Parching Temperature.

FIGURE 22. Drying Rate of Lake Wild Rice
93°C - Parching Temperature.



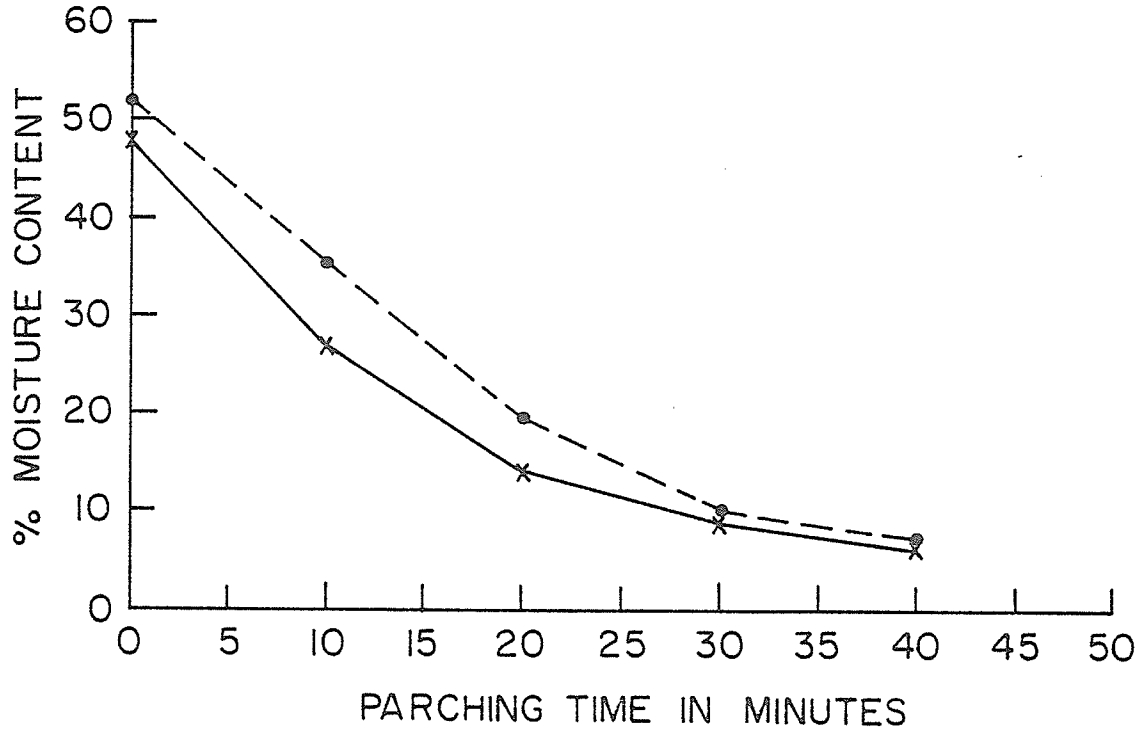
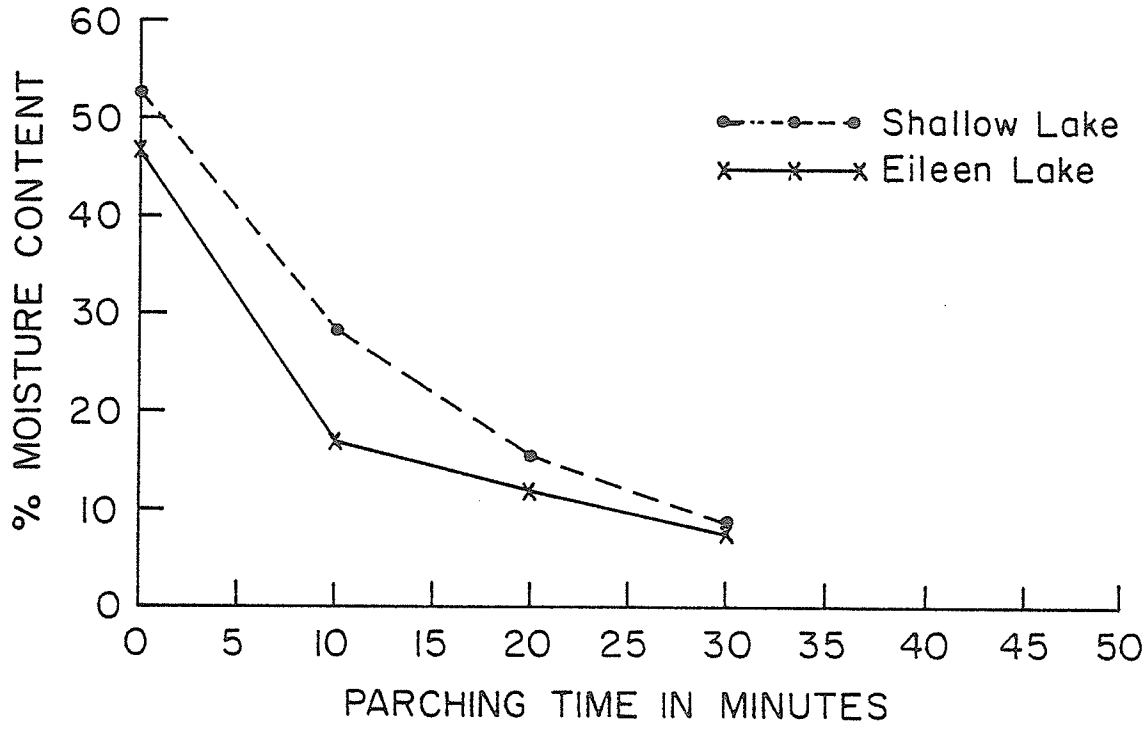


FIGURE 23. Drying Rate of Lake Wild Rice
107°C - Parching Temperature.

FIGURE 24. Drying Rate of Lake Wild Rice
121°C - Parching Temperature.



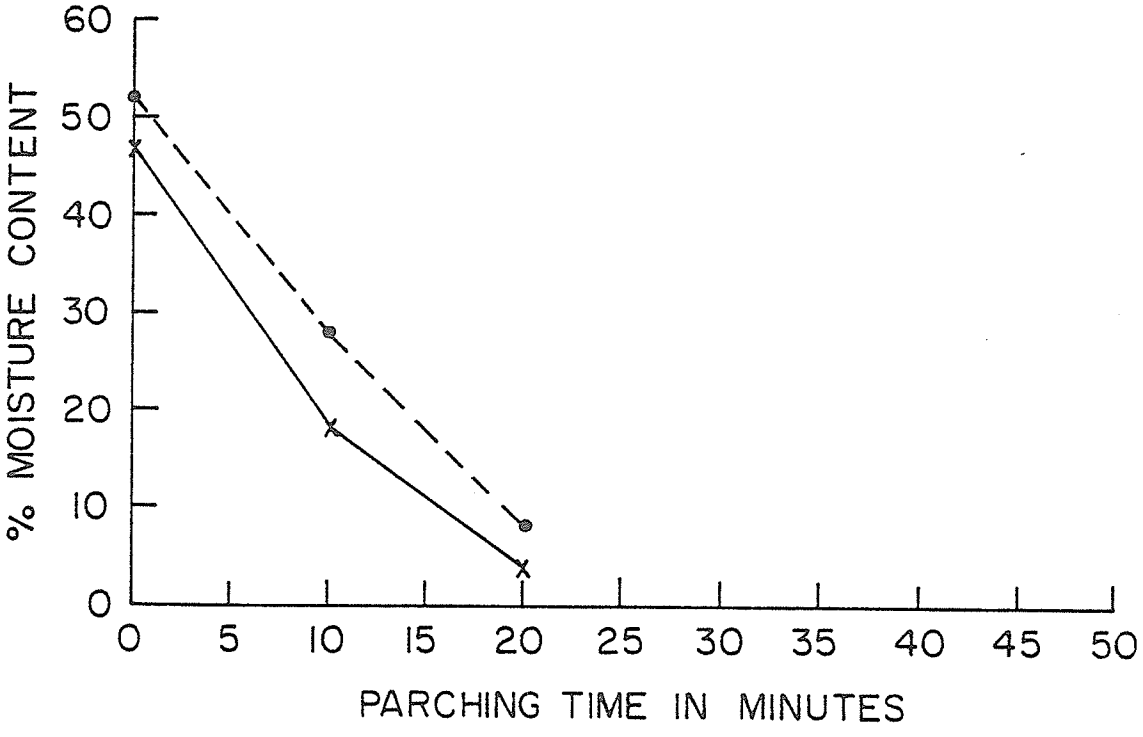
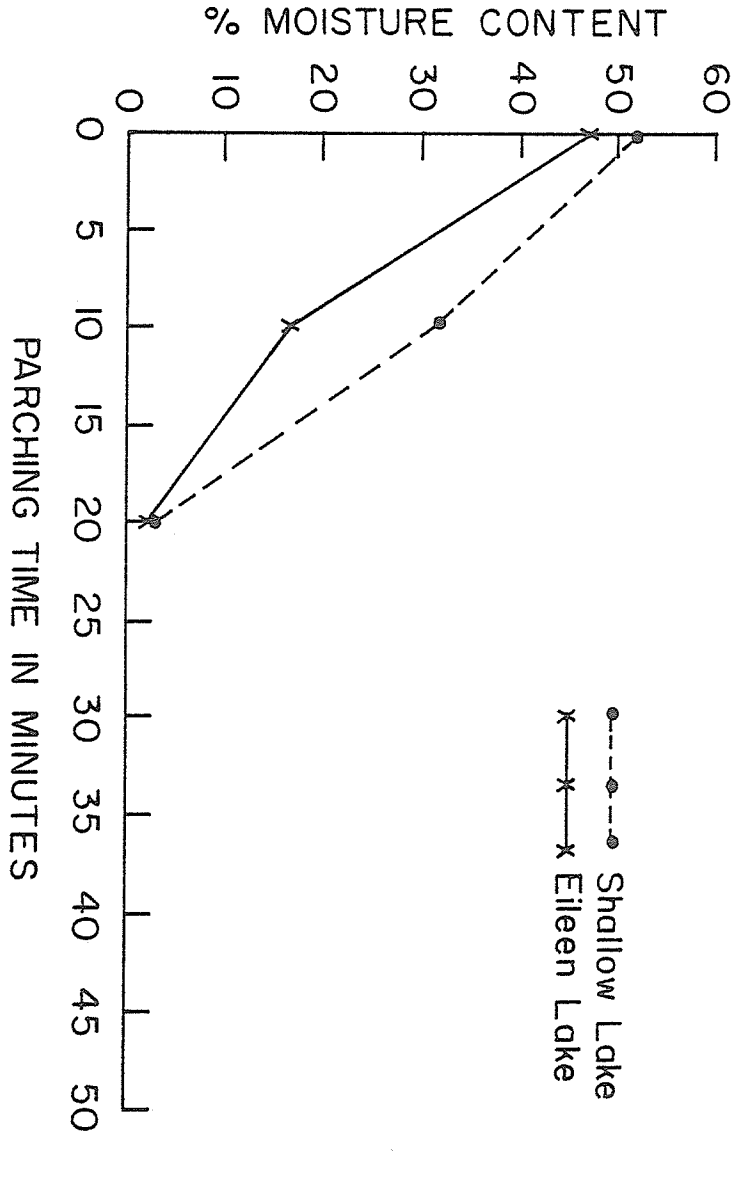


FIGURE 25. Drying Rate of Lake Wild Rice
135°C - Parching Temperature.

FIGURE 26. Drying Rate of Lake Wild Rice
149°C - Parching Temperature.



4.2.2 Effects of Parching and Curing Systems on Percent Total Rice Yield.

When the conditions under which wild rice is cured and parched are well controlled, these variables appear to have little influence on total rice yield (Table 10, 11 and Figs. 27-44). For example, Paddy wild rice yield averaged 15-20% on wet basis for 4 curing and 2 parching systems while the Lake rice yield average ranged very slightly for Lac la Ronge, Shallow Lake (with one exception) and Eileen Lake rice types. On the other hand, Harrop Lake wild rice yield ranged from 40 to 50% which suggests that this source of rice will have a curing-parching system interaction. This interaction is not fully understood at this time. It is of interest to note that the mature fraction of Crowduck Lake wild rice averaged 50%, the mixed fraction averaged 45% and the immature fraction averaged 12% (Table 12). Also the mature fraction of Paddy wild rice averaged 30%, the mixed fraction averaged 20% and the immature fraction averaged 1% (Figs. 43, 44). These support the observation that well controlled curing and parching systems will not affect percent total yield, or that optimum yield will be obtained when these systems are utilized.

4.2.3 The Effect of Storage Time (curing) and Parching Systems on Percent Total Rice Yield.

Maximum yield of wild rice (percent) was obtained shortly after curing started for all curing systems and then gradually decreased throughout storage (Figs. 27-44). This was true for all rice types with the exception of Crowduck Lake rice (Fig. 41, 42) which remained constant throughout that particular study. If the basis for determining the optimum curing time was on yield alone, then short curing periods would be selected. However, other quality factors, such as color and

TABLE 10. Relationship Between Final Moisture Content and Yield of Wild Rice (Eileen Lake).

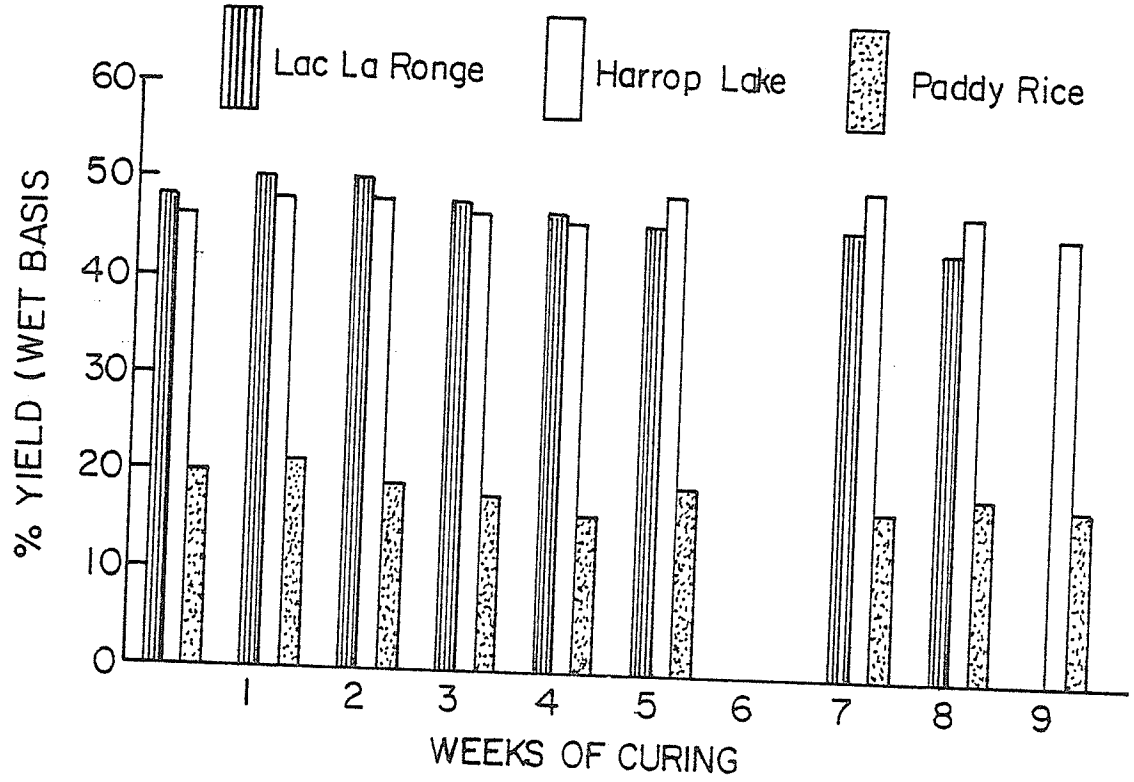
Parching Temp.	Initial M.C. %	Final M.C. %	% Yield	% Whole Grain
Eileen Lake (3°C Curing)				
65	46	10.8	47.0	91.5
79	46	7.8	47.5	83.2
93	47	9.7	47.0	89.4
107	48	7.2	45.0	93.3
121	48	7.2	41.5	89.2
135	48	3.2	39.0	82.1
149	48	3.2	39.0	82.1
Eileen Lake (15°C Curing)				
65	49	10.9	52.0	88.5
79	49	9.5	48.0	91.7
93	48	8.9	46.0	91.3
107	48	7.8	44.0	95.4
121	48	7.5	41.5	75.1
135	48	7.7	39.0	71.8
149	47	5.3	37.0	75.7

TABLE 11. Relationship Between Final Moisture Content and Head Yield of Wild Rice (Shallow Lake).

Parching Temp.	Initial M.C. %	Final M.C. %	% Yield	% Whole Grain
Shallow Lake (3°C Curing)				
65	48	8.5	40.0	82.5
79	48	9.1	39.0	74.3
93	55	9.6	39.5	82.4
107	53	7.3	36.5	93.2
121	54	8.2	40.0	92.5
135	53	5.9	36.0	88.9
149	55	3.9	35.0	85.7
Shallow Lake (15°C Curing)				
65	50	10.9	41.0	86.6
79	56	9.5	40.0	81.3
93	56	8.9	37.5	84.0
107	53	7.8	36.0	94.4
121	53	7.5	38.0	89.5
135	51	7.7	36.0	86.1
149	51	5.3	34.0	88.2

FIGURE 27. Percent Yield of Wild Rice Cured at 3°C and 95% Relative Humidity.

High Temperature Parching



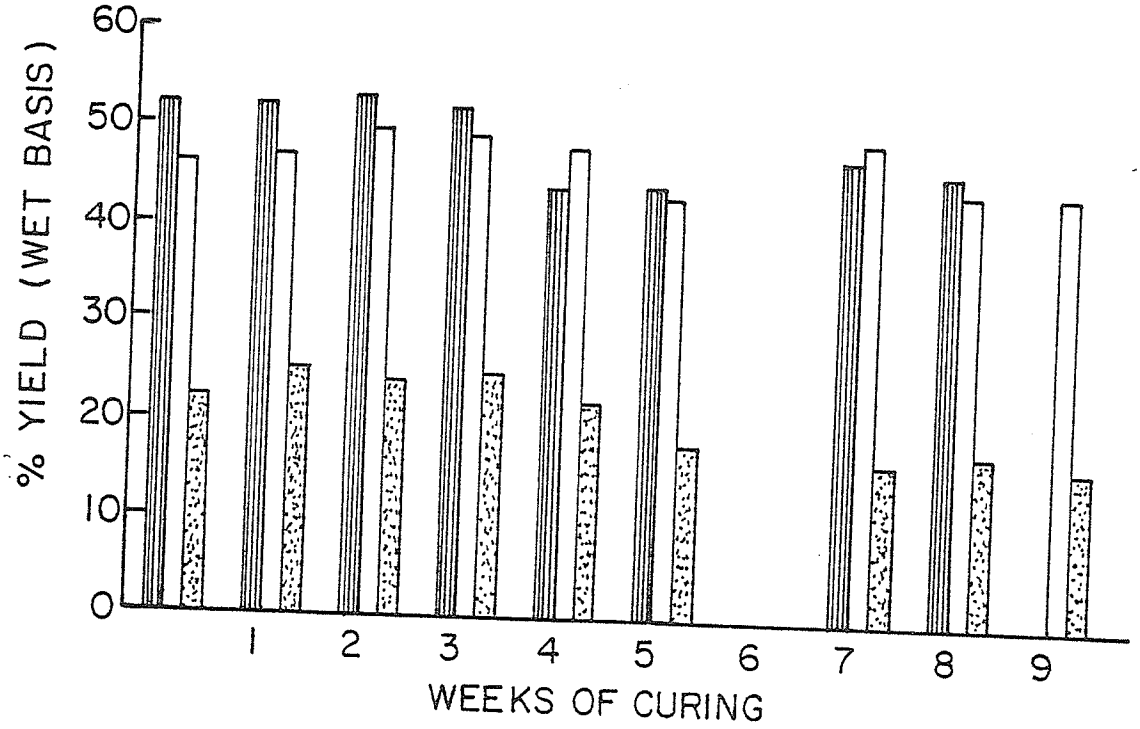
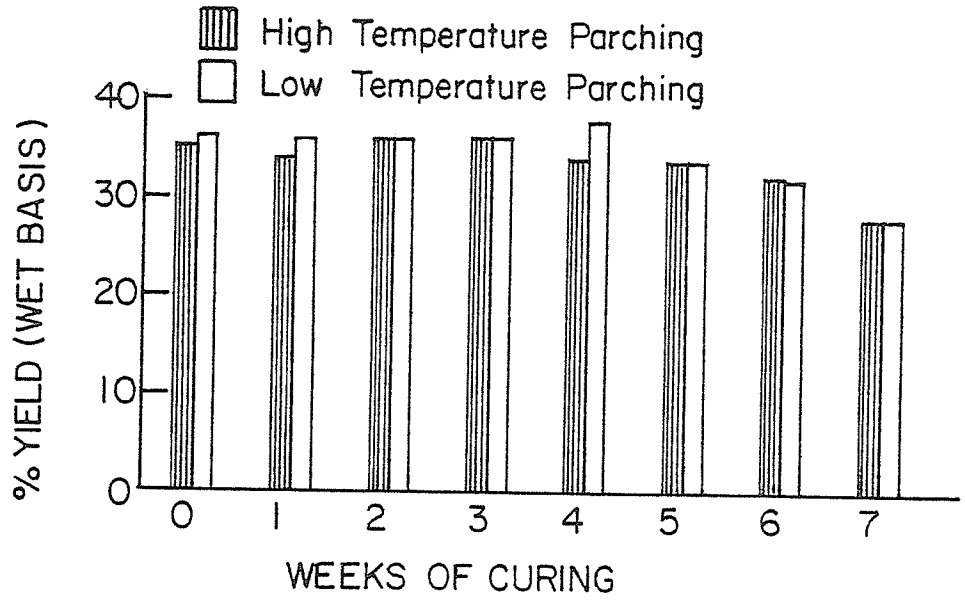


FIGURE 28. Percent Yield of Wild Rice Cured at 3°C and 95% Relative Humidity.

Low Temperature Parching

FIGURE 29. Percent Yield of Lake Wild Rice Cured at 5°C and 95% Relative Humidity. (Shallow Lake)



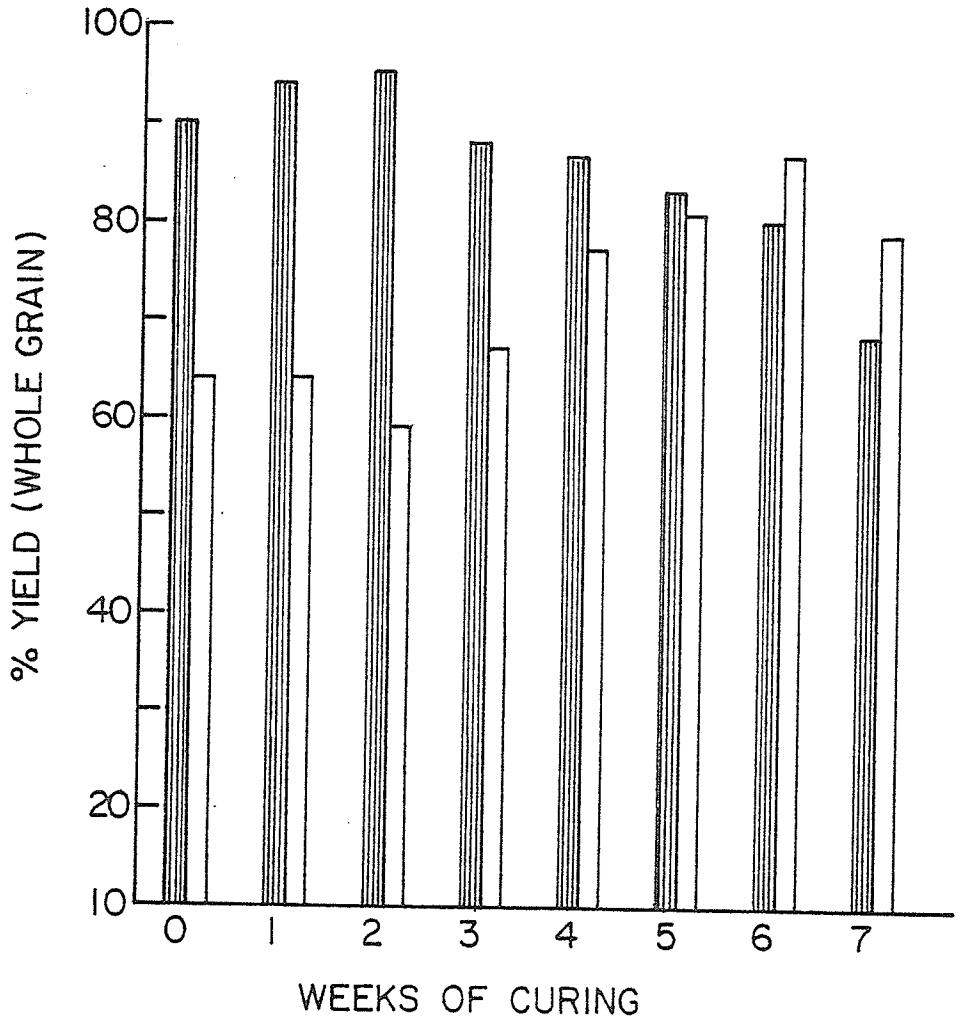
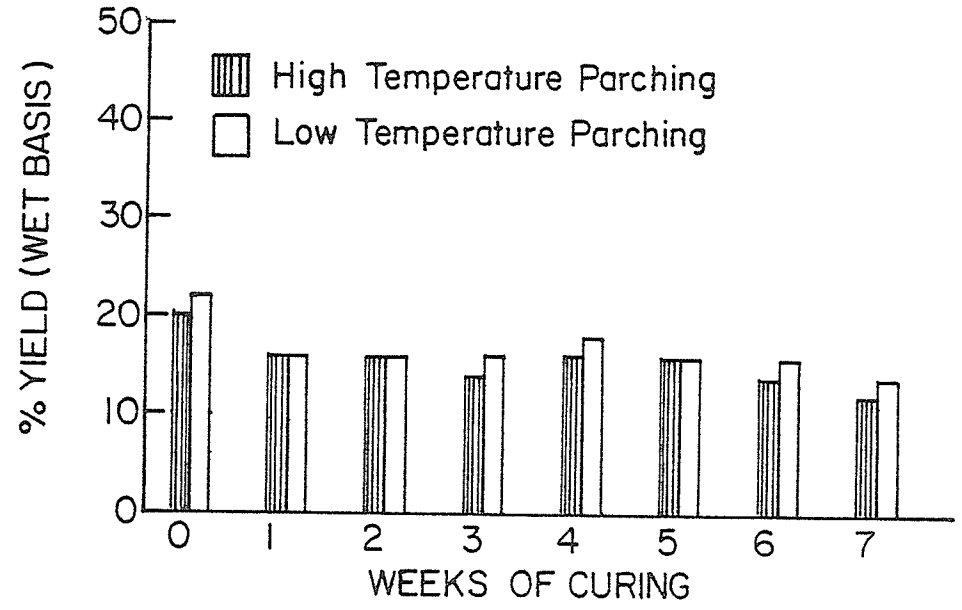


FIGURE 30. Percent Yield of Lake Wild Rice Cured at 5°C and 95% Relative Humidity. (Shallow Lake)

FIGURE 31. Percent Yield of Paddy Wild Rice Cured at 5°C and 95% Relative Humidity.



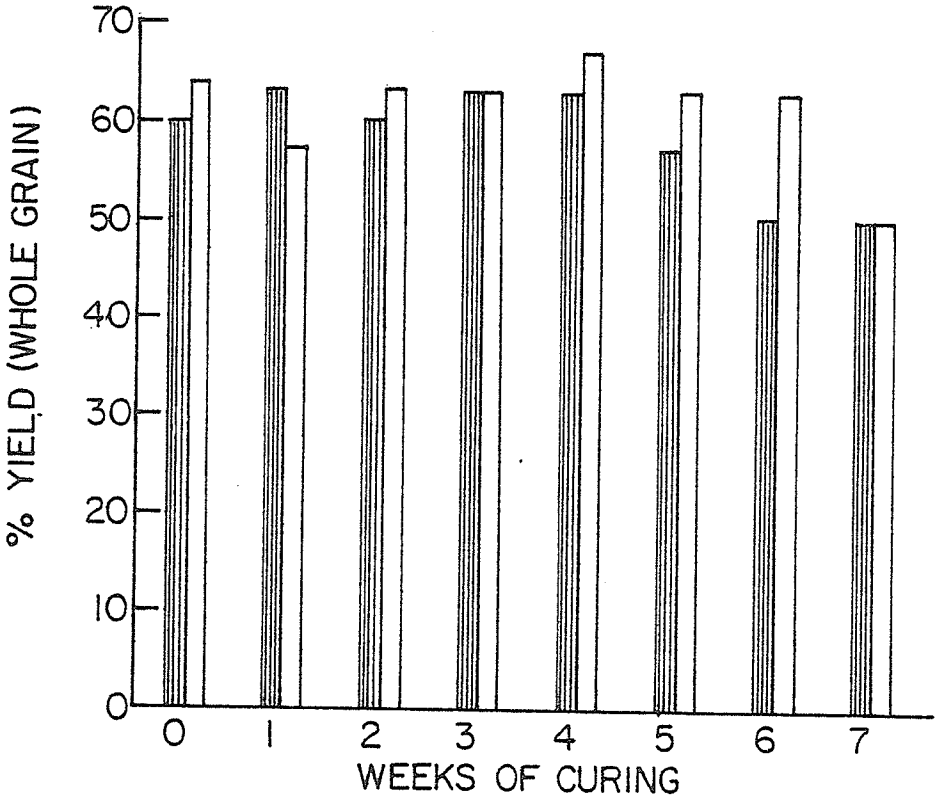
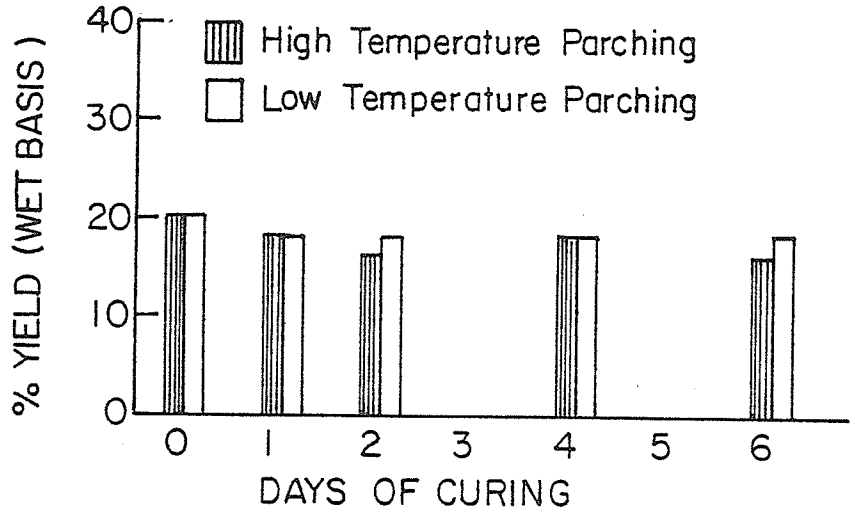


FIGURE 32. Percent Yield of Paddy Wild Rice Cured at 5°C and 95% Relative Humidity.

FIGURE 33. Percent Yield of Paddy Wild Rice Cured at 38°C and 95% Relative Humidity.



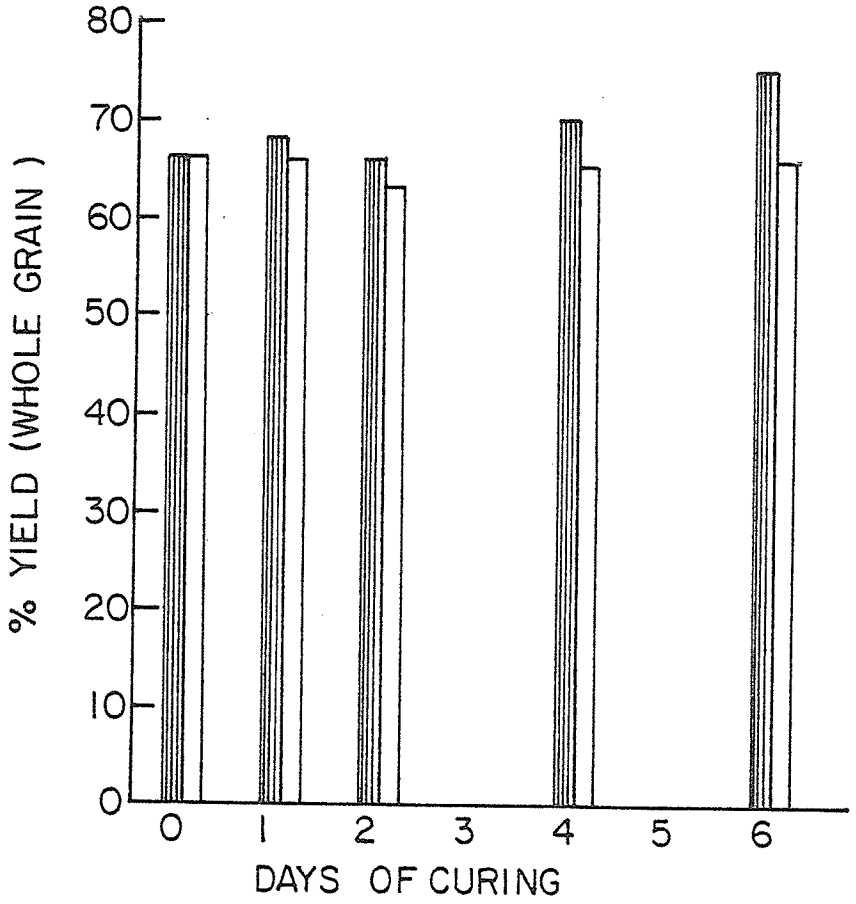
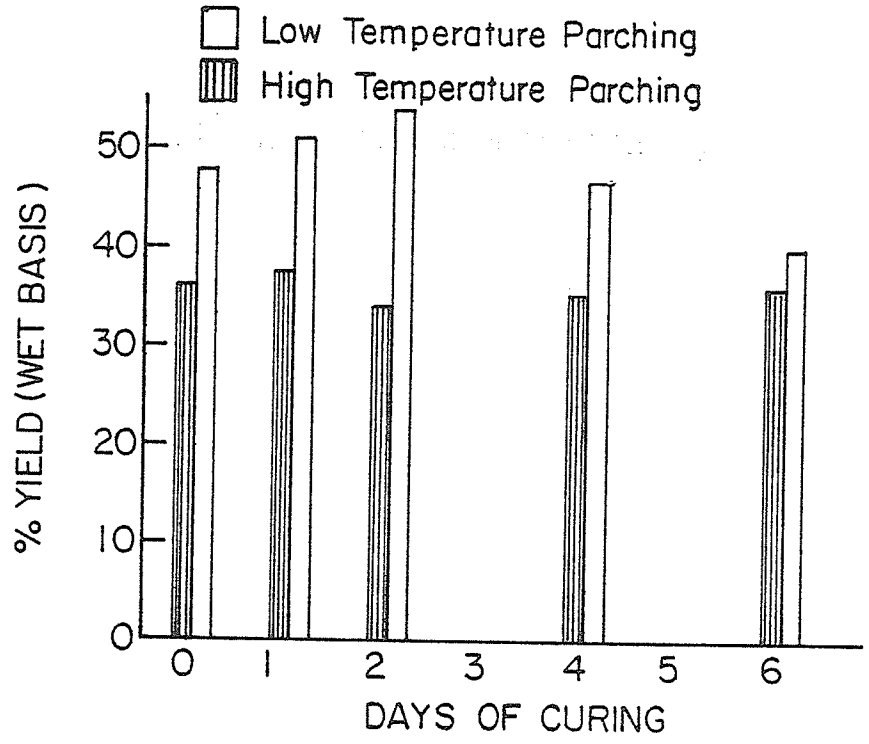


FIGURE 34. Percent Yield of Paddy Wild Rice Cured at 38°C and 95% Relative Humidity.

FIGURE 35. Percent Yield of Lake Rice Cured at 38°C and 95% Relative Humidity (Shallow Lake).



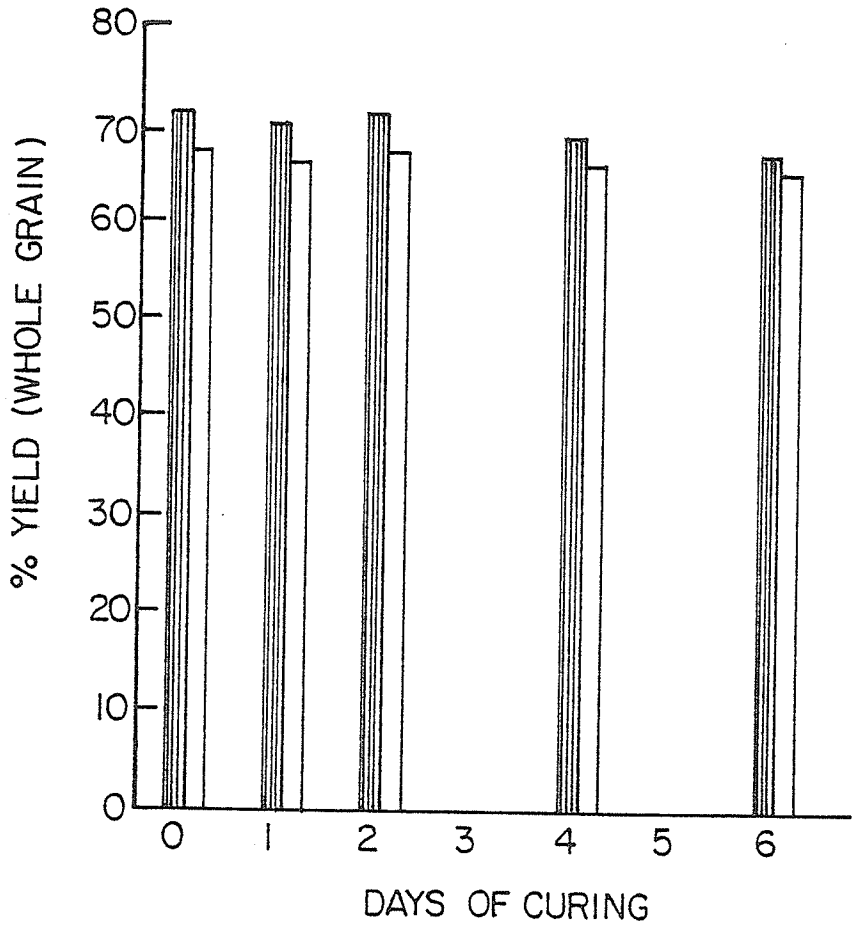
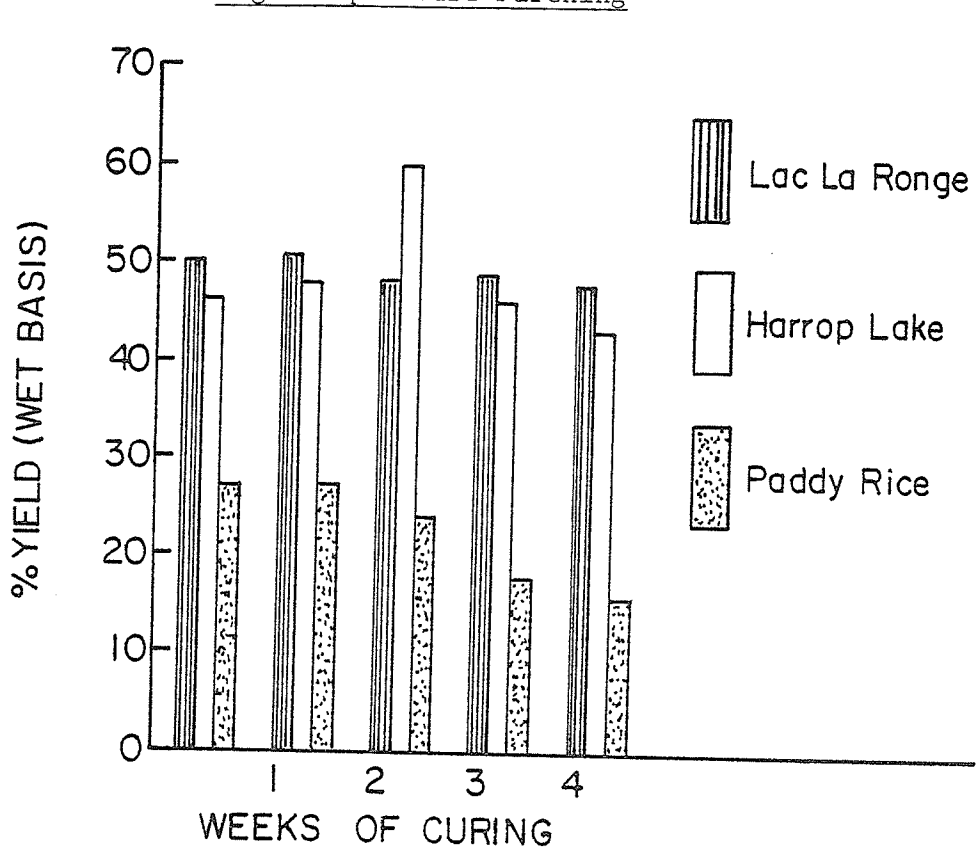


FIGURE 36. Percent Yield of Lake Rice Cured at 38°C and 95% Relative Humidity (Shallow Lake).

FIGURE 37. Percent Yield of Wild Rice Cured at 15°C and 95% Relative Humidity.



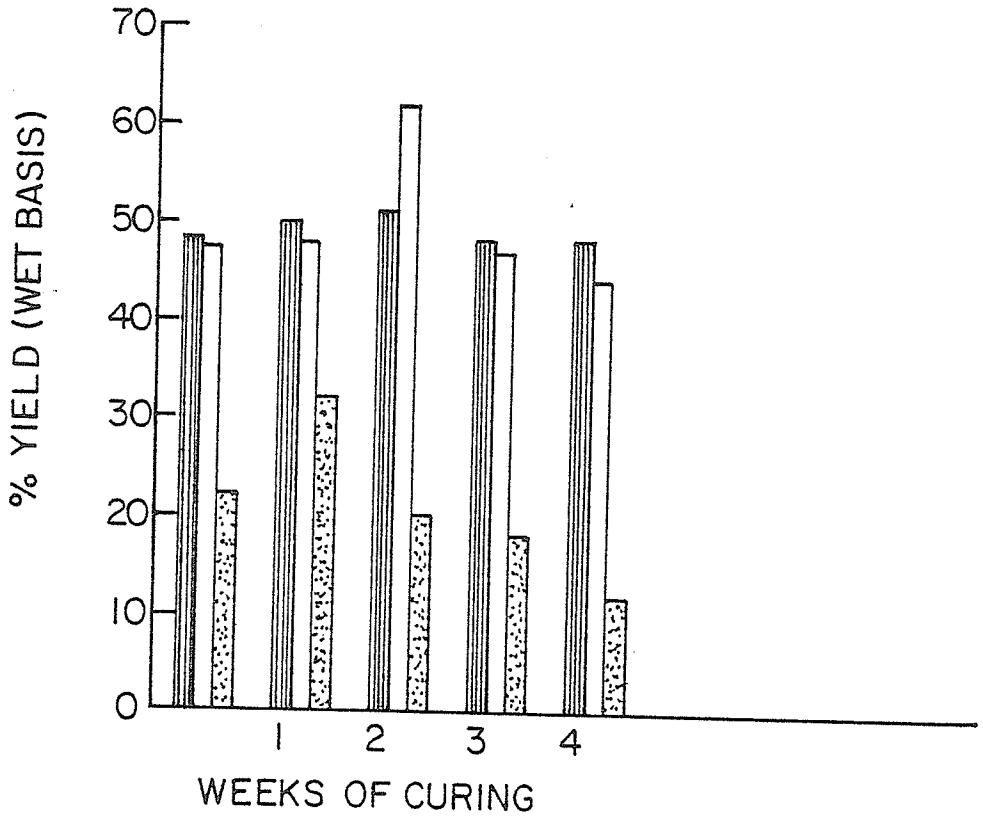
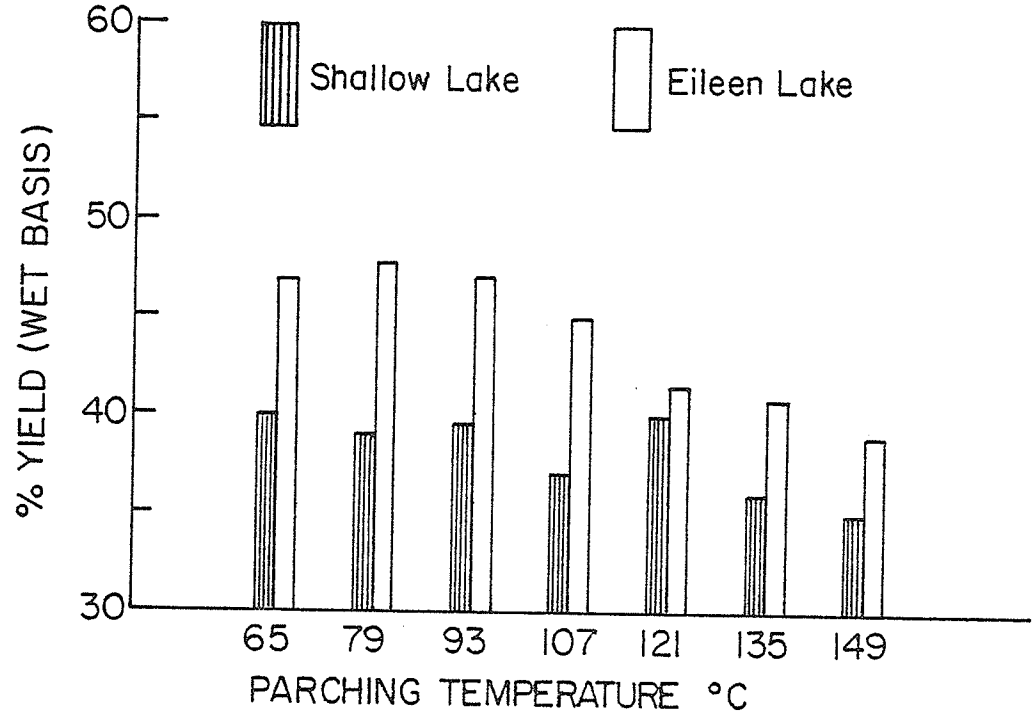


FIGURE 38. Percent Yield of Wild Rice Cured at 15°C and 95% Relative Humidity.
Low Temperature Parching

FIGURE 39. Effects of Parching Temperature on Wild Rice Yield Curing at 3°C and 95% Relative Humidity.



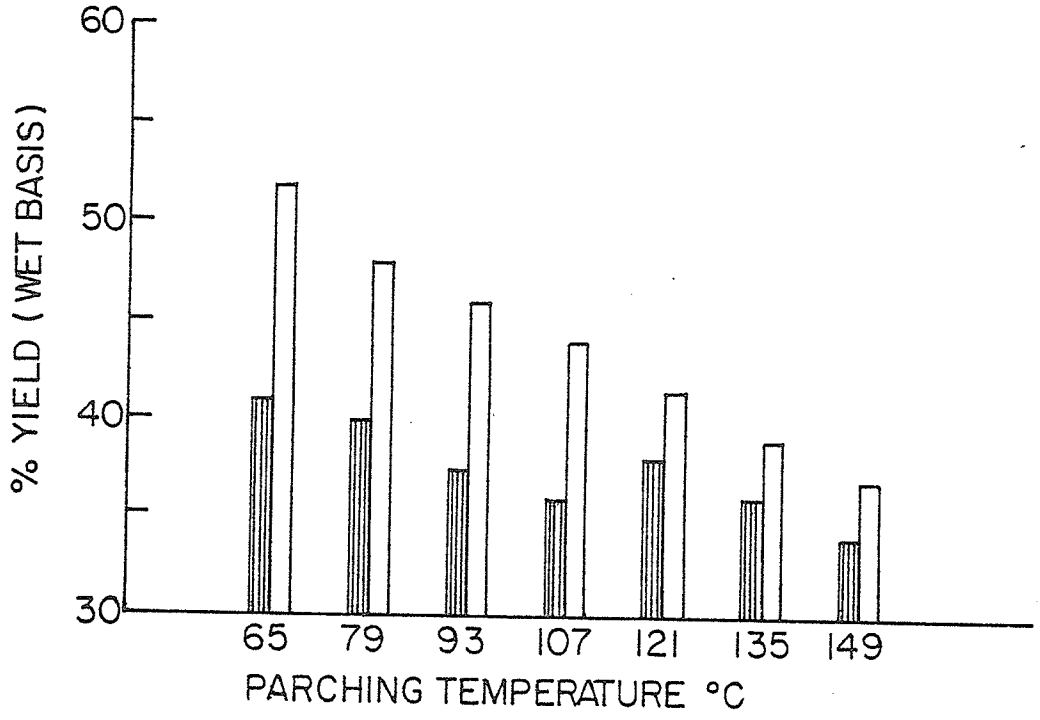
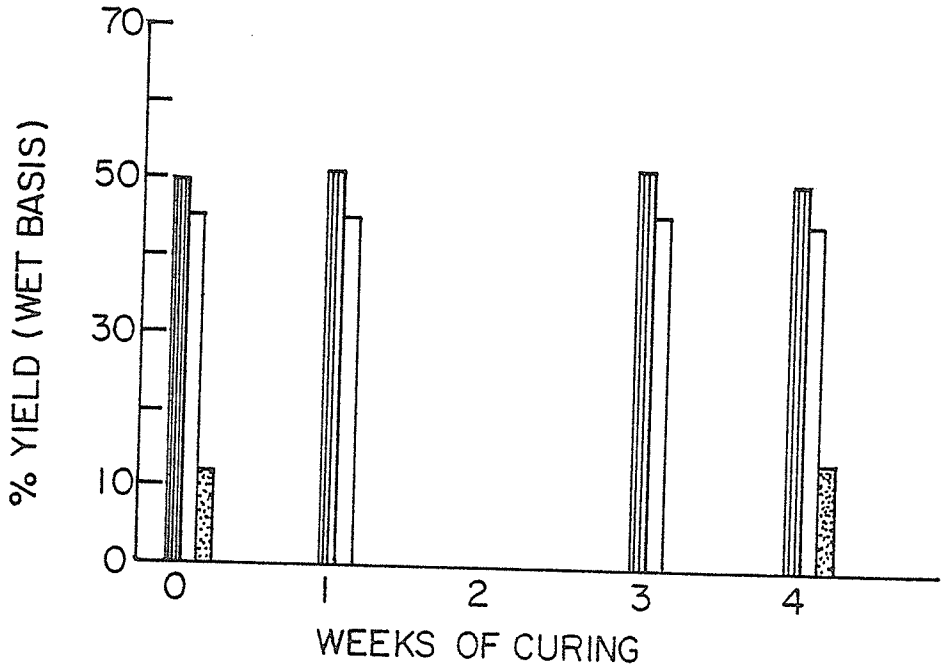


FIGURE 40. Effects of Parching Temperature on Wild Rice Yield Curing at 15°C and 95% Relative Humidity.

FIGURE 41. Percent Yield of Crowduck Lake Rice Cured at 10°C and 75% Relative Humidity.



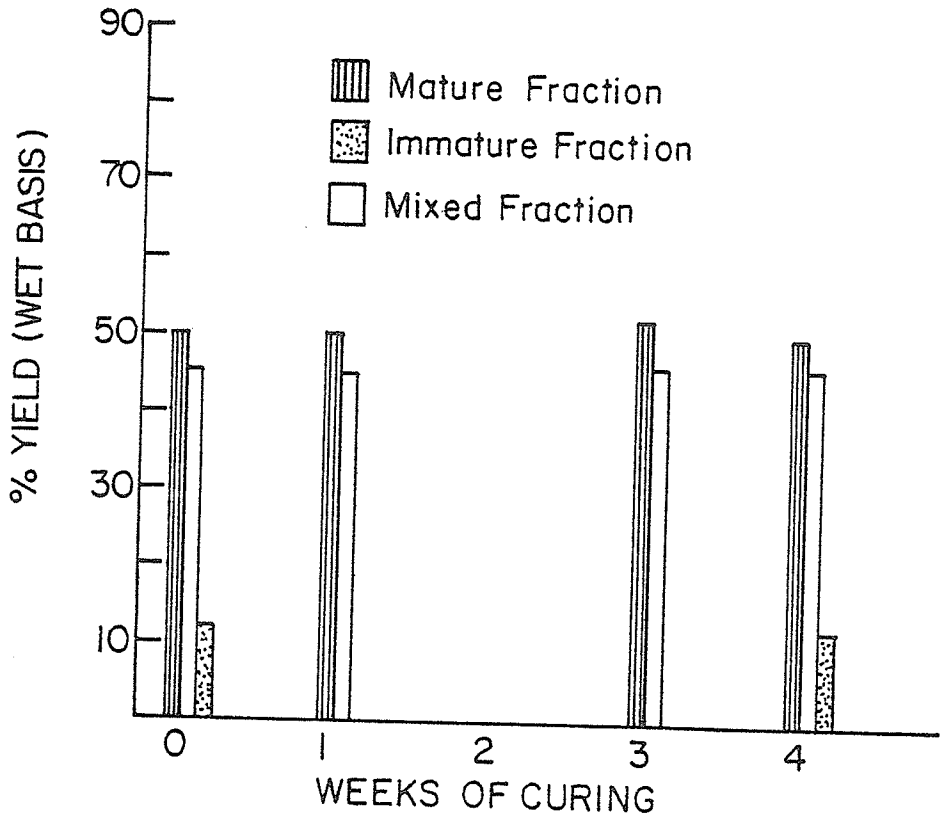
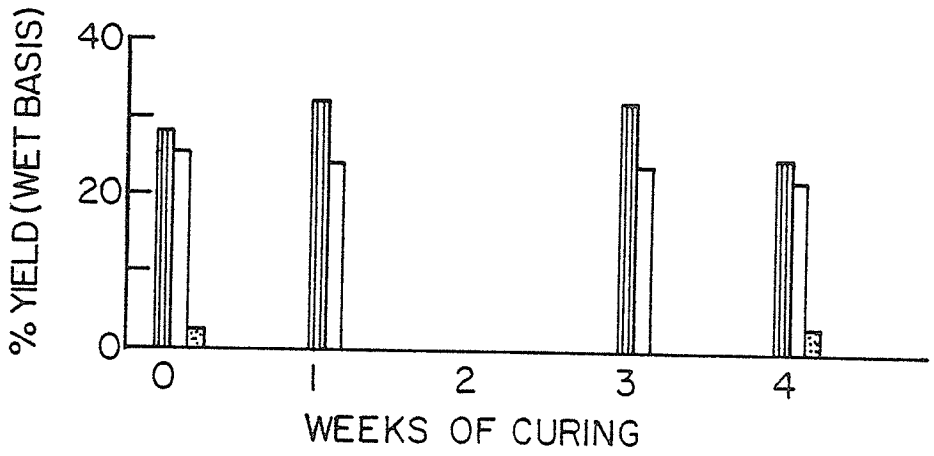


FIGURE 42. Percent Yield of Crowduck Lake Rice Cured at 10°C and 55% Relative Humidity.

FIGURE 43. Percent Yield of Paddy Wild Rice Cured at 10°C and 75% Relative Humidity.



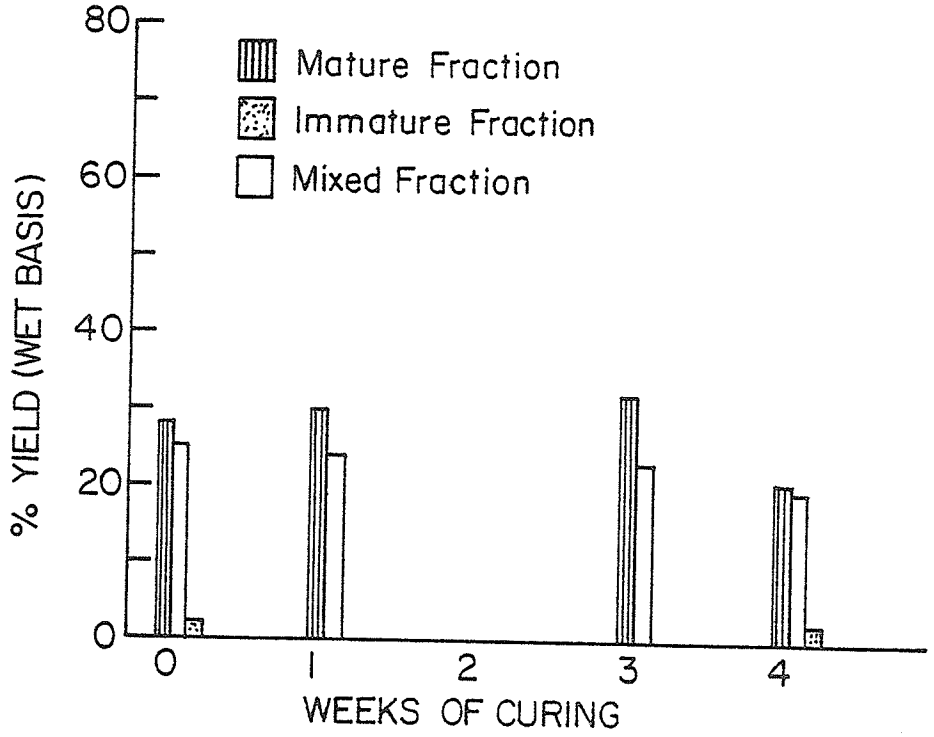


FIGURE 44. Percent Yield of Paddy Wild Rice Cured at 10°C and 55% Relative Humidity.

TABLE 12. Comparison of Average Total Yield (percent by weight) of Cured and Parched Wild Rice.

Rice Type	Curing System	% Yield (by weight) Parching Systems 1	2	3 to 9	6
Lac la Ronge	A	50	48		
	D	50	48		
Harrop Lake	A	40	45		
	D	50	45		
Paddy Rice	A	20	18		
	B	15	15		
	C	20	20		
	D	20	18		
Shallow Lake	A	38		38	
	B	35	35		
	C	48	35		
	D			38	
Eileen Lake	A			45	
	D			45	
Crowduck Lake	E;F				
(a) Mature	"				50
(b) Mixed	"				45
(c) Immature	"				12
Paddy Rice	E;F				
(a) Mature	"				30
(b) Mixed	"				20
(c) Immature	"				1

flavor also are involved in this decision making process.

The parching temperature was found to have a significant effect on total yield (Fig. 39, 40). The percent yield of rice was found to decrease as the parching temperature was increased. The selection of the optimum temperature for parching is based, however, on other factors such as kernel fragility, color and flavor besides total yield. These paramaters will be discussed later.

4.2.4 The Interaction Between the Wild Rice Type and the Curing and Parching Systems on Percent Total Yield.

As pointed out in Section 4.2.2 the yield of Harrop Lake wild rice was affected by the curing and parching system that was used. In addition, the average percent total yield of each rice type (Figs. 27-44) was significantly different. All lake rice types consistently outyielded Paddy rice (Table 12). Among the Lake rice, Lac la Ronge and Crowduck Lake rice had the highest yields (50%) for the curing and parching systems under which they were tested. Harrop Lake rice yielded about 48%, Eileen Lake rice about 46% and Shallow Lake rice about 35%. On the other hand, Paddy wild rice yielded approximately 15-20%.

The low yield in Paddy rice could be attributed to its gross immaturity at harvest and its inability to "finish" ripening in storage. This may also be due to the physiologically poor state of the Paddy rice variety used in this study. Perhaps a higher yield of rice would be obtained if the Paddy variety had been well developed (ie matured enough in the paddy) in order to produce kernels that would mature and develop acceptable characteristics in storage. The difference in yield among Lake rice types could be associated with the different source and hence, different environmental influences, as well as variation in rice genotypes. No comment

can be made on these variables since they were not controlled during these studies.

Prolonged curing at very low temperatures (ie systems A and B, Figs. 27, 28, 29, 31) appeared to cause slight losses in percent total yield for all rice types towards the end of storage (ie after 6 weeks). This would not be a significant factor since the optimum curing time comes before the yields start to decrease (3-5 weeks).

4.2.5 Evaluation of Percent Whole Grain (kernel) Yield of Wild Rice.

In grading, in this study, all rice grains 1.0 cm or longer were considered whole kernels and any grain measuring less than 1.0 cm long was considered broken. Percent (by weight) yield of whole grain rice are presented in Figs. 30, 32, 34, 36, and 45 to 54 inclusive.

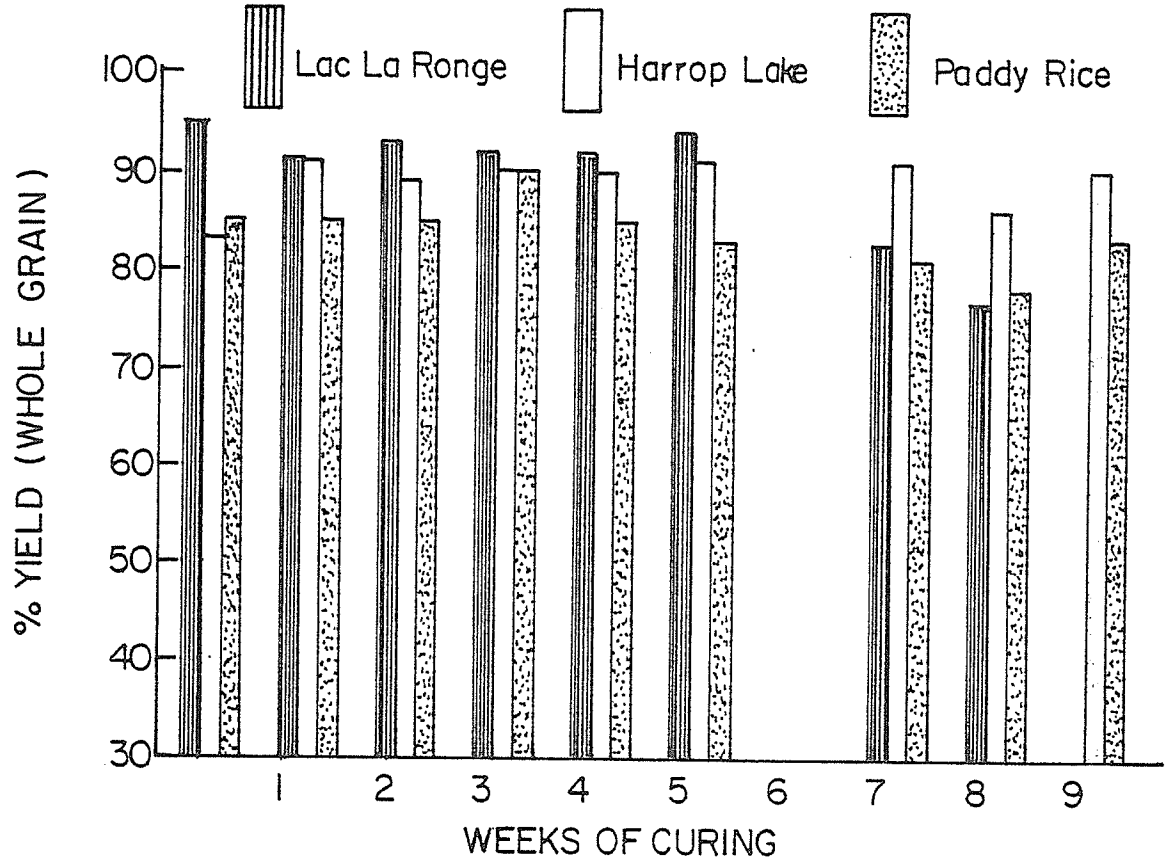
The curing system affected the yield of whole grain rice for certain rice types (Harrop, Paddy and Shallow) but did not for others (Lac la Ronge and Eileen), (Table 13a, Figs. 45-54). In general low temperature curing appears to produce less fragile kernels (the rice samples have a higher percent of whole kernels) than do high temperature curing processes. For example, the average percent yield of whole grain of Shallow Lake rice cured at 5°C was 85-89% and at 38°C was 68-72%. On the other hand, the storage time appeared to have no significant effect on percent yield of whole grain.

Percent yield of whole kernels appeared to be affected by the parching temperature. The highest percent yield was attained by using 107°C (Fig. 49, 50). Shallow and Eileen Lake rice yielded 93 and 95% respectively at this temperature. These dropped to 82% (Shallow Lake) and 90% (Eileen Lake) at 65°C, while at 149°C, the yields were 85% (Shallow Lake) and 82% (Eileen Lake).

Table 13a. Comparison of Average Percent (by weight) Whole Grain Yield of Cured and Parched Wild Rice.

Rice Type	Curing System	% Yield (by weight) Parching Systems		
		1	2	3 to 9
Lac la Ronge	A	90	92	
	D	91	90	
Harrop Lake	A	90	90	
	D	84	82	
Paddy Rice	A	85	85	
	B	60	58	
	C	66	69	
	D	73	70	
Shallow Lake	A			85
	B	85	89	
	C	68	72	
	D			87
Eileen Lake	A			87
	D			84

FIGURE 45: Percent Yield of Wild Rice Cured at 3°C and 95% Relative Humidity. (High Temperature Parching)



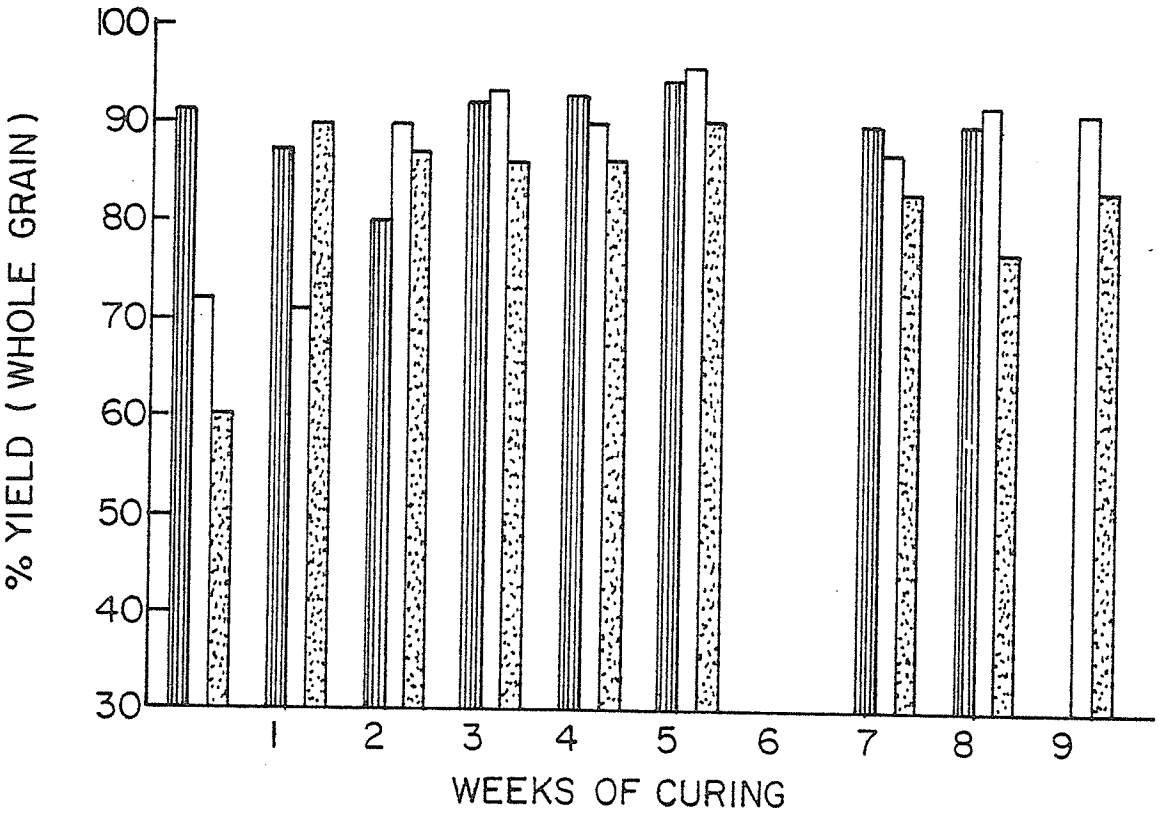
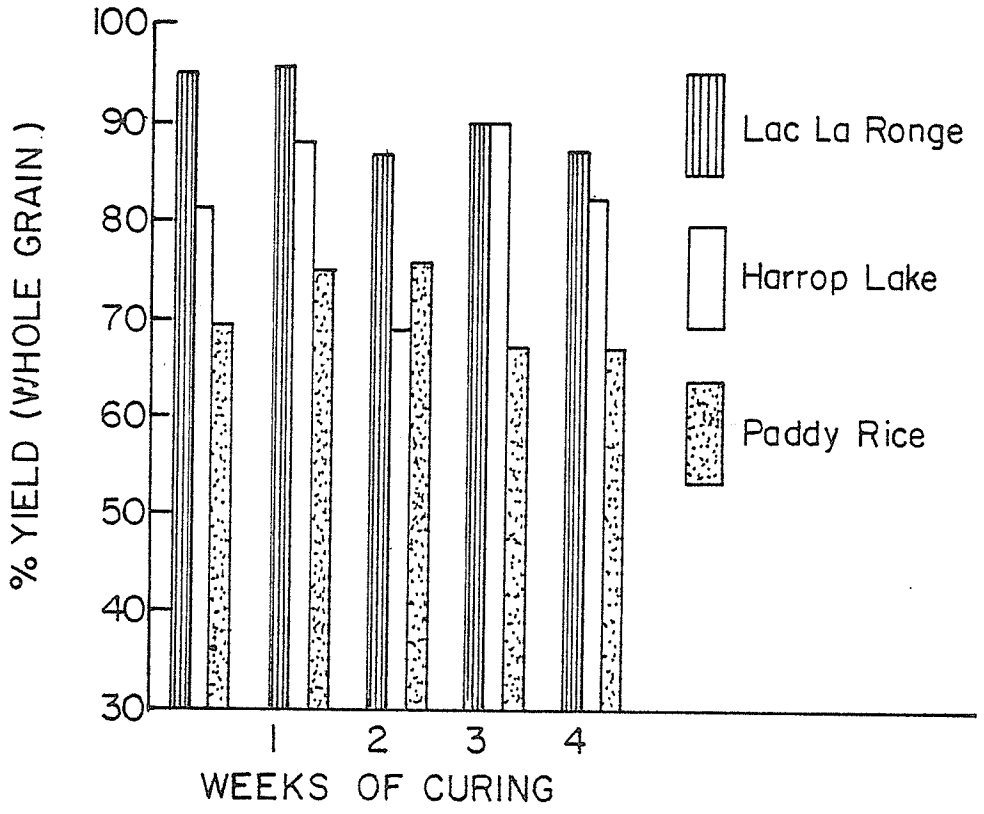


FIGURE 46. Percent Yield of Wild Rice Cured at 3°C and 95% Relative Humidity. (Low Temperature Parching)

FIGURE 47. Percent Yield of Wild Rice Cured at 15°C and 95% Relative Humidity. (High Temperature Parching)



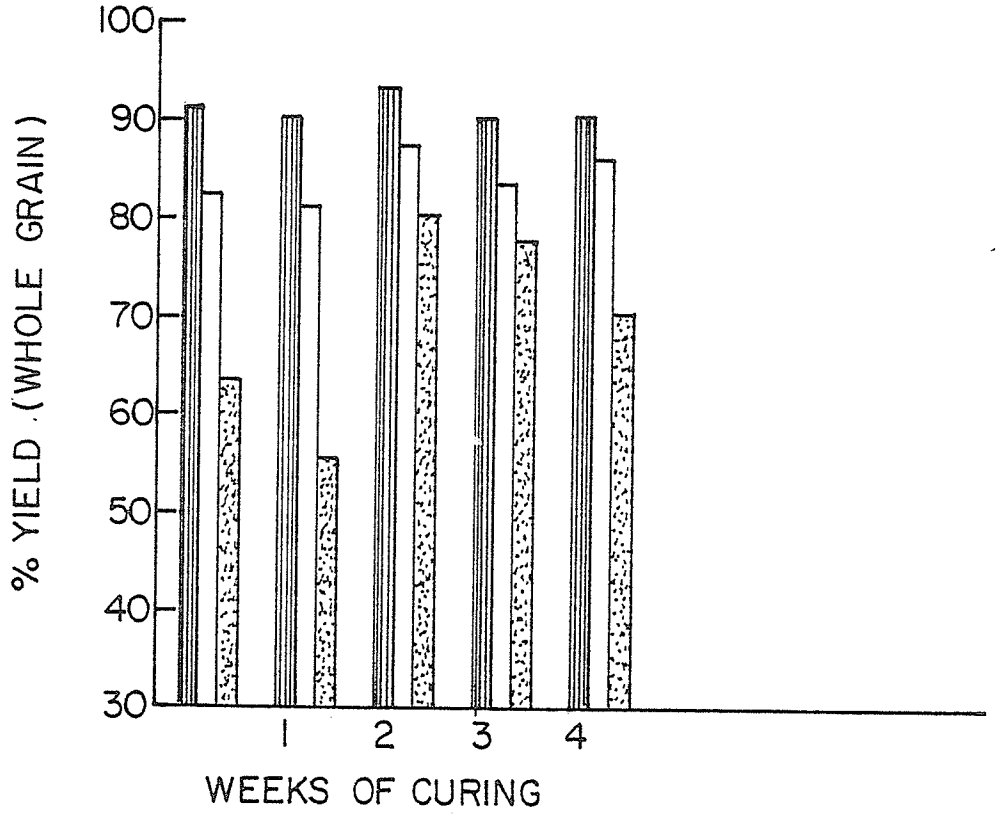
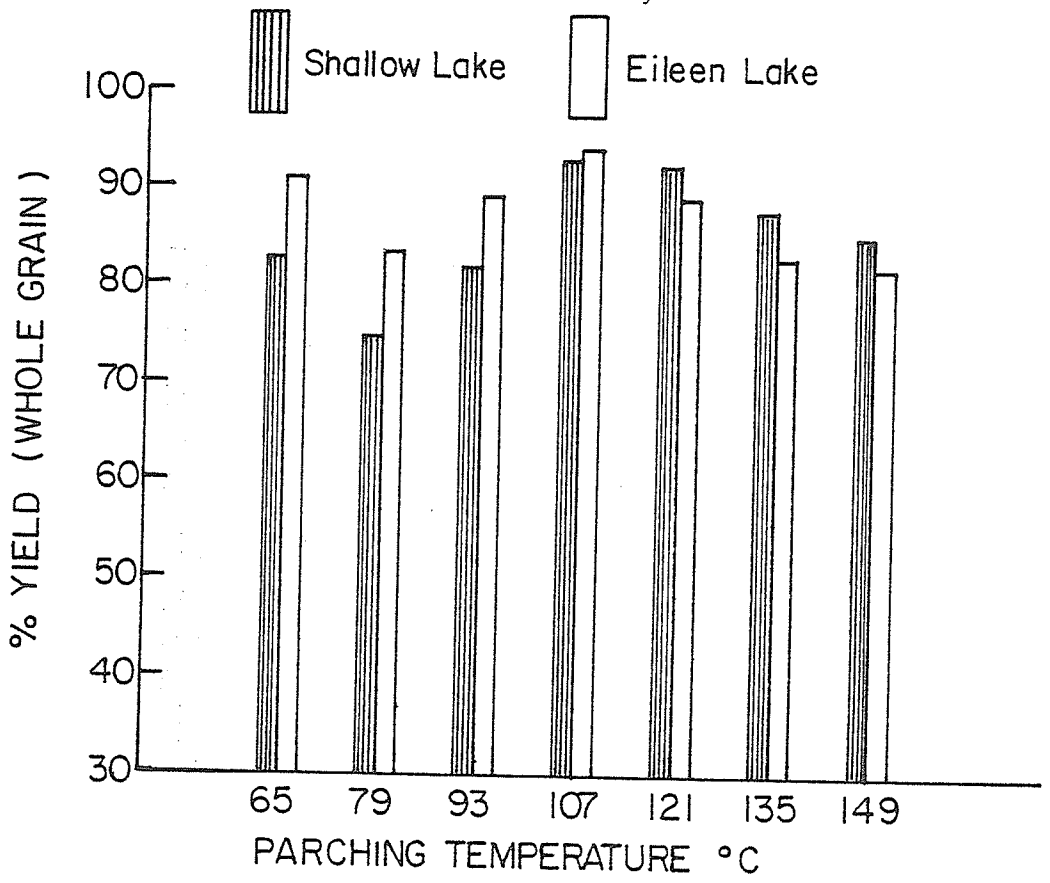


FIGURE 48. Percent Yield of Wild Rice Cured at 15°C and 95% Relative Humidity. (Low Temperature Parching)

FIGURE 49. The Effects of Parching Temperature on Wild Rice Yield Curing at 3°C and 95% Relative Humidity.



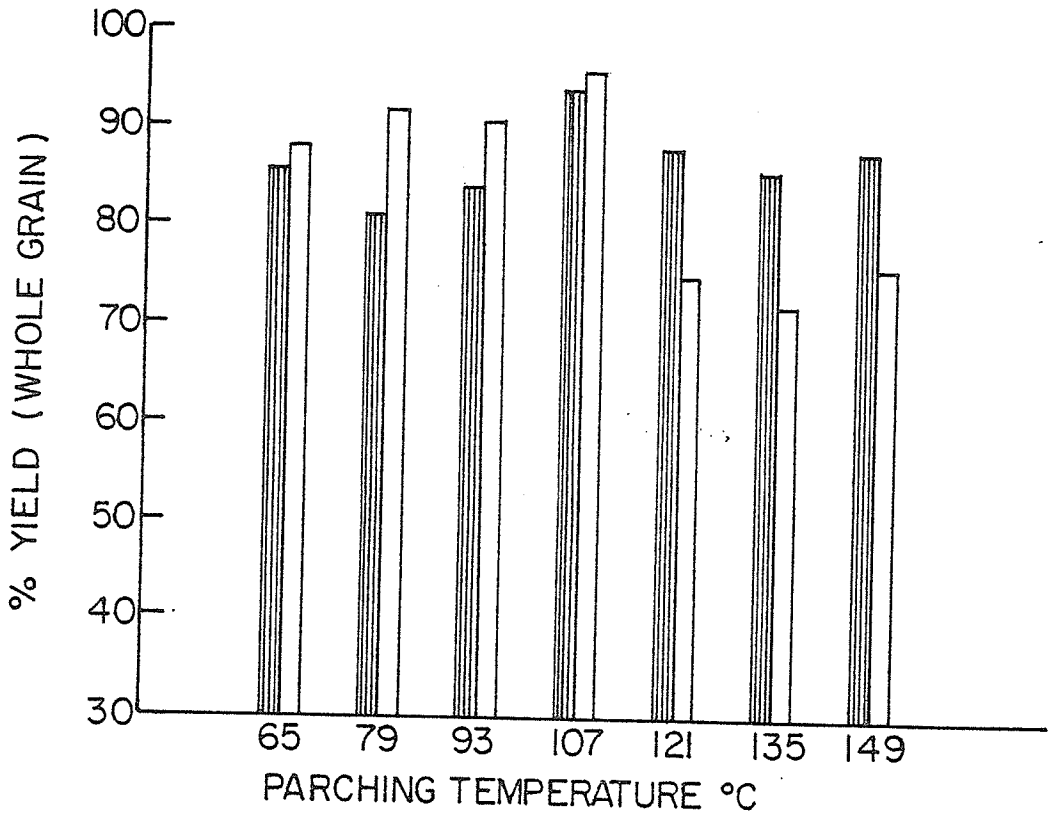
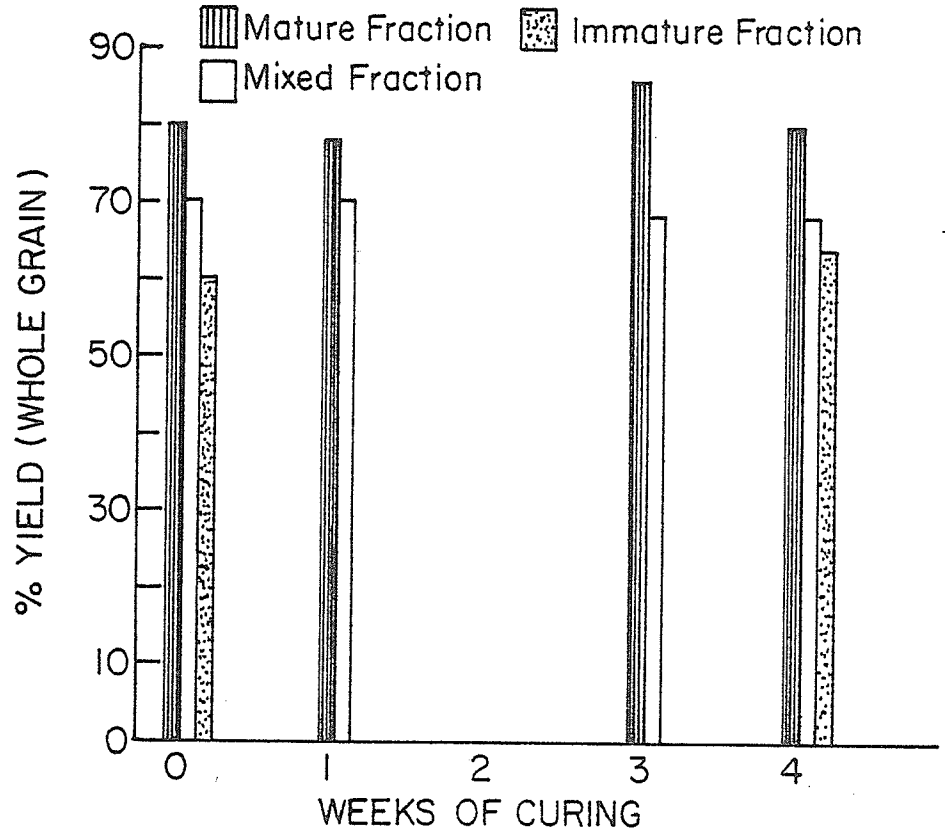


FIGURE 50. Effects of Parching Temperature on Wild Rice Yield Curing at 15°C and 95% Relative Humidity.

FIGURE 51. Percent Yield of Crowduck Lake Rice Cured at 10°C and 75% Relative Humidity.



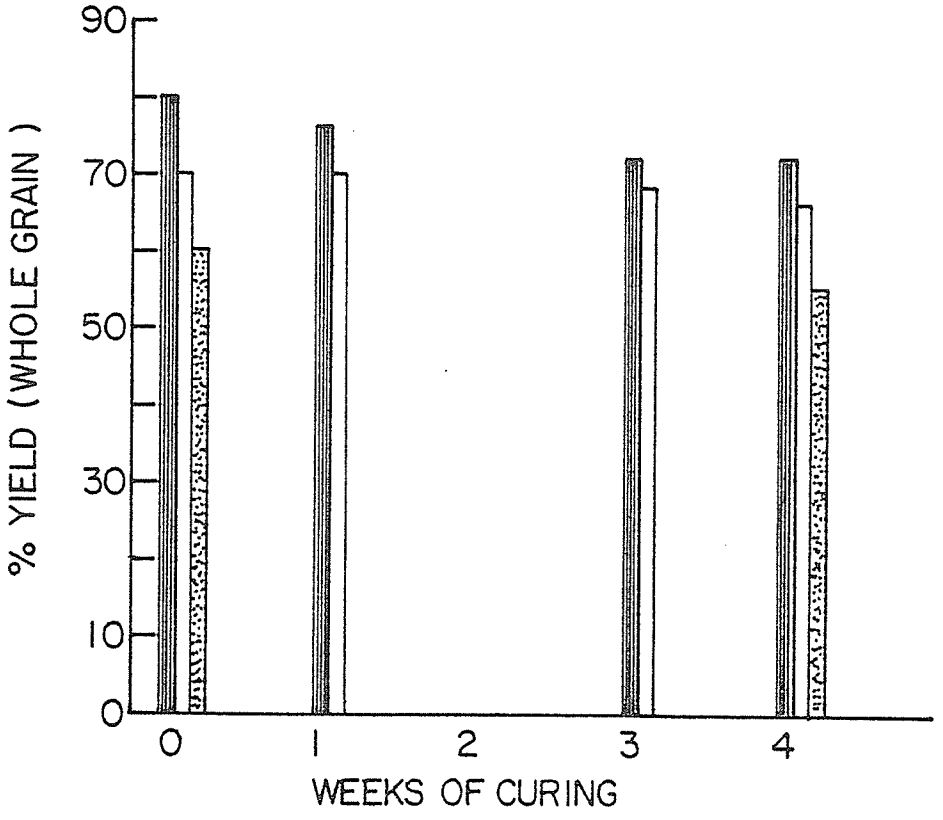
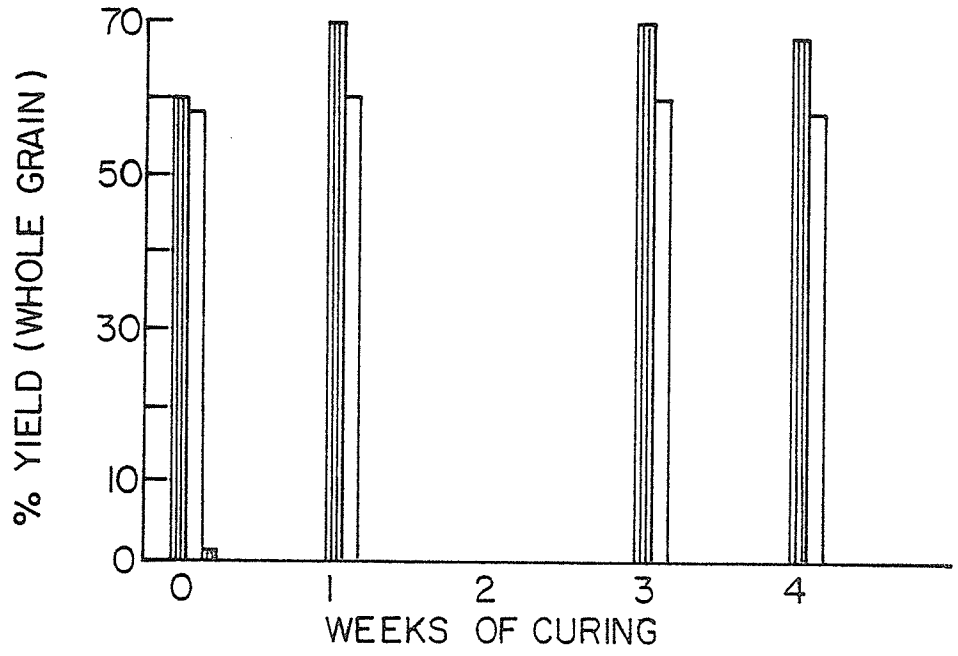


FIGURE 52. Percent Yield of Crowduck Lake Rice Cured at 10°C and 50% Relative Humidity.

FIGURE 53. Percent Yield of Paddy Wild Rice Cured at 10°C and 75% Relative Humidity.



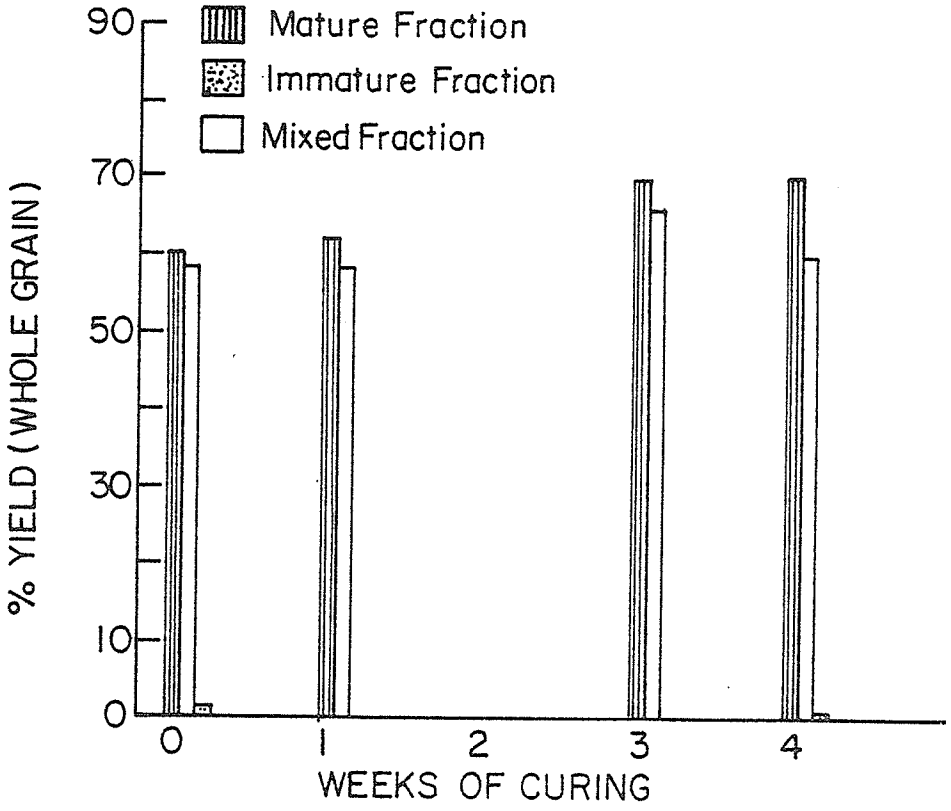


FIGURE 54. Percent Yield of Paddy Wild Rice Cured at 10°C and 55% Relative Humidity.

The Crowduck Lake and Paddy wild rice separated into mature and immature fractions and cured under 55 and 75% relative humidity had a higher content of broken kernels (mixed fraction) than did the other rice types (Table 13b). These were harvested in 1975 and the other types had been harvested in 1974. The humidity of the curing chamber did not appear to affect kernel fragility (curing systems E versus F). The mature fraction (Crowduck and Paddy) yielded more whole grains than either the mixed or immature fraction.

In summary, it can be said that well controlled curing systems do not affect the yield of whole grain wild rice. However, intermediate parching temperatures were found to produce optimum yields of whole grain wild rice.

4.2.6 The Effects of Parching on Other Quality Factors

Wild rice parched by systems 2, 8 and 9 showed hollow centers and/or popping in the kernels (Appendix 9). These undesirable factors were caused as a result of the rapid impact of high temperature to the kernels. Thereby resulting in the center portion of the kernels shrinking rapidly and becoming hollow; or in causing the kernels to become more fragile and hence, results in reduced yield. Such high temperatures also caused a burnt or scorched flavor in the dried product. "White centers", also considered as an undesirable factor in finished rice, was observed in Crowduck Lake rice. This defect, however, is known to be related to the moisture content of the rice before parching rather than an effect of parching temperature (as noted in Section 4.2.1).

In summary, there appears to be no interaction between the curing environment and the parching temperature on finished rice quality. But there is an interaction between the storage time and parching temperature on these criteria. Extremely high parching temperatures are undesirable in processing wild rice since they reduce yield and cause excessive popping and burnt flavor

Table 13b. Comparison of Average Percent (by weight) Whole Grain Yield of Cured and Parched Wild Rice.

Rice Type	Curing System	% Yield (by weight) Parching Systems	
		6	6
Crowduck Lake	E & F		
(i) Mature	"	81	75
(ii) Mixed		70	69
(iii) Immature		62	59
Paddy Rice	E & F		
(i) Mature	"	67	66
(ii) Mixed	"	59	61
(iii) Immature	"	<1.0	

in the finished product. Wild rice of different genotypes is affected to varying degrees by curing systems and times and by parching temperatures.

In general Lake rice kernels were larger and longer than Paddy rice grains. Among the Lake rice types, Lac la Ronge rice had the longest whole (intact) kernels (average length, 2.5 cm). This was followed by Crowduck Lake (2.2 cm), Shallow Lake (2.0 cm), Harrop Lake (1.5 cm), Eileen Lake (1.5 cm) and Paddy rice, (1.0 cm).

4.3 Color Evaluation of Wild Rice

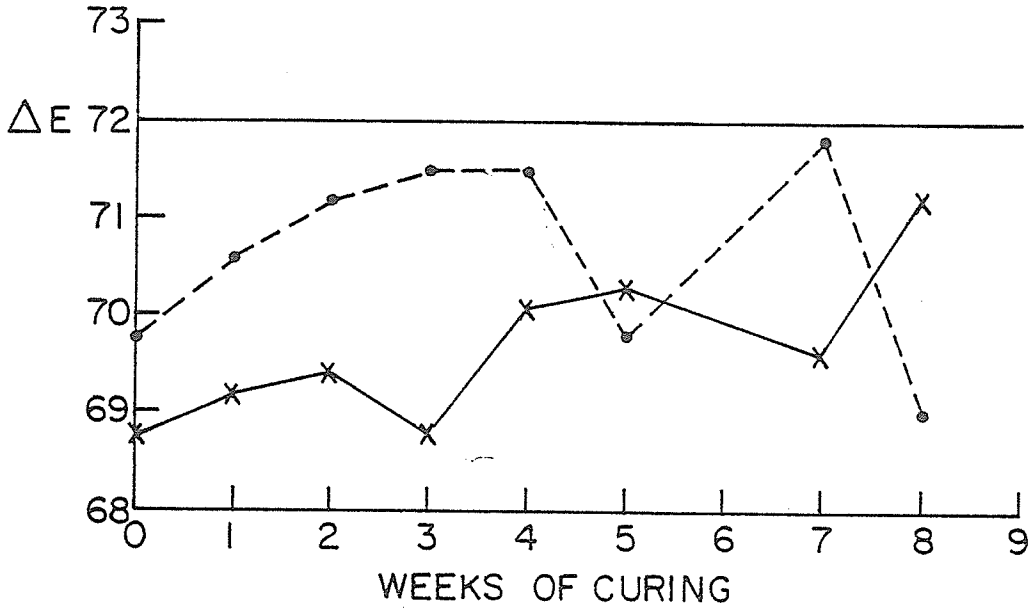
The quality of wild rice is so closely related to its color that the "art" of developing the acceptable color has become a guarded secret in the industry. Hence, wild rice color is considered a critical factor in the acceptability of the finished product.

The color of finished rice obtained in this study, was measured by the Hunter Lab Color Difference Meter Model D25. The ΔE values were calculated and are graphically presented in Figures 55 to 68.

4.3.1 Effects of Curing Systems on Wild Rice Color

Data obtained for rice cured by System A indicated that color changes were very slow and minimal in all rice types. For example, with Lac la Ronge rice, color development did not reach the acceptable level after eight weeks storage (Fig. 55). With Paddy rice, acceptable color was produced by high temperature parching after 3 weeks curing and lasted only for a period of 2 weeks; after which the color faded to below acceptable levels (Fig. 56). Harrop Lake rice treated similarly, also had acceptable color after 3 weeks storage, and no decline in color intensity was observed at the end of the 9 weeks curing period (Fig. 57).

FIGURE 55. The Color Changes of Lac La Ronge Rice Cured at 3°C and 95 % Relative Humidity.



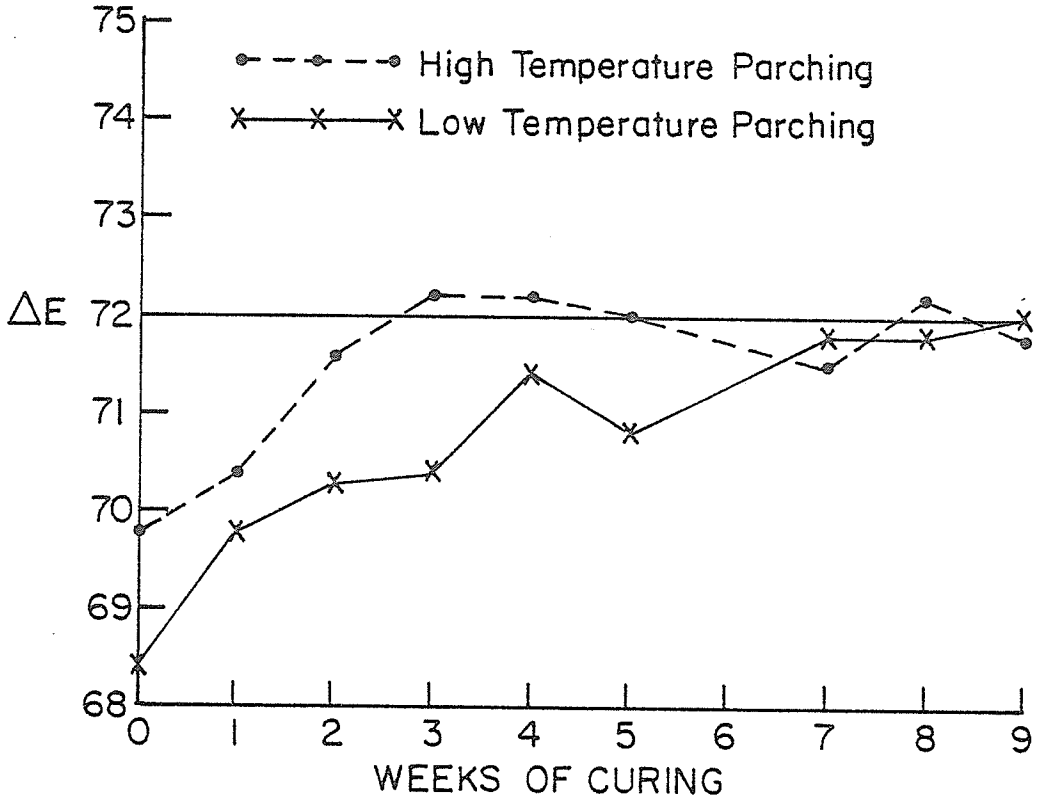
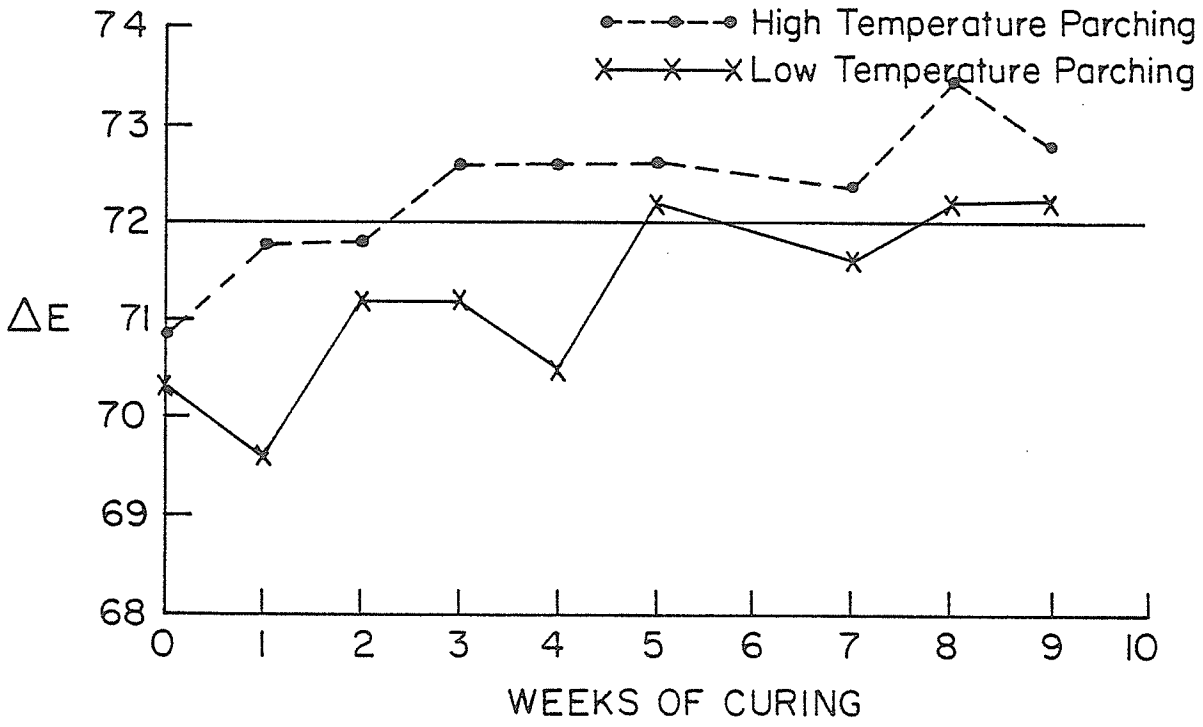


FIGURE 56. The Color Changes of Paddy Wild Rice Cured at 3°C and 95% Relative Humidity.

FIGURE 57. The Color Changes of Harrop Lake Rice Cured at 3°C and 95% Relative Humidity.



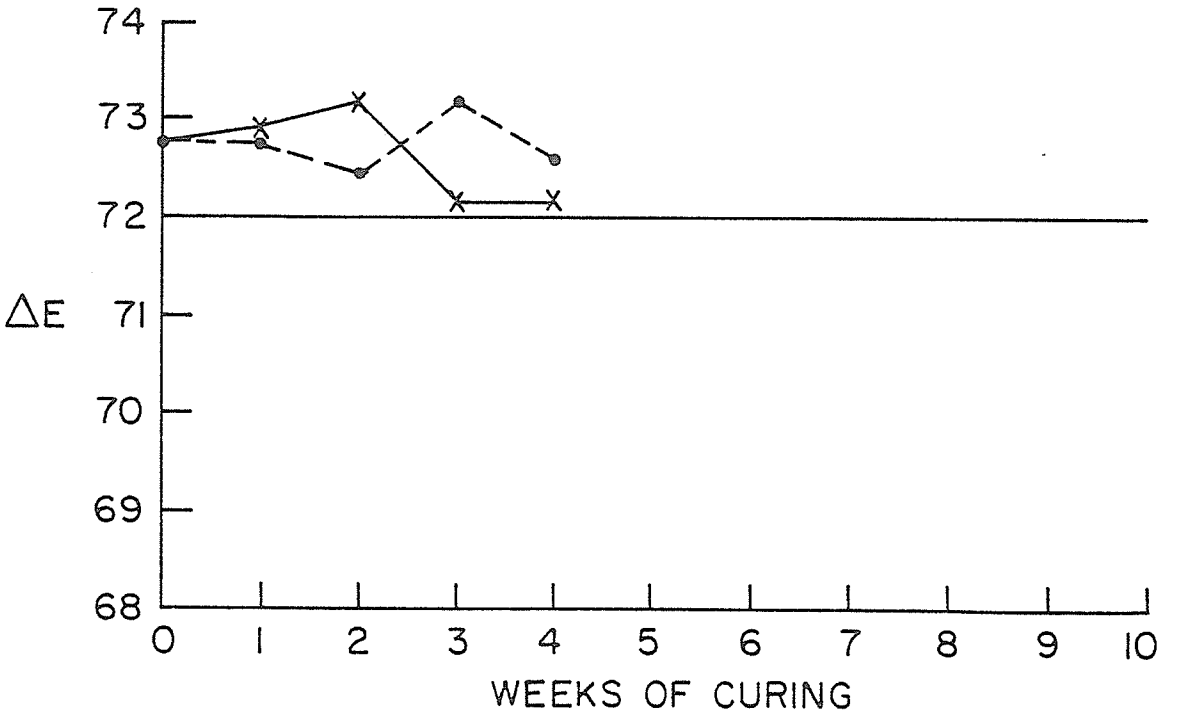
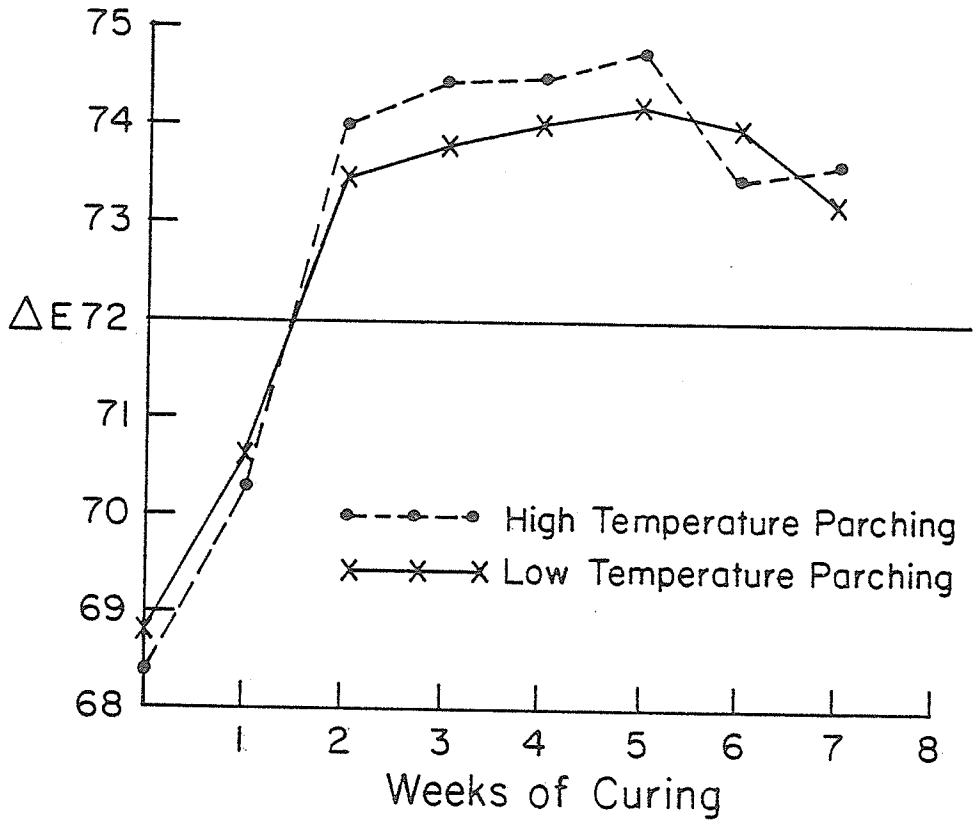


FIGURE 58. The Color Changes of Harrop Lake Rice Cured at 15°C and 95% Relative Humidity.

FIGURE 59. The Color Changes of Shallow Lake Rice Cured at 5°C and 95% Relative Humidity.



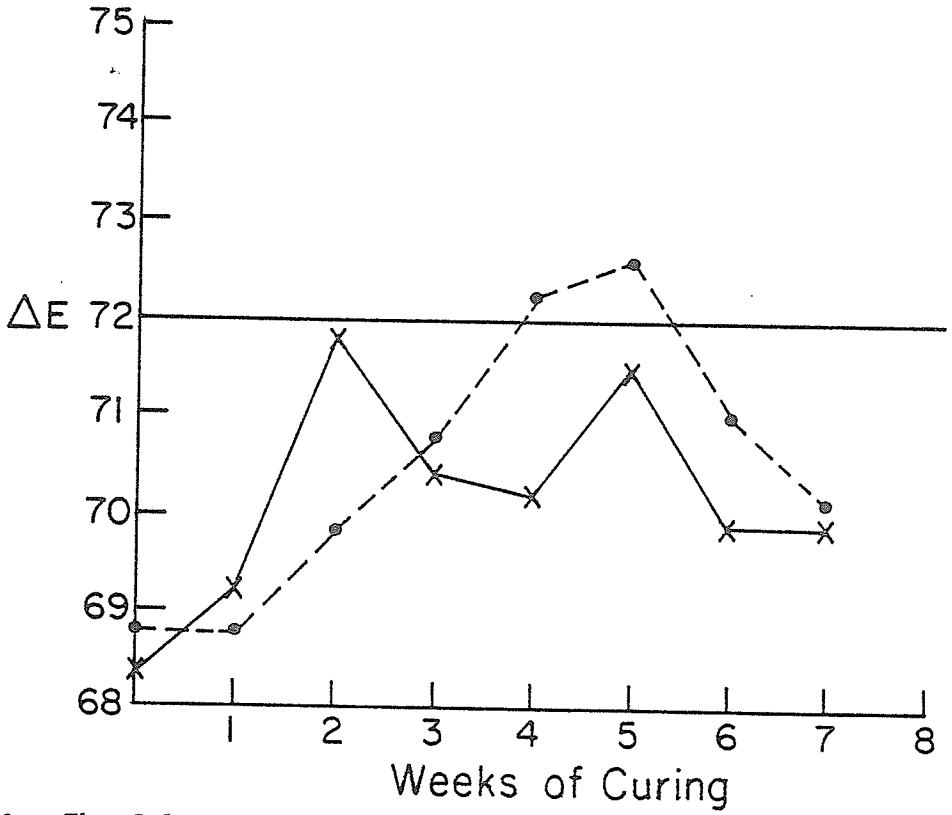
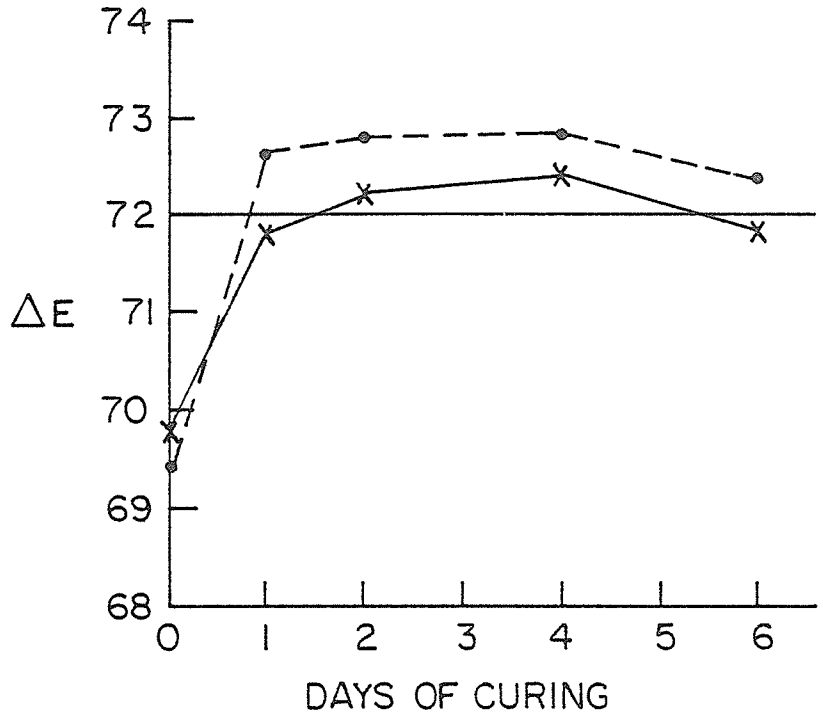


FIGURE 60. The Color Changes of Paddy Wild Rice Cured at 5°C and 95% Relative Humidity.

FIGURE 61. The Color Changes of Shallow Lake Rice Cured at 38°C and 95% Relative Humidity.



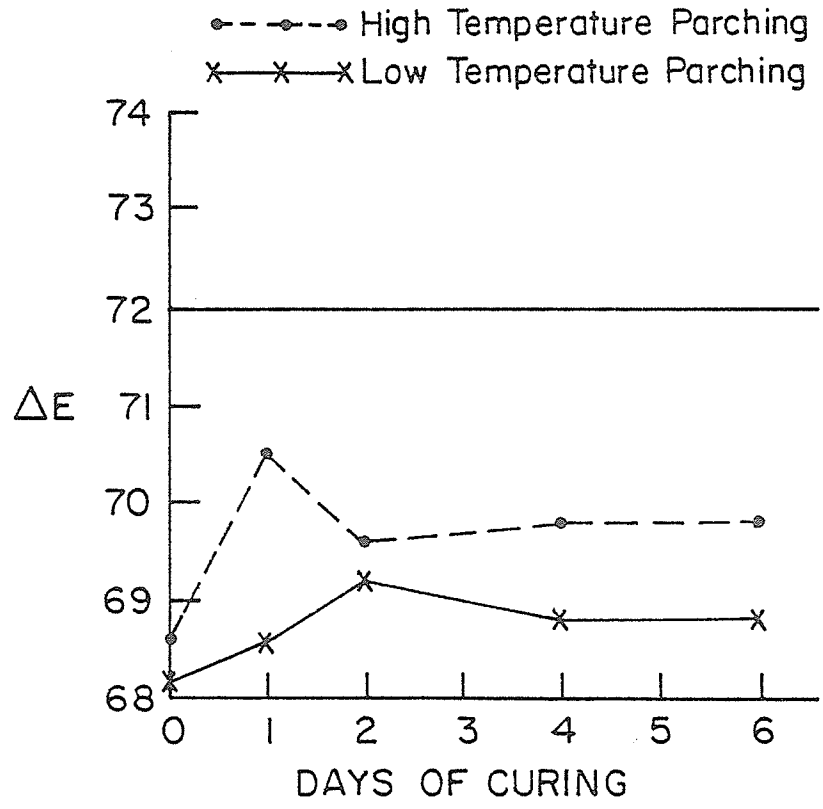
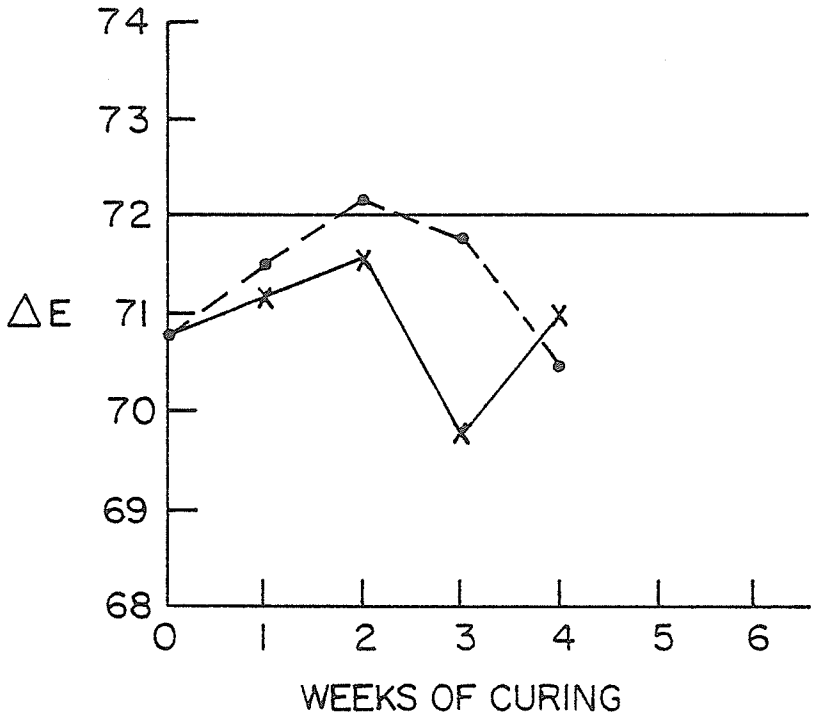


FIGURE 62. The Color Changes of Paddy Wild Rice Cured at 38°C and 95% Relative Humidity.

FIGURE 63. The Color Changes of Lac La Ronge Rice Cured at 15°C and 95% Relative Humidity.



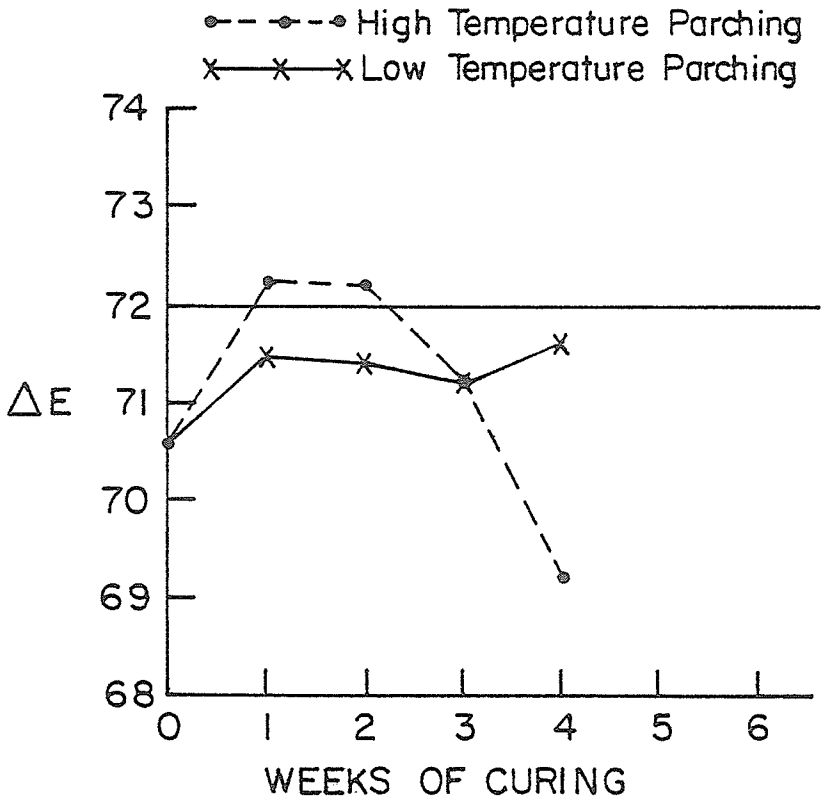
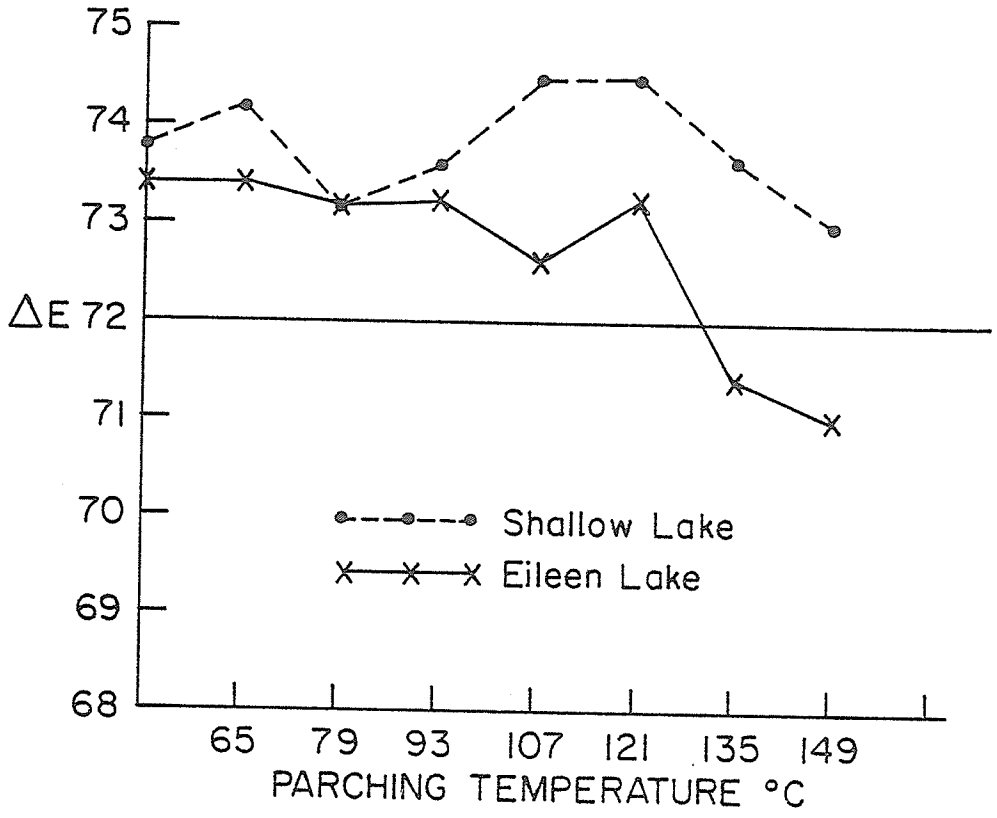


FIGURE 64. The Color Changes of Paddy Wild Rice Cured at 15°C and 95% Relative Humidity.

FIGURE 65. The Effects of Parching Temperature on the Color of Wild Rice Cured at 3°C and 95% Relative Humidity.



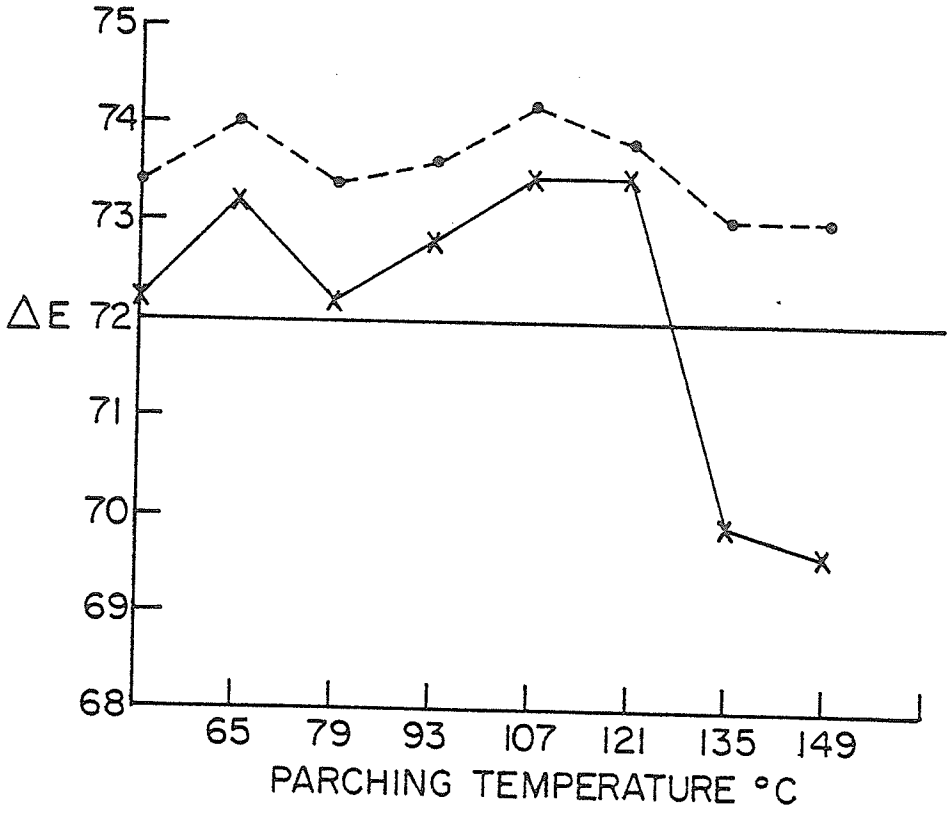
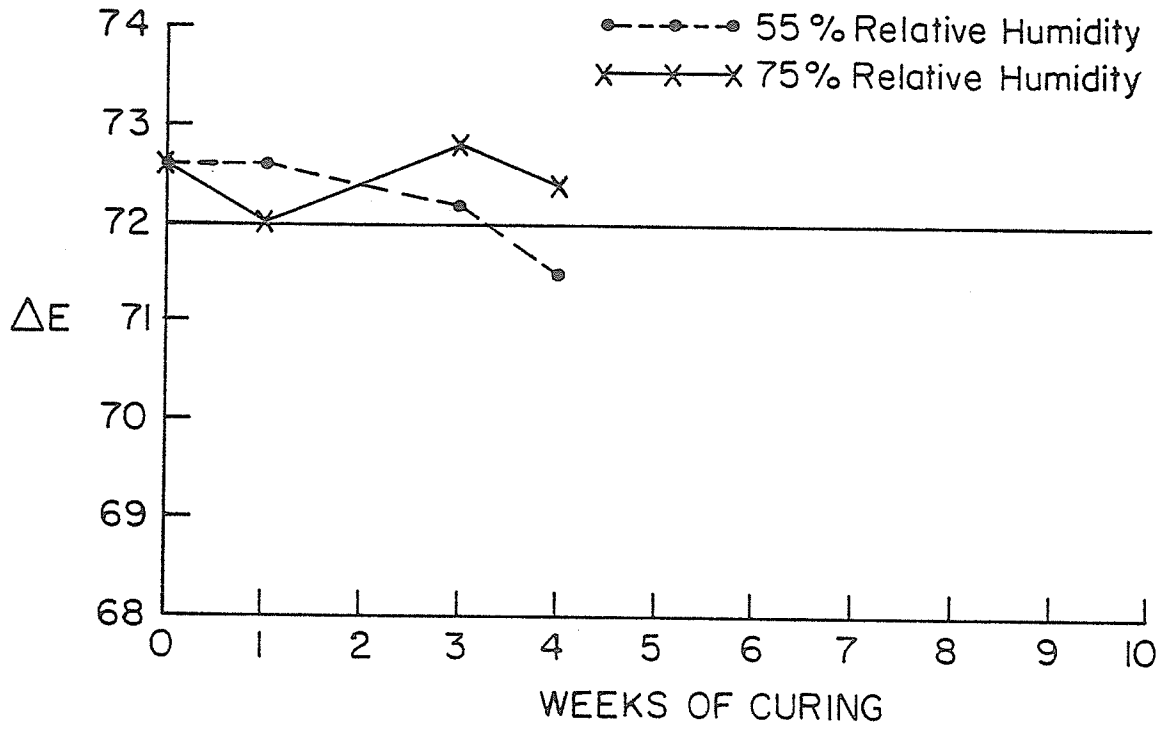


FIGURE 66. The Effects of Parching Temperature on the Color of Wild Rice Cured at 15°C and 95% Relative Humidity.

FIGURE 67. The Color Changes of Crowduck Lake Rice Cured at 10°C.



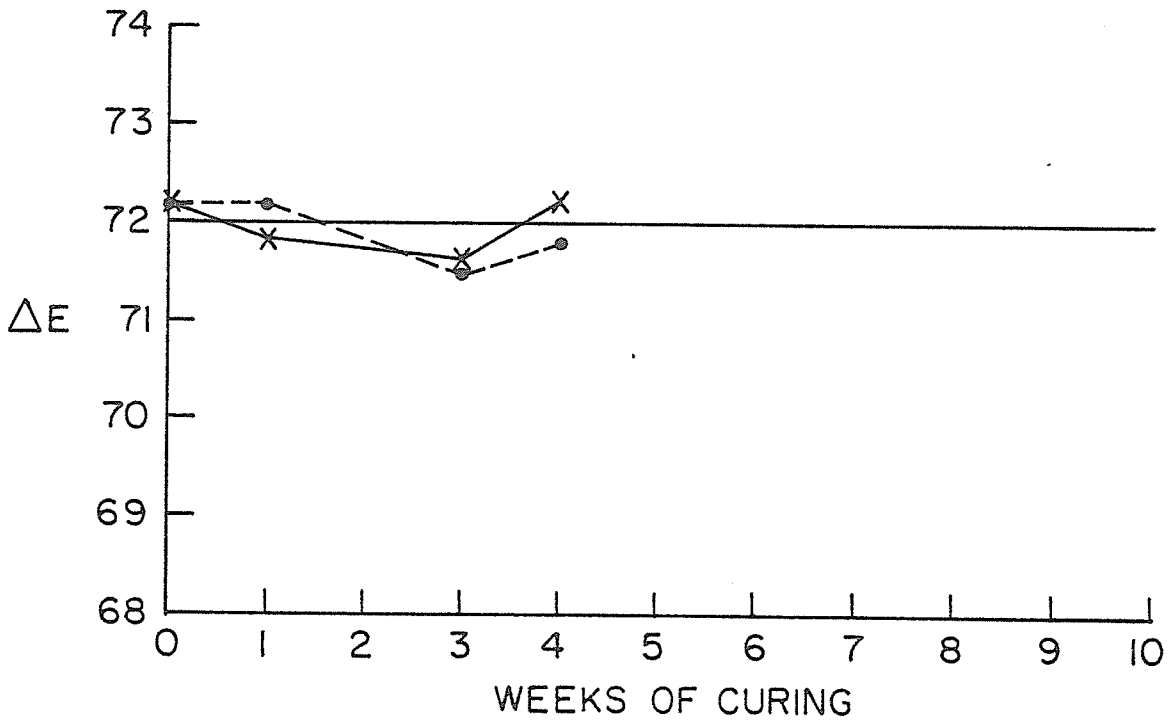


FIGURE 68. The Color Changes of Paddy Wild Rice Cured at 10°C.

For Shallow Lake rice cured by System B, acceptable color was developed after 2 weeks storage and began to fade after 6 weeks of curing (Fig. 59).

The development of acceptable color in Paddy Wild rice cured by this system (B) was evident after 4 weeks storage when high temperature parching was used. The color then began fading after 5 weeks of curing (Fig. 60).

When utilizing curing System C, Shallow Lake rice developed acceptable color within 1 day of storage and remained acceptable to the end of the curing period. The Paddy rice cured by this system failed to develop any acceptable color throughout the entire curing period.

When curing System D was utilized, Harrop Lake rice appeared to have had acceptable color prior to and throughout the curing period (Fig. 58). The color of Lac la Ronge rice reached acceptable level in 2 weeks (with high temperature parching) and faded to below acceptability level in week 3 of curing (Fig 63). On the other hand, Paddy rice color was acceptable after 1 week storage and for 2 weeks (with high temperature parching) then the color faded to below the acceptable level towards the end of the curing period (Fig. 64).

For Eileen Lake and Shallow Lake rice cured by Systems A and D, (Figs. 65, 66), acceptable color was developed in all samples. However, this color faded when extremely high parching temperature was used.

Under curing Systems E and F, the color of Crowduck Lake rice was acceptable throughout both curing systems (with the exception of rice cured for 4 weeks by System F) (Fig. 67). These samples were parched at 107°C. Paddy rice color was acceptable during week 1 and 4 of curing and unacceptable between 2 and 3 weeks of storage (Fig. 68).

4.3.2 Effects of Parching Systems on Color

For all rice types cured by Systems A and B, the color of rice appeared to have been improved when parching System 2 was used, as opposed to parching System 1 (Figs. 55, 56, 57).

Rice cured by Systems C and D showed similar trends (behaviour) in color improvements under parching Systems 1 and 2, for all rice types.

The color of rice parched by Systems 3 to 9 were acceptable (ie above a ΔE value of 72) in all samples for Shallow Lake. However, Eileen Lake rice color was not acceptable when systems 8 and 9 were utilized.

The wild rice cured by Systems E and F were parched by System 6. The color of Crowduck treated by these systems was acceptable throughout the curing period (with the exception of rice cured for 4 weeks by System F, Fig. 67). The color of the Paddy rice used in this system was barely affected by the parching system.

In general, comparisons of data indicated that Lake rice developed or had more acceptable color than Paddy rice in all curing environments (Fig. 55-68). However, Lac la Ronge rice, like the Paddy rice, failed to develop an acceptable color with any processing system. In all rice types, the rate of color change was found to be directly proportional to the curing environment ie the higher the curing temperature, the faster the development of color. However, the quality of color development differed with respect to the various rice types.

Curing time also affected color development. In all rice types and specific curing systems, the color development reached a maximum and then faded towards the end of the storage period.

Parching temperatures significantly affected the color of all rice types. It was found that the high temperature systems tended to improve the color of all rice types used in these studies (Figs. 55-68). However,

extremely high parching systems could adversely affect color. Rice parched in these systems tended to pop and the popped fragments would produce a lighter color.

4.4 Cooking Study and Kernel Fragility

The appearance of cooked wild rice is an important factor in the acceptability of the finished product. It was observed in Chung's (1975) study that some whole grain rice broke up into small fragments upon cooking. This behavior in the cooked rice produced a very unattractive, mushy looking product. Consequently some of the rice obtained in this study was examined for stress points which were likely to break when the rice was cooked.

4.4.1 Kernel Fragility

A summary of results obtained from stress point analysis are presented in Table 14 and Figs. 69 & 70.

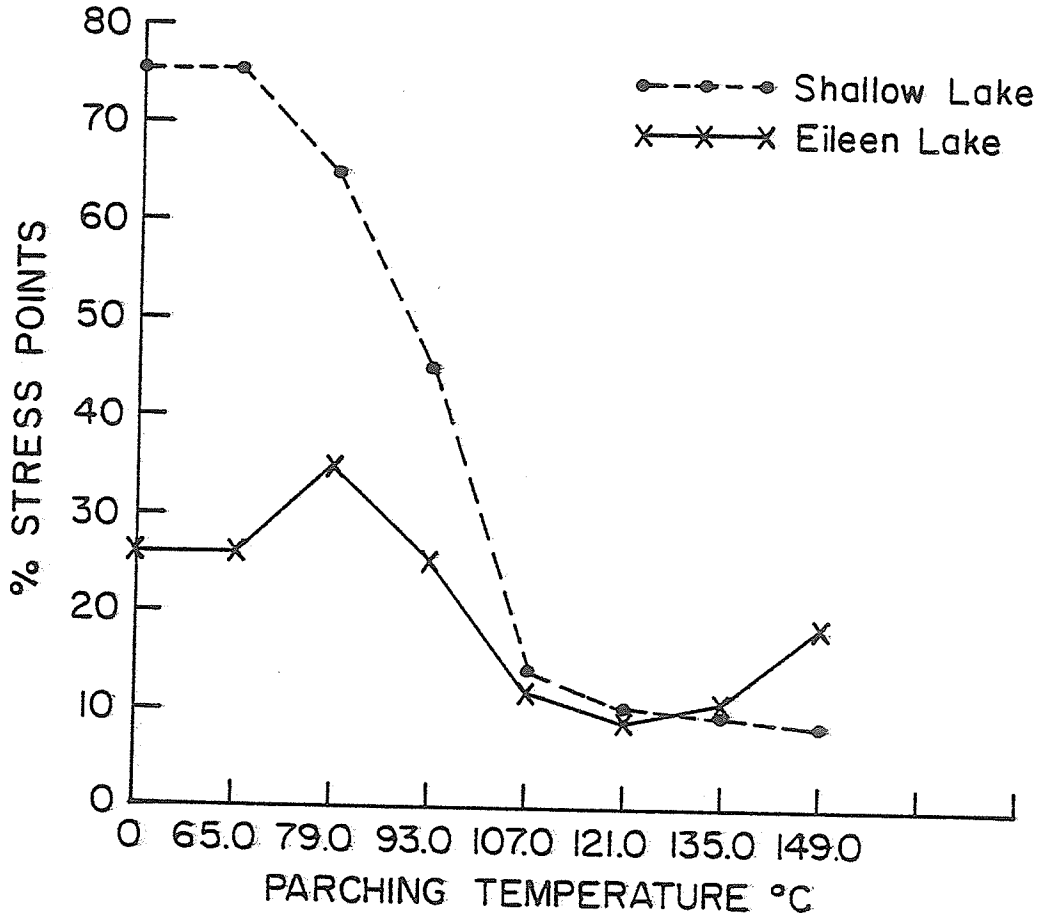
The results indicated that low parching temperatures produce a greater number of stress points than high parching temperatures. The data showed that Eileen Lake rice is not as susceptible to the production of stress points as is Shallow Lake rice. The curing system appeared to have a variable effect on the production of stress points. However, both rice types seemed to have been affected similarly (with regard to number of stress points) under curing system D and parching system 3: (both rice types showed highest number of stress points under these conditions (Table 14).

4.4.2 Cooking Study

Data obtained from this study were analyzed statistically by the randomized blocks design, and are presented in Figs. 71-78.

The results illustrated that low temperature parching systems (65°-120°C)

FIGURE 69. The Effects of Parching Temperature on Kernel Breakage in Wild Rice Cured at 3°C.



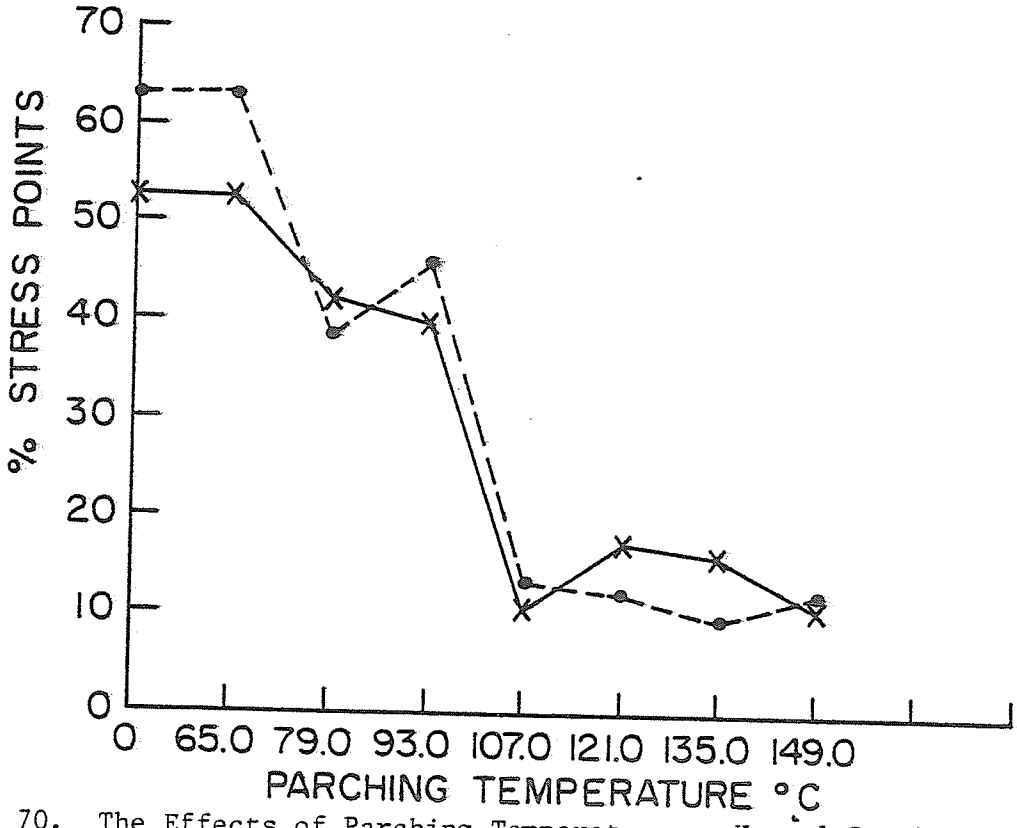


FIGURE 70. The Effects of Parching Temperature on Kernel Breakage in Wild Rice Cured at 15°C.

TABLE 14. Stress Point Analysis of Cured and Parched Eileen and Shallow Lake Wild Rice.

Rice Type	Curing System	Parching System	Number of Stress Points (%)	
Eileen Lake	A	4	35	h
		7	10	1
	D	3	52	h
		6,9	10	1
Shallow Lake	A	3	75	h
		10	9	1
	D	3	62	h
		8	10	1

h - highest; 1 - lowest

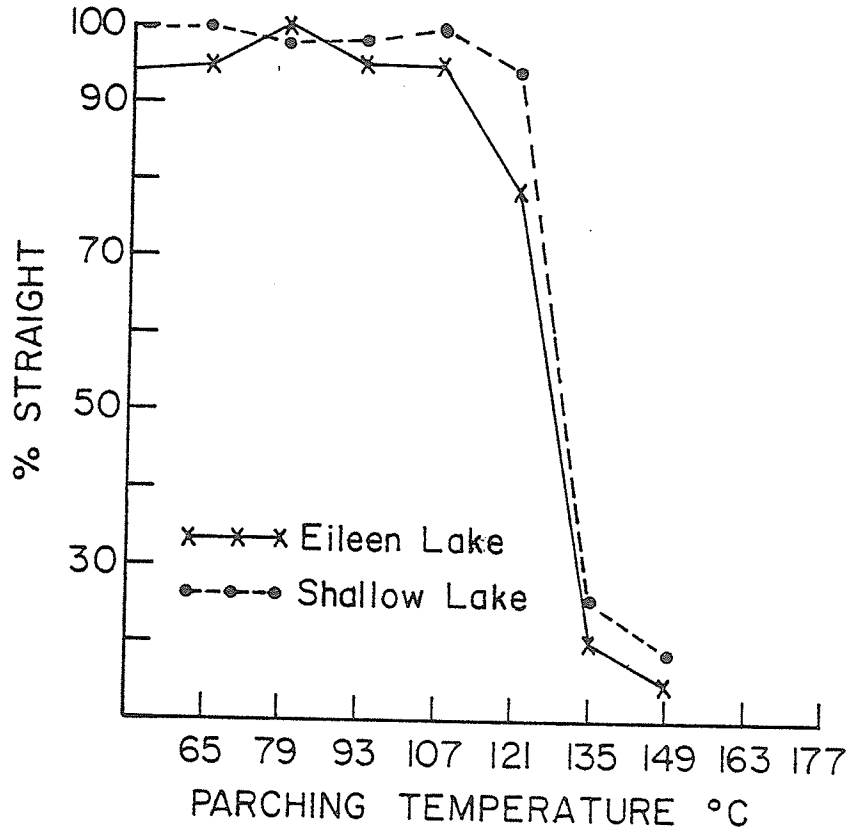
produced rice which retained their conformation during cooking and that high parching temperatures (135° - 150°C) produced rice that curled excessively (hence, unattractive) when cooked (Figs. 71-78). This phenomenon was true for both rice types (Eileen and Shallow Lake). It was anticipated that rice containing a high percentage of kernels with stress points would break up more when cooked and hence produce a softer textured product. However, this was not the case in this study. None of the cooked rice appeared mushy or broken up after cooking. In fact, the percentage of kernels that remained whole and intact (ie not split) was higher among the rice samples found to contain kernels with a high percentage of stress points. This may indicate that these (fissures) stress points are not susceptible to breakage during cooking. The rice genotype could also have contributed to this phenomenon. There were no significant differences between curing systems A and D with respect to the cooking properties of the rice types used in this study.

4.5 Appearance, Flavor and Texture of Finished Wild Rice

A major factor in wild rice quality is its flavor. In some cases a plain toasted flavor was found to be acceptable, but usually this flavor coupled with a grainy and a slightly earthy flavor was preferable (Chung, 1975). The primary objectives of this study were: (1) to evaluate the effects of curing and parching systems on the appearance, flavor and texture of the processed wild rice. A second objective was to improve and finalize the flavor profile for good quality wild rice.

The data obtained from the sensory studies were analyzed statistically by means of the randomized blocks design and a computer "stat 13" program developed by the Computer Center, University of Manitoba. Duncan's Multiple Range test was also applied to compare the experimental means obtained for each curing and parching system.

FIGURE 71. The Effects of Parching Temperature on the Cooking Properties of Wild Rice Cured at 3°C.



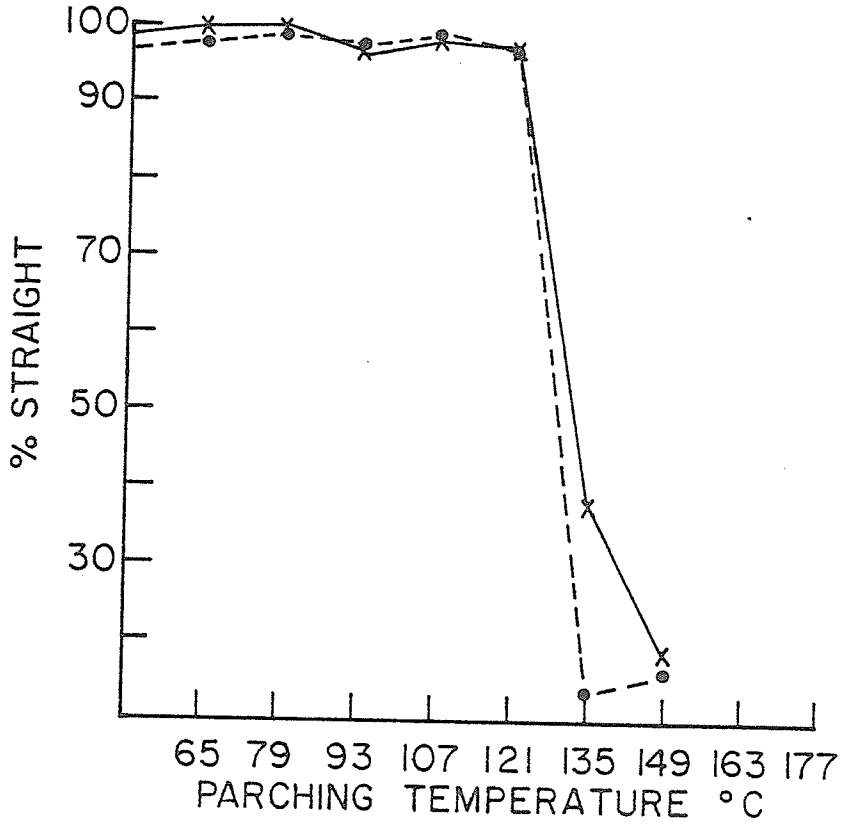
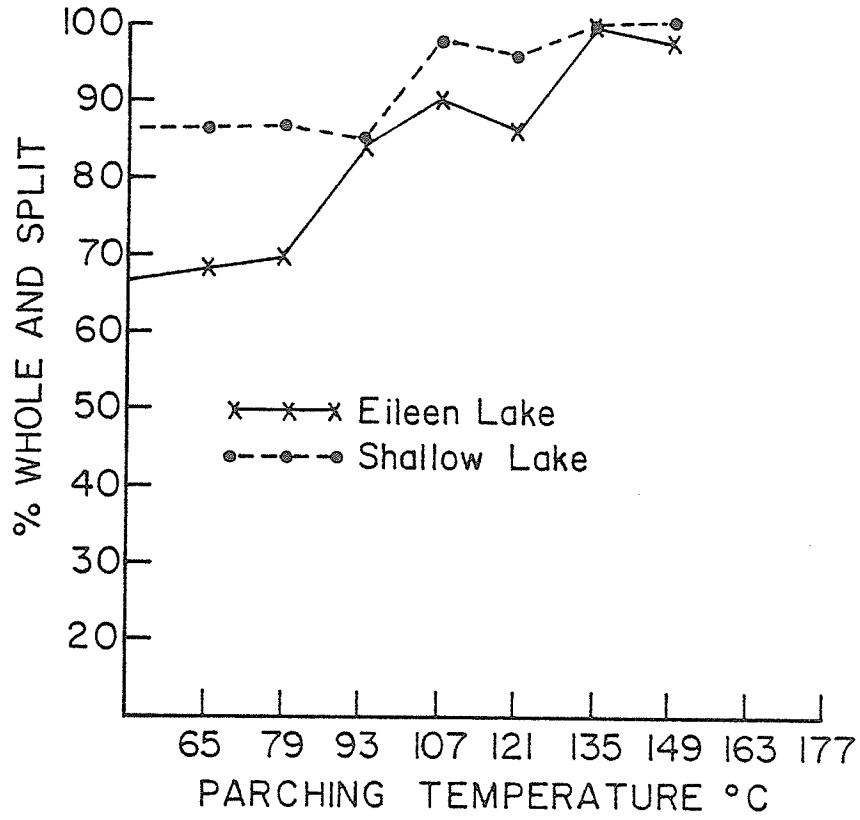


FIGURE 72. The Effects of Parching Temperature on the Cooking Properties of Wild Rice Cured at 15°C.

FIGURE 73. The Effects of Parching Temperature on the Cooking Properties of Wild Rice Cured at 3°C.



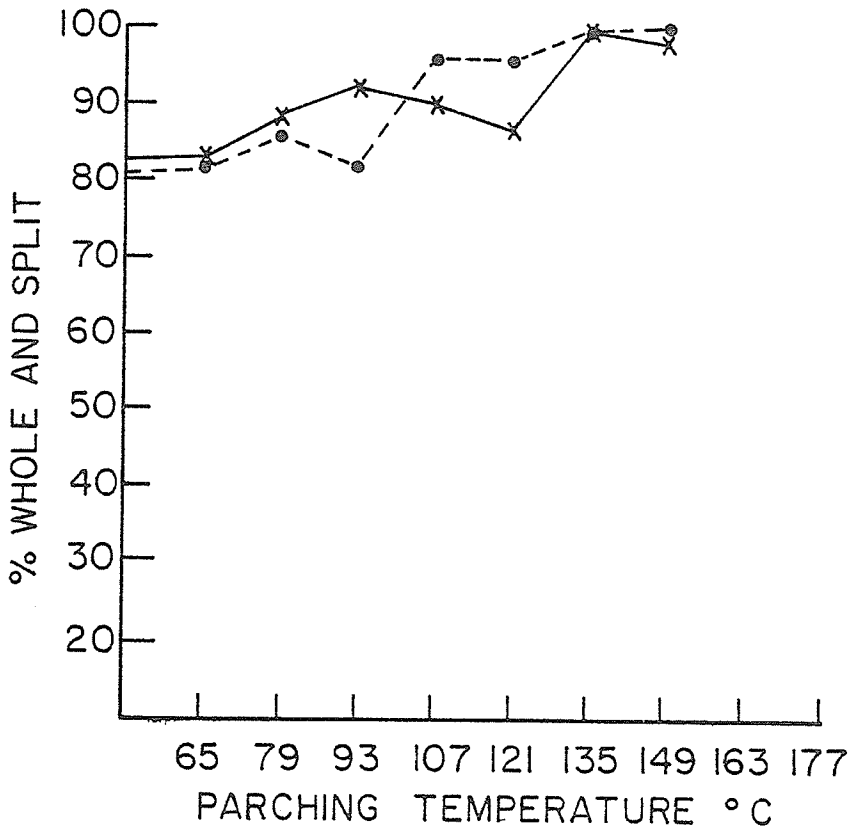
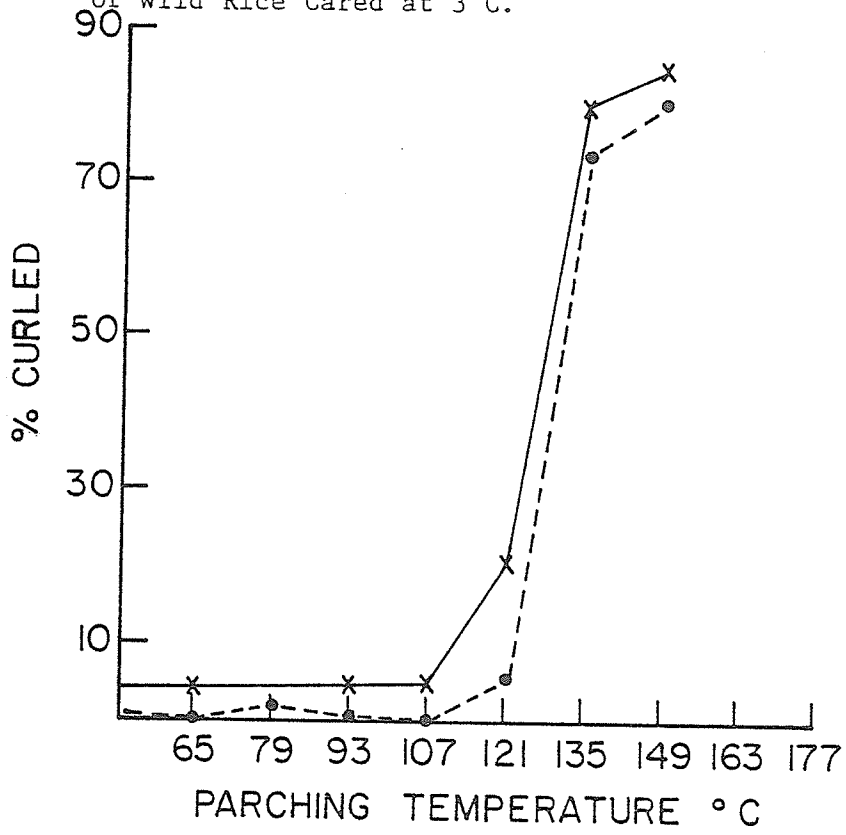


FIGURE 74. The Effects of Parching Temperatures on the Curing Properties of Wild Rice Cured at 15°C.

FIGURE 75. The Effects of Parching Temperature on the Cooking Properties of Wild Rice Cared at 3°C.



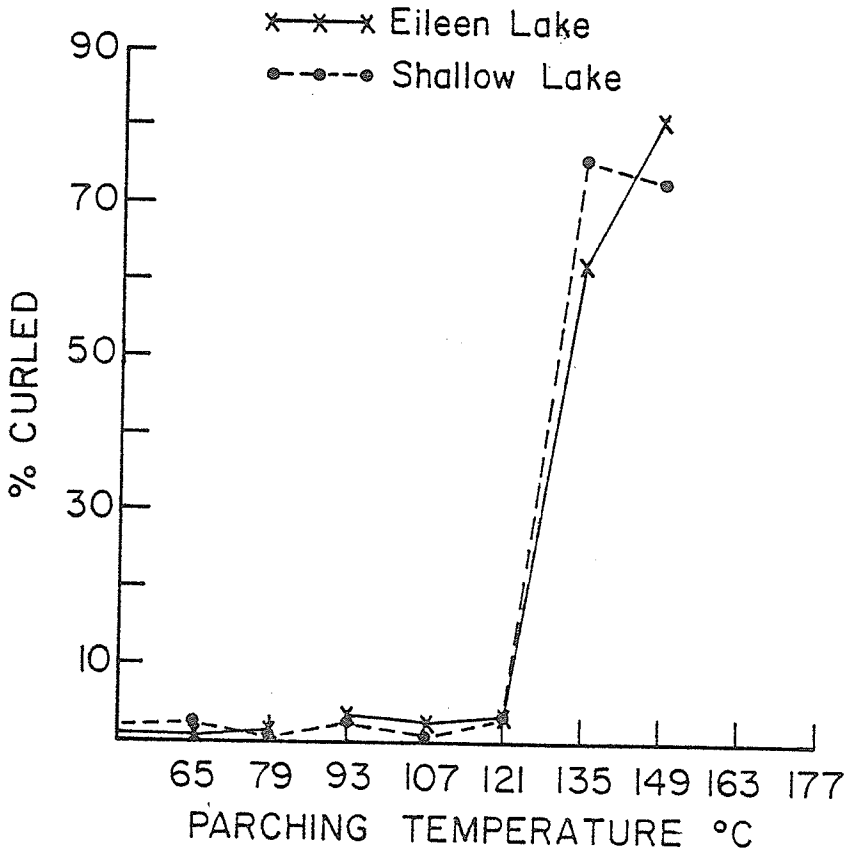
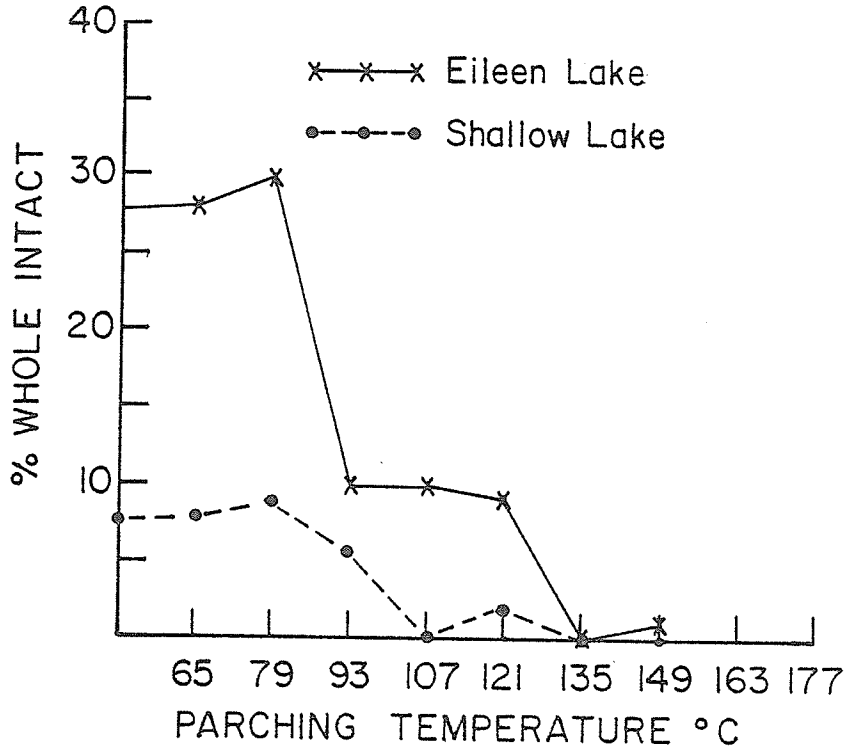


FIGURE 76. The Effects of Parching Temperature on the Cooking Properties of Wild Rice Cured at 15°C.

FIGURE 77. The Effects of Parching Temperature on Cooking Properties of Wild Rice Cured at 3°C.



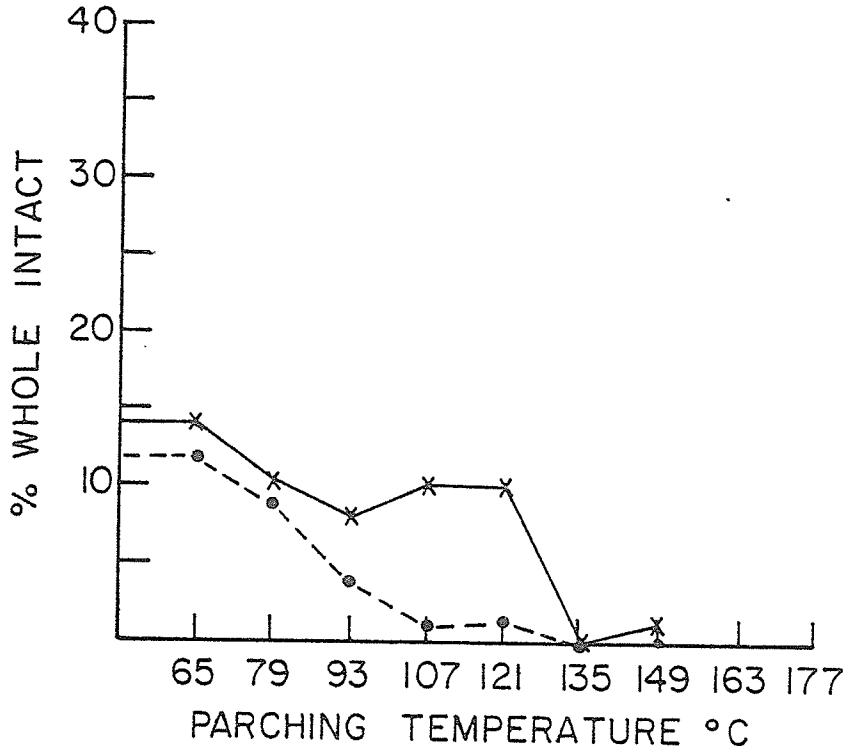


FIGURE 78. The Effects of Parching Temperature on Cooking Properties of Wild Rice Cured at 15°C.

4.5.1 The Effects of Curing Systems on the Flavor Quality of Wild Rice

The curing environment had a more significant effect on the flavor of the final product than did the parching systems (Figs. 79-92). In all systems, the flavor was generally not acceptable during the first week of curing, but became more and more acceptable as curing progressed and then deteriorated towards the end of the curing period. Generally, low temperature cured rice had better flavor than high temperature cured rice. For instance, when wild rice was cured for 7 weeks at 5°C, the flavor was acceptable throughout storage (Fig. 83). When this rice was cured at 38°C, the flavor deteriorated after 2 days storage (Fig. 85). This trend was true for all rice types. The humidity of the curing environment also appeared to have influenced the flavor of the finished rice (Fig. 91 & 92). These figures indicate that high humidity environments (75% - 95%) have a more positive effect on the acceptability of flavor of finished wild rice than low humidity environments (55%).

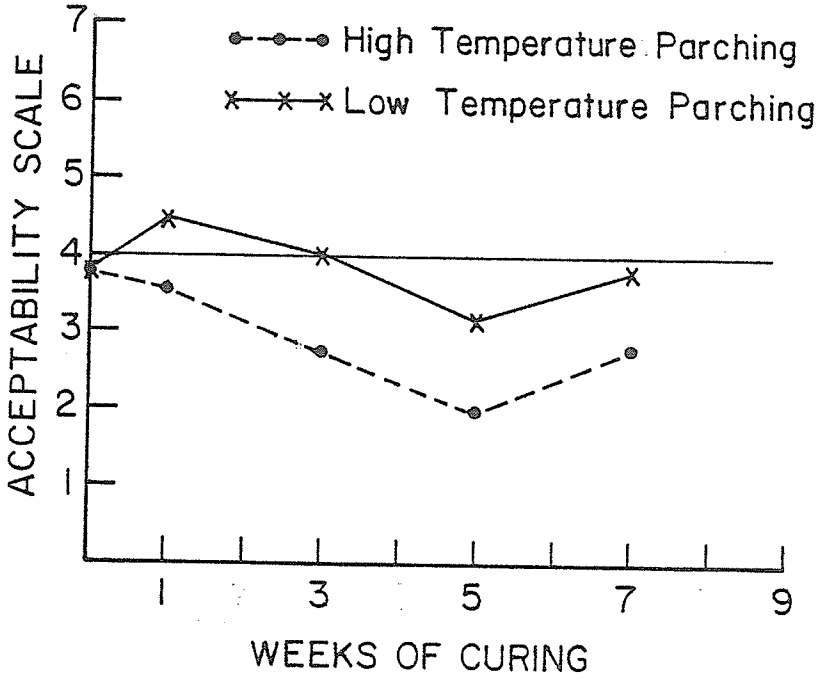
4.5.2 The Effects of Parching Systems on the Flavor Quality of Wild Rice

According to the judgement of the panelists, low parching temperature systems produced rice with more acceptable flavor than extremely high parching temperatures (Fig. 79-92). For example, rice parched at 65°C to 121°C had acceptable flavor whereas that parched at over 130°C was ranked unacceptable (Fig. 89 & 90). These effects of parching systems on the flavor of wild rice were common to all rice types used in this study.

4.5.3 Flavor Acceptability of Rice Types

There was a common pattern of flavor acceptability for all rice types processed by the different curing and parching systems. However, the extent

FIGURE 79. Acceptability Scale of Lac La Ronge Rice Cured at 3°C and 95% Relative Humidity.



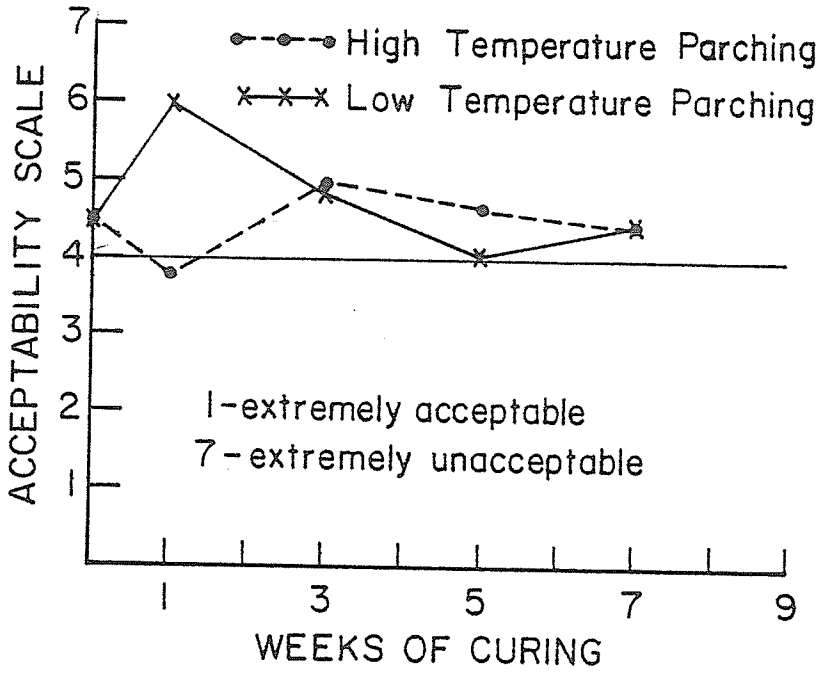
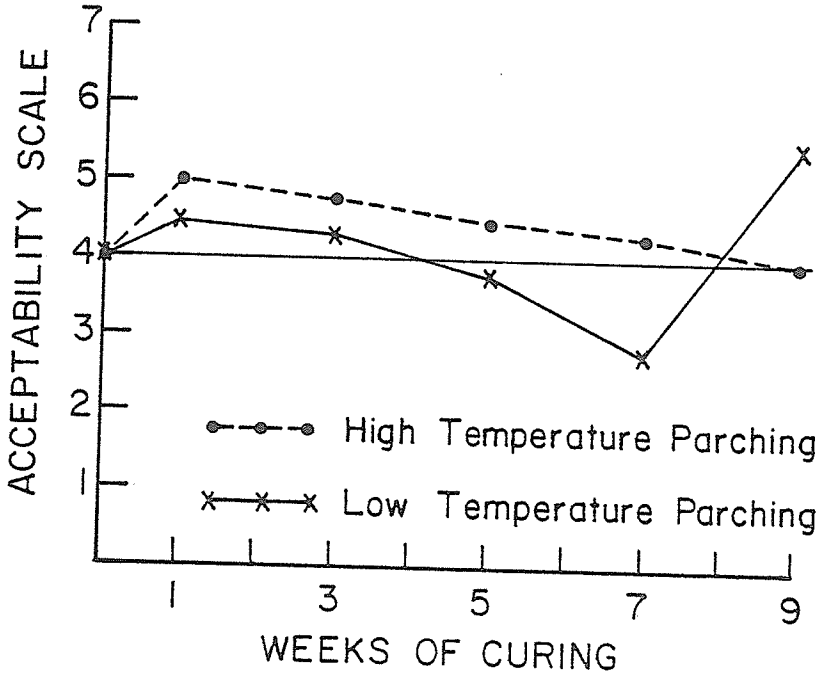


FIGURE 80. Acceptability Scale of Paddy Wild Rice Cured at 3°C and 95% Relative Humidity.

FIGURE 81. Acceptability Scale of Harrop Lake Rice Cured at 3°C and 95% Relative Humidity.



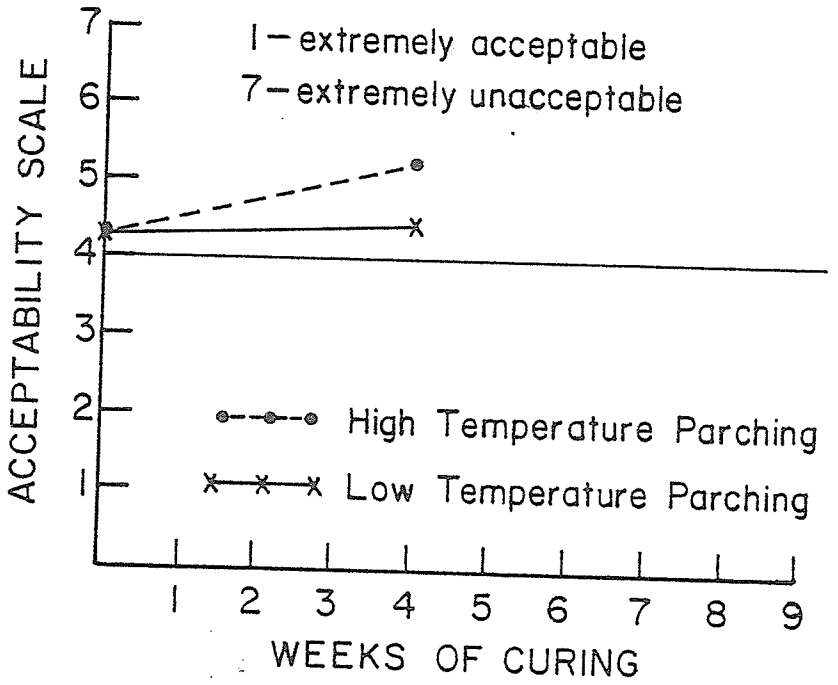
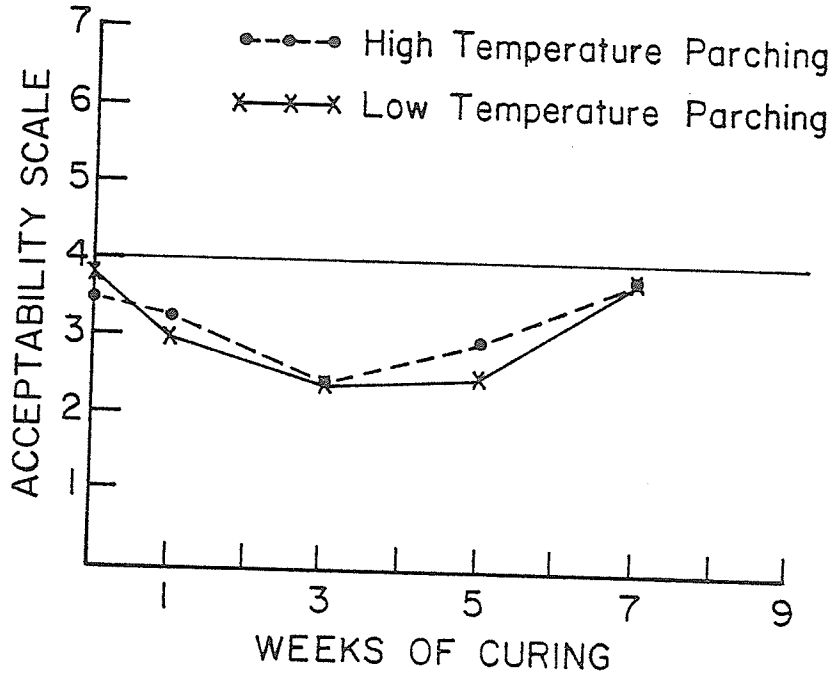


FIGURE 82. Acceptability Scale of Harrop Lake Rice Cured at 15°C and 95% Relative Humidity.

FIGURE 83. Acceptability Scale of Shallow Lake Rice Cured at 5°C and 95% Relative Humidity.



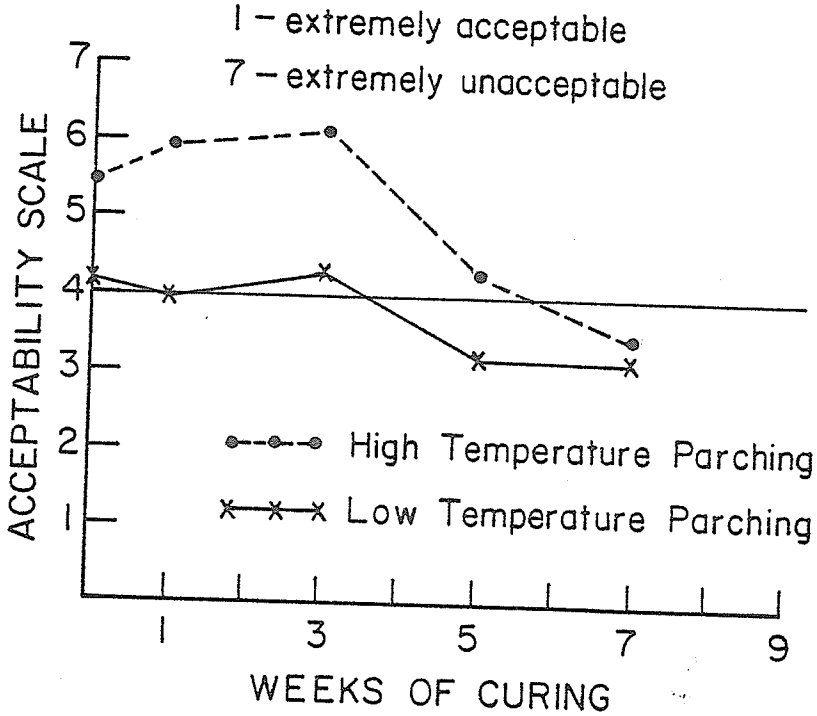
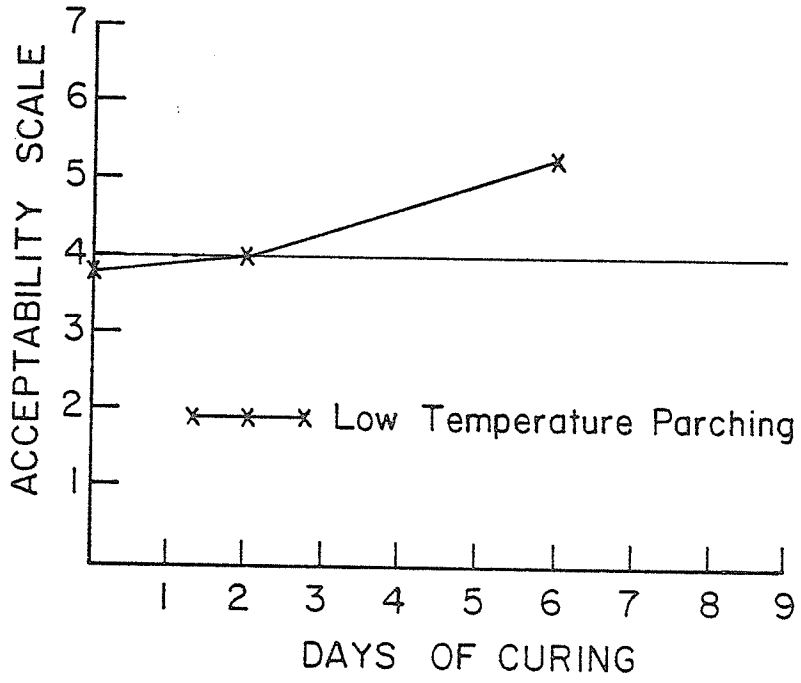


FIGURE 84. Acceptability Scale of Paddy Wild Rice Cured at 5°C and 95% Relative Humidity.

FIGURE 85. Acceptability Scale of Shallow Lake Rice Cured at 38°C and 95% Relative Humidity.



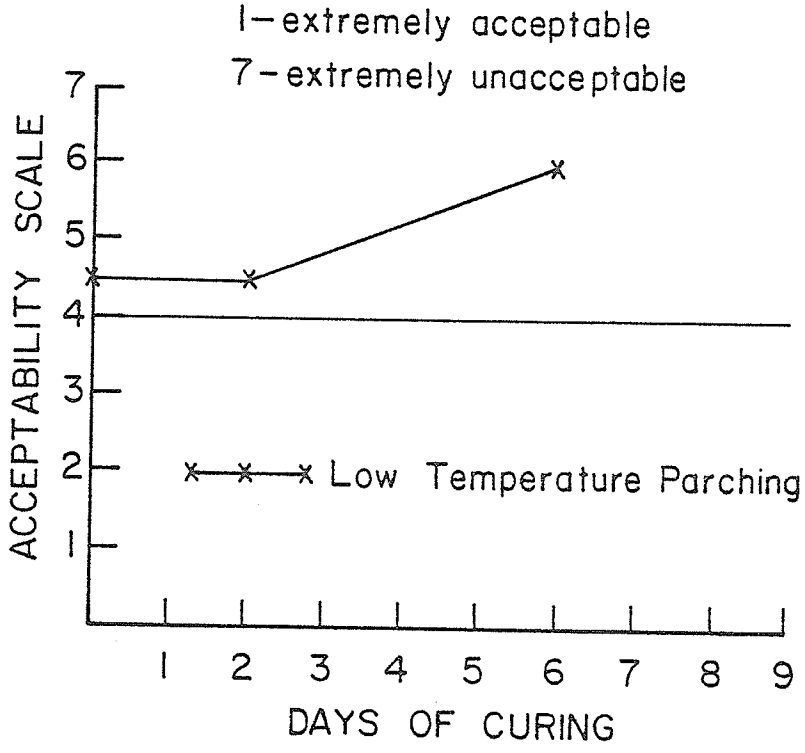
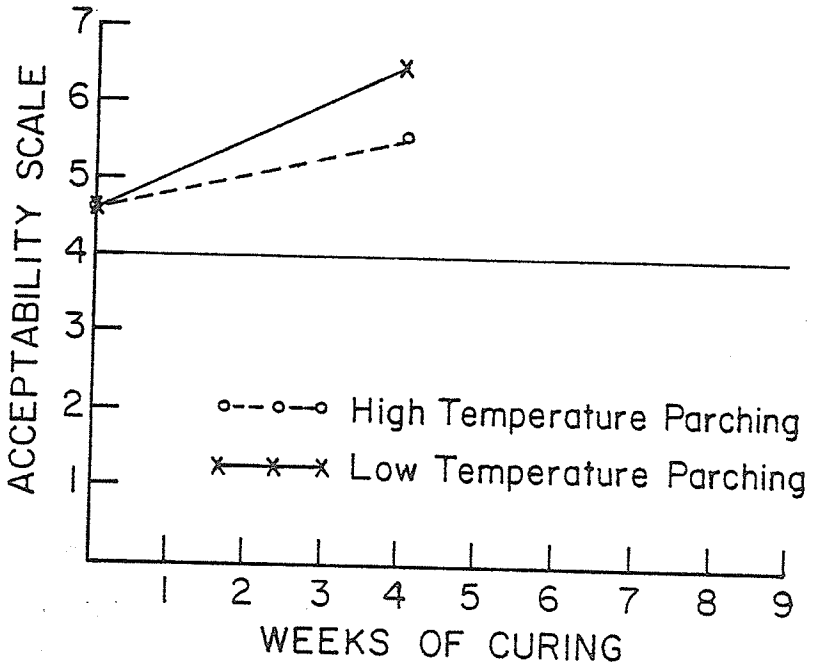


FIGURE 86. Acceptability Scale of Paddy Wild Rice Cured at 38°C and 95% Relative Humidity.

FIGURE 87. Acceptability Scale of Lac La Ronge Cured at 15°C and 95% Relative Humidity.



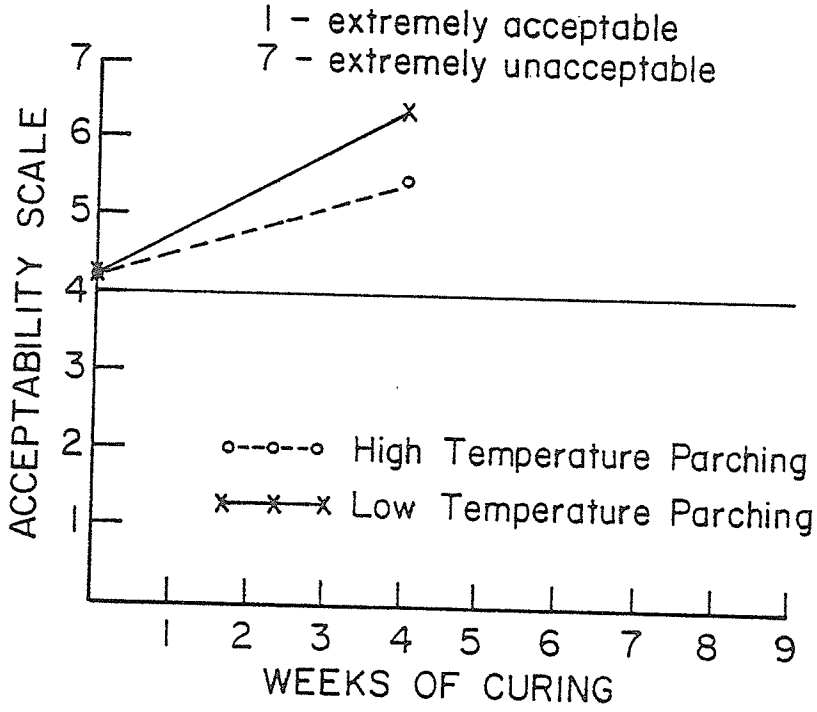
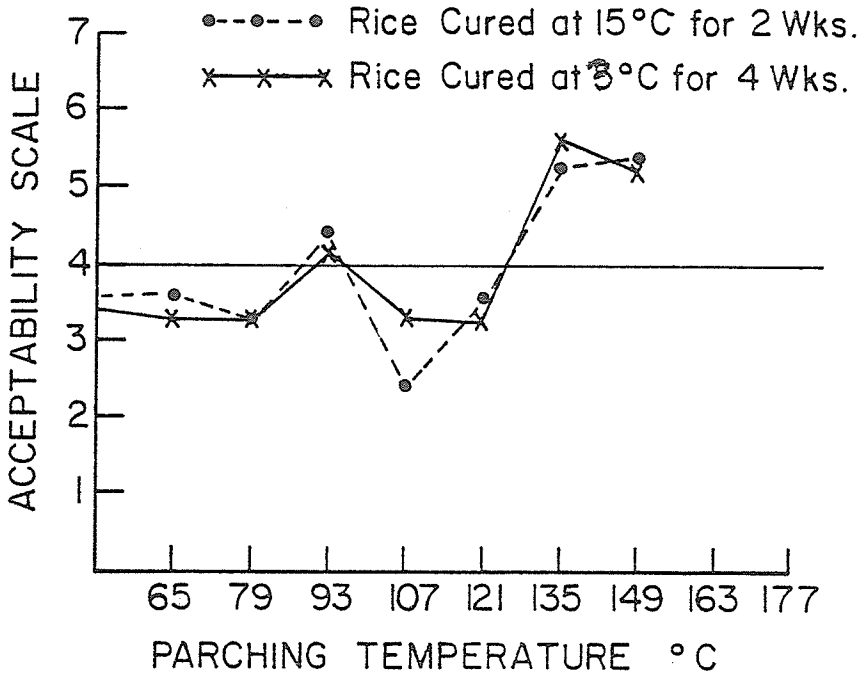


FIGURE 88. Acceptability Scale of Paddy Wild Rice Cured at 15°C and 95% Relative Humidity.

FIGURE 89. Effects of Parching Temperature on Acceptability of Shallow Lake Rice.



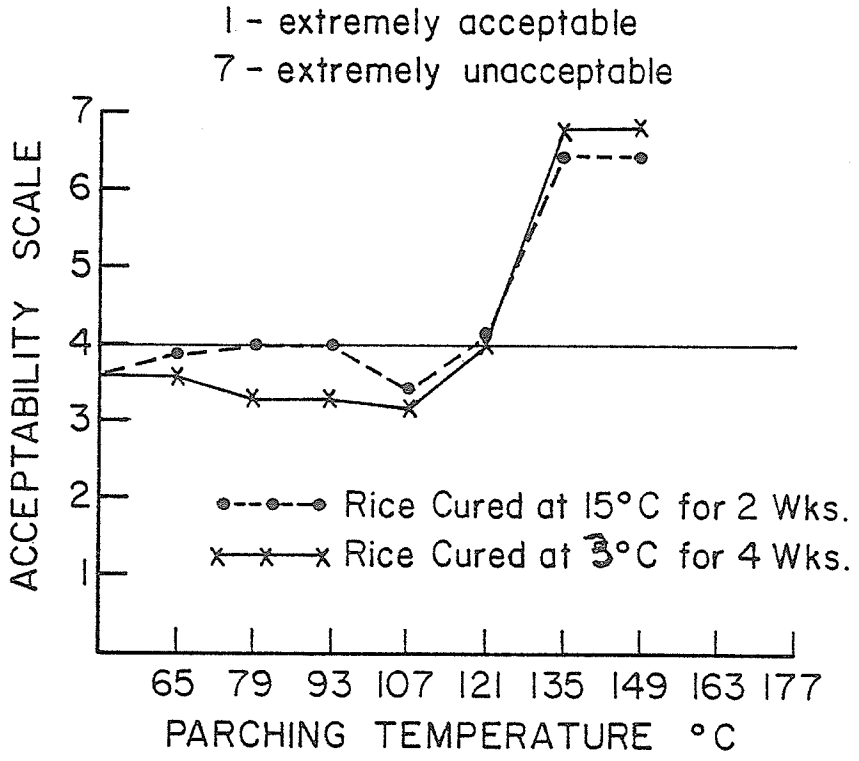
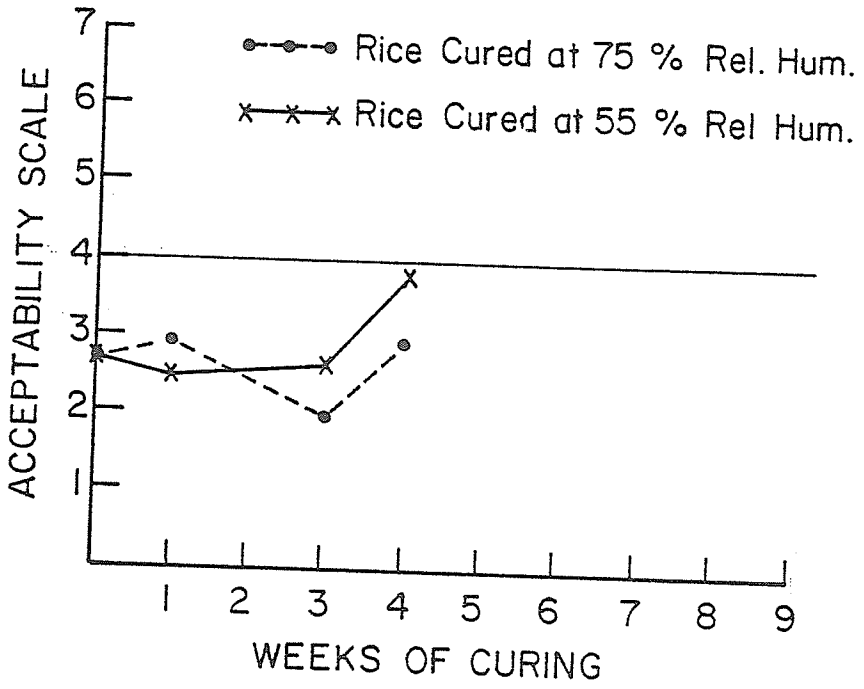


FIGURE 90. Effect of Parching Temperature on Acceptability of Eileen Lake Rice.

FIGURE 91. Acceptability Scale of Crowduck Lake Rice at 10°C.



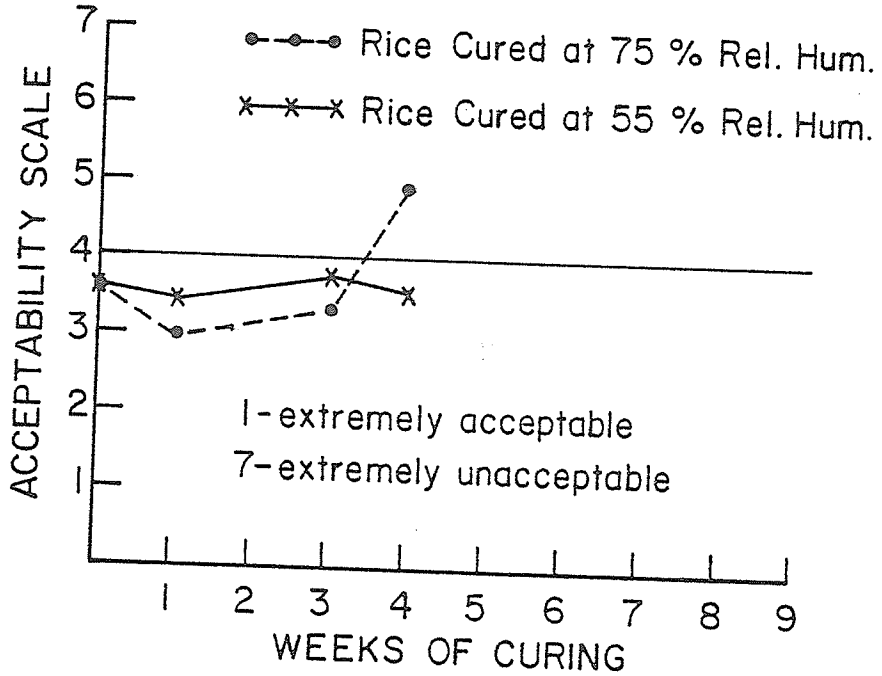


FIGURE 92. Acceptability Scale of Paddy Wild Rice Cured at 10°C.

of these processing effects on flavor differed for each rice type. For instance, Lac la Ronge rice parched by System 2 had a more acceptable flavor than when it was parched by System 1. In general, flavor deteriorated towards the end of the curing period for all rice types (Figs. 79-92).

Lake rice types had more acceptable flavor than Paddy rice. However, the degree of acceptability of flavor differed among the lake rice types, probably due to the fact that these lots of rice were obtained from different sources and therefore were of varying genotypes. The level of flavor acceptability of Lake rice were: Shallow Lake, Eileen Lake, Crowduck Lake, Harrop Lake and Lac la Ronge rice in descending order. Hence, the acceptability of flavor of finished wild rice is also affected by the source or origin of the rice.

In summary, it can be said that the overall acceptance of the flavor of finished wild rice is most dependent on the aroma, taste and after-taste. The major factors describing a good quality and acceptable wild rice was one with the following flavor characteristics:

(a) - Appearance - dark brown to black, straight and split along the major axis of the kernel and not mushy.

(b) - Aroma - grainy and slightly toasted.

(c) - Taste - grainy, slightly toasted and slightly earthy.

(d) - Texture - slightly hard and chewy.

(e) - After-taste - pleasant ie not objectionable.

Conversely, wild rice with a green, curled and mushy appearance; swampy odor; moldy, burnt, extremely earthy and bitter taste; extremely soft and cohesive texture and an objectionable after-taste was considered highly unacceptable. Both the curing and parching systems had significant effects on the flavor of finished wild rice. Low temperature curing (5-10°C) and parching (108°-121°C) environments produce finished rice with the most acceptable flavor.

4.6 Consumer Survey

The characteristics of respondents obtained in this study are presented in Appendix 3, which illustrates the distribution of participants by employment, education, age and family size.

The data obtained in this study were analyzed statistically by the randomized blocks design and Chi square relationships between rice types and dimensions (eg color, size) as judged by the consumer.

4.6.1 Consumer Practices

All the respondents in this survey stated that the price of wild rice is the major limiting factor in the use of this grain. However, in general, consumers judged wild rice primarily by color and secondly by size (Appendix 30, 31). The darker the color of rice, the better respondents liked it. Rice color was associated with its final flavor whereas size was attributed to immaturity. It was also found that consumers purchase wild rice on the basis of its "good name" and that most of the respondents interviewed had very little knowledge of the actual nutrient content of this grain. At the present time, consumers use wild rice mainly as fowl stuffing, in puddings and special gourmet dishes. Cooking information is generally obtained from magazines, cookbooks, friends and relatives.

4.6.2 Consumer Preferences

It was found that although long and plump rice kernels were preferred, this factor was overruled by color. Respondents would select a dark colored rice regardless of its size (Appendix 31) and as long as the rice was free of chaff and other foreign materials.

Consumers, also would prefer packaging systems that will enable them to see the grain before purchasing it. This will permit them to check the color,

size and cleanliness and ensure that they are getting their money's worth. Perhaps, as the popularity of wild rice increases, more of it will be available to the consumer at a reasonably low price in order that the lower income group may also enjoy this unique flavored grain.

In summary, consumers judge wild rice quality primarily by its color, then size and cleanliness. Present high prices limit the use of wild rice to gourmet cooking mostly. It is anticipated that increased production will subsequently decrease the price and will result in more frequent use by consumers.

5. Summary and Conclusion

Lake and Paddy Wild rice used in these studies were obtained by the Food Science Department in 1974 and 1975. All the rice was placed in frozen storage (-40°C) upon arrival at the department and was processed approximately four months later. The rice was washed prior to processing. The washed rice was cured, parched, hulled, cleaned, size graded and quality evaluated. The criteria for quality evaluation were based on total percent yield, percent whole grain (kernels), color, cooking properties, sensory analyses and consumer preference tests.

All curing systems produced finished wild rice with highly acceptable color and flavor, but the low temperature (3°C, 5°C, 10°C) systems were judged to be superior. These systems produced consistently higher yields, more acceptable flavor and the curing could be extended to 5-7 weeks. Rice curing at temperatures of 15°C and 38°C developed acceptable color, but did not have acceptable flavor. At 15°C curing, the rice had to be parched within 2 weeks and that cured at 38°C had to be parched after 2 days. All the low temperature curing systems produced acceptable color in all rice types with the exception of Lac La Ronge and Paddy (1974) wild rice which failed to develop acceptable color in the environments that were tested.

However, the rate of color development was directly proportional to the temperature of the curing environment. The higher this temperature the faster the color development. This color change was also dependent on the rice type, ie the rate and quality of color changes differed with respect to the origin or source of rice, and of rice genotype. The percent total yield of wild rice was not affected by the curing environment when this was well controlled. Only Harrop Lake rice showed a reaction to the various curing systems. In all curing systems, total yield tended to decrease (insignificantly) slightly, towards the end of the storage period. Percent whole grain yield of rice was also not affected by the curing systems when they were well controlled. It was found that, under all the curing systems investigated, Lake rice outyielded Paddy wild rice; and that the yield of rice, among Lake rice types, differed significantly.

Comparison of the parching systems utilized in this study indicated that, in general, low parching temperatures (65°C - 120°C) produced higher yields of rice with acceptable flavor. Whereas high temperature parching systems (135°C - 150°C) produced rice with undesirably burnt flavor and fragile kernels and hence less yield. In all rice types, intermediate temperature (100°C - 121°C) parching was seen to have improved the color of the finished rice. However, extremely high parching temperatures (135°C - 150°C) produced rice with unacceptable color and flavor characteristics.

Taste panel results demonstrated that wild rice which had the desirable dark color did not necessarily have well-developed flavor (although dark color contributed favorably to the acceptability of the overall flavor of the finished rice). Color and flavor of wild rice did not develop concurrently. The initial state of rice at harvest, ie rice genotype and maturity seemed to be the major factor governing the development of color in wild rice. Curing temperature, aeration during curing as well as parching temperature were

factors which apparently governed the flavor development of wild rice. A good quality wild rice, according to the concensus of the taste panel, was rice that had acceptable dark color and acceptable flavor. Acceptable flavor in cooked rice was defined as follows: dark-brown to black, straight and split and not mushy appearance; slightly grainy and toasted aroma; slightly earthy, grainy, and toasted (not burnt) taste; slightly chewy texture and a pleasant after-taste. Sensory characteristics, such as green color, swampy odor, moldy and extremely earthy taste, mushy and soft texture and objectionable after-taste were those indicating unacceptable finished wild rice.

Wild rice with very dark color, plump and long kernels and very few broken grains were judged as top quality rice by consumers. In general, consumers judged wild rice primarily by color and secondly by size. The darker the color of rice, the better consumers liked it. Rice color was associated with its final flavor, whereas size was attributed to immaturity. It was also found that consumers purchase wild rice on the basis of its "good name" and that most of the respondents interviewed had very little knowledge of the actual nutrient content of this grain. At present, wild rice is used mainly as fowl stuffing, in puddings and special gourmet dishes. Owing to its high price, wild rice is considered a "luxury" item in the food market today. It is hoped that, as the popularity of this grain increases, more of it will be available to the consumer at a reasonably low price so that the lower income group may also enjoy this unique flavored grain.

Most problems associated with the quality of finished wild rice were reviewed in this study. Problems such as decreased yield, swampy odor, broken kernels, and mushy texture were found to be controllable.

The problem of color development is still the major problem in the processing of wild rice. This problem was found to be primarily dependent on the rice genotype, ie degree of maturity at time of harvest. No correlation seems apparent

between color development in wild rice during curing and flavor development of the finished product. Further research work is required in this area. The production of Paddy wild rice in Manitoba requires improvement in this variety by a sound breeding program. Due to the various aspects of research in this study, and to the limited time involved, some of the results are not positively confirmed. However, most of the information contained here, concerning the processing of wild rice are reliable and available for commercial use or as guidelines for future research.

5.1 Recommendations

This section will indicate the area where further research on the processing of wild rice appears to be required. It will also indicate those conclusions that the industry may utilize to their advantage.

5.2. Recommendations for Further Research

The commercial wild rice processor handles lots of rice with varying degrees of maturity. Immature rice is found to produce finished rice which gives a lower yield with poor quality. Maturity, for this grain, is not well defined but primarily based on darkness in color of kernels at time of harvest. This should be more specifically defined to enable growers to select one "proper" time to harvest the crop. Meanwhile, new rice varieties should be developed by the plant breeders especially since the existing Paddy rice variety needs improvements desperately. This would have the potential of giving uniform maturation and hence uniform color to the finished product.

This study has revealed that it is beneficial to thoroughly wash the harvested rice prior to curing in order to decrease spoilage problems during curing; by removing sand, plant debris, ergot bodies and eliminating the rice worm from the curing pile. This washing operation has not yet been adapted

to the industry. Perhaps a washing system, as used in the sugar beet industry could be adapted for wild rice prior to curing. Further research is necessary here to confirm the economical feasibility of such a system.

Further research is required to more precisely verify the effects of curing and parching systems on total yield and color development of various rice types.

5.3 Recommendations for Application by the Industry

The transportation system for harvested rice from the field to the processing plant is still very inefficient and hence needs improvement. This will ensure that the rice is handled properly, thus minimizing losses and helping to reduce costs. There is also a great deal of improvement required in harvesting techniques. It is a fact that in Manitoba most of the natural (Lake) stand rice is harvested by the ancient method. This method is rather inefficient, resulting in poor harvesting (yield) per acre, high losses of grain and improper handling prior to curing.

The curing pile of rice must be well controlled to ensure optimum quality of the finished rice. Rice bed temperatures must not be allowed to exceed 10°C to 15°C of the curing environment. The moisture content of the rice during curing is extremely important and must never be allowed to fall below 40 percent in order to prevent aflatoxin development and white centers in the finished rice. Wherever possible, ie economically feasible, a controlled environment system will be the best type of system to use for this stage in the processing of wild rice.

Parching or drying can be carried out in any type of hot air dryer system. This study has illustrated that consumers prefer finished wild rice with a slightly toasted flavor. This quality factor was found to be successfully achieved when intermediate parching temperatures were utilized. It was also

found in this study that the production of high quality wild rice can be achieved by the following processing systems:

Curing: low temperature (5-10°C) and high humidity (75-95%) environment for 3 to 5 weeks.

Parching: temperature range of 107°C to 121°C for 20 to 30 minutes.

These systems would produce rice with acceptable color, flavor and optimum yield.

The hulling process in also very critical as it removes the hull and polishes the final product. Hence, great care must be taken to prevent or minimize breakage of the rice. It is recommended that the parched rice should be hulled within 24 hours after parching to ensure maximum yield of whole grains. A series of Japanese Kyowa (spring) adjustable hullers can be used successfully for this operation.

The flavor of wild rice was described under 22 different characteristics. Various specific characteristics and processing systems were identified as contributing to undesirable and unacceptable flavored wild rice, such as moldiness, swampiness, high temperature curing and prolonged storage in curing as well as extremely high parching temperatures. These systems must be avoided by the processors. Consumers were found to prefer finished rice with bland to slightly toasted taste and an overall "gamey" flavor. Consumers associate dark color and size with final flavor and hence commercial processors should endeavor to produce wild rice that best accords to these preferences.

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APPENDIX 1.

Instructions

1. You will be served four samples all at once.
2. Please examine each one separately and use one ballot sheet per sample.
3. Examine each sample carefully and indicate your opinion in the areas specified in the questionnaire.
4. It is advisable to rinse mouth well between samples.
5. Please use empty containers provided for expectoration.

APPENDIX 2.

Sample: Name: Date:

APPEARANCE

Scale I

All Straight /—/—/—/—/—/—/ All Curled

Scale II

Green /—/—/—/—/—/—/ Dark Brown

Scale III

All Split /—/—/—/—/—/—/ All Intact

Scale IV

Mushy /—/—/—/—/—/—/ Not Mushy

Scale V

Appear. Acceptable /—/—/—/—/—/ Appear. Unacceptable

AROMA

Scale I

Bland /—/—/—/—/—/—/ Grainy

Scale II

Bland /—/—/—/—/—/—/ Swampy

Scale III

Bland /—/—/—/—/—/—/ Toasted

Scale IV

Aroma Accept. /—/—/—/—/—/—/ Aroma Unaccept.

TASTE

Scale I

Bland /—/—/—/—/—/—/ Ext. Burnt

Scale II

Bland /—/—/—/—/—/—/ Ext. moldy-like

Scale III

Bland /—/—/—/—/—/—/ Ext. grainy-like

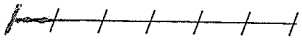
Scale IV

Bland /—/—/—/—/—/—/ Earthiness

Scale V

Bland Bitter

Scale VI

Bland  Sweet

Scale VII

Taste Acceptable Taste Unaccept.

TEXTURE

Scale I

Very Soft Very Hard

Scale II

No Cohesiveness Ext. Cohesive

Scale III

No Chewiness

Scale IV

Texture Accept. Texture Unaccept.

AFTERTASTE

Scale I

Objectionable Not Objectionable

This sample is Acceptable Unacceptable

APPENDIX 3.

Characteristics of Respondents (1)

Characteristics		Number	Percent
Exmployment:	Professional	45	64.3
	White Collar	15	21.4
	Blue Collar	6	8.6
	Student	4	5.7
	Total	70	100.0
Education:	< High School	0	0
	High School	6	8.6
	> High School	64	19.4
	Total	70	100.0
Age:	< 30	10	14.3
	31-45	49	70.0
	46-50	9	12.8
	>60	2	2.9
	Total	70	100.0
Number of Persons Per Household	1-2	12	17.1
	3-4	41	58.6
	5-7	17	24.3
	Total	70	100.0

APPENDIX 4.

CONSUMER QUESTIONNAIRE

Hello, I am from the University of Manitoba and am doing a study on the use of wild rice. Your help would be most appreciated.

1. First of all, who in your household does most of the grocery shopping?

a) you alone ( )
b) spouse alone ( )
c) both ( )
d) other ( )
specifiy

Now, I am looking for people with certain characteristics.

2. Are you employed outside your home? yes ( ) No ( )

3. What is the occupation of the main wage earner in your home? Specify.

_____

4. How often do you serve wild rice in your home?

Not at all	Once a year	2 or 3 times/year	More than 3 times/year	Once a month	More than once/month
( )	( )	( )	( )	( )	( )

If wild rice is not served at least once a year, thankyou, and indicate completion of interview. Complete ( )

5. Do you ever buy wild rice in bulk? yes ( ) No ( )

6. How often do you buy retail, or receive wild rice?

Not at all	Once a year	2 or 3 times/year	More than 3 times/year	Once a month	More than once/month
( )	( )	( )	( )	( )	( )

7. Do you buy them prepackaged or from the grocer? _____

8. What is the most important characteristic you look for when you buy (or receive) wild rice?

COLOR
a) Black ( )
b) Dark Brown ( )
c) Light Brown( )
d) Green ( )

SIZE
a) Long ( )
b) Short ( )
c) Plump/fat ( )
d) Small/skinny ( )

9. How is wild rice prepared in your home?

a) casserole ( )
b) game bird dressing ( )
c) turkey or chicken dressing ( )
d) plain side dish ( )
e) meat loaf ( )
g) other (specify) _____

QUESTIONNARIE (contin)

10. How do you cook your wild rice?

PROBE

a) time ( )
b) temperature ( )
c) excess water ( )
d) soak overnight ( )
e) degree doneness ( )
f) other (specify) _____

11. Where do you obtain your information on cooking wild rice?

a) trial and error ( )
b) mother, family friends ( )
c) cookbooks, magazines ( )
d) anything else (specify) _____

SHOW SAMPLES - LET RESPONDENT CHOOSE ONE

12. a) What color would you say is the rice you chose? _____
b) What does color mean to you? _____
c) What color of rice would you avoid? _____
d) What would that color indicate to you? _____

13. a) I would like you to rank the three other rice on display. Which would be your second, third and fourth choice?

2nd _____ 3rd _____ 4th _____

b) Why did you select rice _____ as your last choice?

_____

Finally, just a few background questions and this will complete the interview.

14. Where were you brought up?

a) city ( )
b) country ( )
c) other ( ) _____

15. How long have you known about and eaten wild rice?

_____

16. How many people in your household?

a) 1 - 2 ( )
b) 3 - 4 ( )
c) 5 - 7 ( )

17. Which age group do you fall into?

a) under 30 ( )
b) 31 - 45 ( )
c) 46 - 60 ( )
d) 60 - over ( )

Thank you for participating in our survey.

APPENDIX 5. Increase in Moisture Content of Wild Rice Cured at 3°C.

% Moisture Content Before Parching

Weeks of Curing

Rice Type (Variety)	0	1	3	4	5	7	9
Paddy	63.4	63.2	66.5	68.9	70.5	70.4	70.5
Shallow Lake	48.2			54.1			
Harrop Lake	45.1	47.3	52.4	52.6	52.9	55.6	59.6
Lac la Ronge	45.3	53.3	53.8	53.9	55.8	58.7	
Eileen Lake	45.9			48.2			

APPENDIX 6. Increase in Moisture Content of Wild Rice Cured at 5°C.

% Moisture Content Before Parching

Weeks of Curing

Rice Type	0	1	3	5	7
Paddy	63.8	68.2	69.5	69.5	70.2
Shallow Lake	48.9	52.1	52.8	52.5	56.4

APPENDIX 7. Increase in Moisture Content of Wild Rice at 15°C.

	% Moisture Content Before Parching		
	Weeks of Curing		
Rice Type	0	1	4
Paddy	63.9	69.9	74.4
Shallow Lake	48.1	50.1	53.6
Harrop Lake	46.3	56.3	65.3
Eileen Lake	46.4	49.7	48.1
Lac la Ronge	45.8	47.8	56.4

APPENDIX 8. Increase in Moisture Content of Wild Rice Cured at 38°C.

	% Moisture Content Before Parching		
	Days of Curing		
Rice Type	0	2	6
Paddy	63.4	66.3	66.2
Shallow Lake	45.1	45.8	51.5

Appendix 9 Relationship Between Initial Moisture Content, Parching Temperature, Parching Time and Proportion of Parched Wild Rice Kernels with Hollow Centers and/or Popped Grains.

Parching Temp.	Parching Time	Initial M.C. %	% of Whole Wild Rice Kernels Popped and/or with Hollow Centers	
			% Popped Kernels	Kernels with Hollow Centers (%)
Eileen 3°C				
65	70	46	0	0
79	55	46	0	0
93	45	47	0	0
107	40	48	0	0
121	30	48	2	3
135	25	48	38	81
149	20	48	49	93
Shallow Lake 3°C				
65	70	48	0	0
79	55	48	0	0
93	45	55	0	0
107	40	53	0	0
121	30	54	0	2
135	25	53	20	76
149	20	55	9	89

APPENDIX 10. Comparison of Acceptability Score of Lac La Ronge Rice Processed by Systems A and 1.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	2.4	3.6	A B C D
Dark Brown	1.8	6.1	A B C D
Split	2.1	1.6	A B C D
Mushy	4.4	0.2	A B C D
Appearance Acceptable	3.9	1.3	A B C D
Grainy (odor)	3.6	2.2	A B C D
Swampy	3.2	8.7	A B C D
Toasted	2.2	1.1	A B C D
Aroma Acceptable	3.5	6.2	A B C D
Burnt	1.5	1.1	A B C D
Moldy	2.5	11.6	A B C D
Grainy (taste)	3.1	2.1	A B C D
Earthy	2.2	2.1	A B C D
Bitter	2.1	2.8	A B C D
Sweet	2.7	2.8	A B C D
Taste Acceptable	4.1	5.2	A B C D
Hard	3.2	3.6	B A C D
Cohesive	3.8	1.0	A B C D
Chewy	3.4	2.1	A B C D
Texture Acceptable	3.1	1.5	A B C D
After Taste Objectionable	4.7	6.6	A B C D
Sample Acceptable	4.3	6.9	A B C D

Curing System A - 3°C, 95% R.H.
Parching System 1 - Low Temperature (79°C)
Storage Time in weeks A - 1
B - 3
C - 5
D - 7

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 11. Comparison of Acceptability Score of Lac La Ronge Rice Processed by Systems A and 2.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	3.4	1.5	A B C D
Dark Brown	4.2	1.4	A B C D
Split	1.9	0.6	A B C D
Mushy	3.8	2.7	A B C D
Appearance Acceptable	3.2	0.5	A B C D
Grainy (odor)	3.9	0.7	A B C D
Swampy	2.2	4.7	A B C D
Toasted	4.3	4.8	A C B D
Aroma Acceptable	3.0	11.6	A B C D
Burnt	3.2	3.2	A D B C
Moldy	2.1	14.5	A B C D
Grainy (taste)	3.5	1.3	A B C D
Earthy	2.1	2.5	A B C D
Bitter	2.9	2.7	A B C D
Sweet	1.9	0.8	A B C D
Taste Acceptable	3.6	6.9	A B C D
Hard	3.5	0.3	A B C D
Cohesive	3.7	0.3	A B C D
Chewy	3.7	0.7	A B C D
Texture Acceptable	2.7	7.4	A B C D
After Taste Objectionable	5.5	6.6	A B C D
Sample Acceptable	3.4	13.3	A B C D

Curing System A - 3°C, 15% R.H.
Parching System 2 - High Temperature (135°C)
Storage Time in weeks - A - 1
B - 3
C - 5
D - 7

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 12. Comparison of Acceptability Score of Harrop Lake Rice Processed by Systems A and 1.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	3.2	1.6	A B C D E
Dark Brown	5.4	3.5	A B C D E
Split	2.6	1.5	A B C D E
Mushy	4.4	1.0	A B C D E
Appearance Acceptable	2.9	3.2	A B C D E
Grainy (odor)	3.5	1.5	A B C D E
Swampy	2.7	1.1	A B C D E
Toasted	2.6	6.2	A B C D E
Aroma Acceptable	3.7	2.3	A B C D E
Burnt	2.2	10.4	A B C D E
Moldy	2.9	0.6	A B C D E
Grainy (taste)	3.1	0.7	A B C D E
Earthy	3.9	1.1	A B C D E
Bitter	2.7	2.2	A B C D E
Sweet	2.1	1.9	A B C D E
Taste Acceptable	4.2	4.0	A B C D E
Hard	4.1	0.9	A B C D E
Cohesive	3.4	1.3	A B C D E
Chewy	4.4	2.0	A B C D E
Texture Acceptable	3.5	3.8	A B C D E
After Taste Objectionable	4.6	4.4	A B C D E
Sample Acceptable	4.2	2.6	A B C D E

Curing System A - 3°C, 95% R.H.
Parching System 1 - Low Temperature (79°C)
Storage Time in weeks - A - 1
B - 3
C - 5
D - 7
E - 9

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 13. Comparison of Acceptability Score of Harrop Lake Rice Processed by Systems A and 2.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	2.9	2.7	A B C D E
Dark Brown	5.9	0.9	A B C D E
Split	2.8	2.7	A B C D E
Mushy	5.4	1.7	A B C D E
Appearance Acceptable	2.9	1.4	A B C D E
Grainy (odor)	3.5	0.6	A B C D E
Swampy	3.7	1.4	A B C D E
Toasted	2.9	0.5	A B C D E
Aroma Acceptable	3.9	2.6	A B C D E
Burnt	2.1	0.4	A B C D E
Moldy	3.5	1.7	A B C D E
Grainy (taste)	2.6	1.0	A B C D E
Earthy	3.0	1.1	A B C D E
Bitter	3.7	1.9	A B C D E
Sweet	2.7	1.1	A B C D E
Taste Acceptable	1.9	0.2	A B C D E
Hard	4.4	3.0	A B C D E
Cohesive	4.9	3.4	A C E B D
Chewy	3.0	0.7	A B C D E
Texture Acceptable	4.8	3.2	A B C E D
After Taste Objectionable	4.4	1.5	A B C D E
Sample Acceptable	4.8	2.8	A B C D E

Curing System A - 3°C, 95% R.H.
Parching System 2 - High Temperature (135°C)
Storage Time in weeks - A - 1
B - 3
C - 5
D - 7
E - 9

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 14. Comparison of Acceptability Score of Paddy Rice Processed by Systems A and 1.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	2.5	1.8	A B C D E
Dark Brown	2.9	4.2	A B C D E
Split	3.2	2.8	A B C D E
Mushy	4.5	2.6	A B C D E
Appearance	3.5	0.3	A B C D E
Grainy (odor)	3.4	2.3	A B C D E
Swampy	4.0	4.8	A B C D E
Toasted	2.4	2.9	A B C D E
Aroma Acceptable	4.2	4.1	A B C D E
Burnt	1.7	3.4	A B C D E
Moldy	3.6	2.5	A B C D E
Grainy (taste)	2.9	1.4	A B C D E
Earthy	2.8	0.3	A B C D E
Bitter	3.2	0.9	A B C D E
Sweet	2.3	1.0	A B C D E
Taste Acceptable	5.0	4.3	A B C D E
Hard	3.8	1.8	A B C D E
Cohesive	3.4	1.3	A B C D E
Chewy	4.1	1.3	A B C D E
Texture Acceptable	3.7	0.4	A B C D E
After Taste Acceptable	4.2	4.5	A B C D E
Sample Acceptable	5.1	3.6	B A C D E

Curing System A - 3°C, 95% R.H.
Parching System 1 - Low Temperature (79°C)
Storage Time in weeks - A - 0
B - 1
C - 3
D - 5
E - 7

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 15. Comparison of Acceptability Score of Paddy Rice Processed by Systems A and 2.

Characteristics	Experimental Mean	F. Values	Duncan's Multiple Range Test
Straight	2.9	0.4	A B C D E
Dark Brown	4.7	5.6	A B C D E
Split	3.5	0.6	A B C D E
Mushy	4.8	1.2	A B C D E
Appearance Acceptable	3.2	1.7	A B C D E
Grainy (odor)	3.8	1.2	A B C D E
Swampy	2.7	2.5	A B C D E
Toasted	3.8	8.3	A B C D E
Aroma Acceptable	3.8	0.2	A B C D E
Burnt	3.4	5.6	A B C D E
Moldy	2.4	0.4	A B C D E
Grainy (taste)	3.2	0.4	A B C D E
Earthy	2.2	0.7	A B C D E
Bitter	3.4	5.3	A B C D E
Sweet	2.0	0.7	A B C D E
Taste Acceptable	4.3	1.4	A B C D E
Hard	4.7	1.0	A B C D E
Cohesive	3.0	0.2	A B C D E
Chewy	3.8	0.1	A B C D E
Texture Acceptable	3.8	0.2	A B C D E
After Taste Objectionable	4.3	0.9	A B C D E
Sample Acceptable	4.7	2.0	A B C D E

Curing System A - 3°C, 95% R.H.
Parching System 2 - High Temperature (135°C)
Storage Time in weeks - A - 0
B - 1
C - 3
D - 5
E - 7

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 16. Comparison of Acceptability Score of Eileen Lake Rice Cured by System A.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	4.1	29.5	A B C D E F G
Dark Brown	4.6	21.6	A B C D E F G
Split	1.5	2.6	A B C D E F G
Mushy	3.5	4.3	A B C D E F G
Appearance Acceptable	4.5	7.6	A B C D E F G
Grainy (odor)	3.7	0.7	A B C D E F G
Swampy	1.9	1.6	A B C D E F G
Toasted	3.8	13.3	A B C D E F G
Aroma Acceptable	3.6	3.3	A B C D E F G
Burnt	3.1	11.6	A B C D E F G
Moldy	1.7	2.3	A B C D E F G
Grainy (taste)	3.0	1.1	A B C D E F G
Earthy	1.9	1.1	A B C D E F G
Bitter	3.4	5.8	A B C D E F G
Sweet	2.0	1.6	A B C D E F G
Taste Acceptable	4.3	6.1	A B C D E F G
Hard	3.3	13.5	A B C D E F G
Cohesive	3.4	0.7	A B C D E F G
Chewy	3.4	13.9	A B C D E F G
Texture Acceptable	3.9	3.2	A B C D E F G
After Taste Objectionable	4.4	6.0	A B C D E F G
Sample Acceptable	4.7	8.0	A B C D E F G

Curing System A - 3°C, 95% R.H.
Parching Systems - A - 3 - 65°C
B - 4 - 79°C
C - 5 - 93°C
D - 6 - 107°C
E - 7 - 121°C
F - 8 - 135°C
G - 9 - 149°C

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 17. Comparison of Acceptability Score of Shallow Lake Rice Cured by System A.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	3.3	33.4	A B C D E F G
Dark Brown	5.8	1.2	A B C D E F G
Split	1.8	5.6	A B C D E F G
Mushy	4.4	1.6	A B C D E F G
Appearance Acceptable	3.4	3.9	A B C D E F G
Grainy (odor)	3.9	1.4	A B C D E F G
Swampy	2.1	3.7	A B C D E F G
Toasted	3.5	12.1	A B C D E F G
Aroma Acceptable	3.7	3.3	A B C D E F G
Burnt	3.2	24.3	A B C D E F G
Moldy	2.3	2.1	A B C D E F G
Grainy (taste)	3.2	1.1	A B C D E F G
Earthy	2.4	1.5	A B C D E F G
Bitter	2.8	5.9	A B C D E F G
Sweet	1.8	2.9	A B C D E F G
Taste Acceptable	4.4	2.6	A B C D E F G
Hard	3.9	6.3	A B C D E F G
Cohesive	3.6	0.4	A B C D E F G
Chewy	4.3	5.2	A B C D E F G
Texture Acceptable	3.6	1.5	A B C D E F G
After Taste Objectionable	5.5	0.9	A B C D E F G
Sample Acceptable	4.1	2.8	A B C D E F G

Curing System A - 3°C, 15% R.H.
Parching Systems - A - 3 - 65°C
B - 4 - 79°C
C - 5 - 93°C
D - 6 - 107°C
E - 7 - 121°C
F - 8 - 135°C
G - 9 - 149°C

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 18. Comparison of Acceptability Score of Shallow Lake Rice Processed by Systems B and 1.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	3.1	18.6	A B C E D
Dark Brown	5.9	3.8	A B C D E
Split	2.2	7.3	A B C D E
Mushy	3.9	2.4	A B C D E
Appearance Acceptable	3.2	0.5	A B C D E
Grainy (odor)	4.3	1.2	A B C D E
Swampy	1.9	1.8	A B C D E
Toasted	2.8	0.8	A B C D E
Aroma Acceptable	2.7	1.4	A B C D E
Burnt	1.8	1.1	A B C D E
Moldy	1.9	1.9	A B C D E
Grainy (taste)	3.4	0.6	A B C D E
Earthy	2.3	1.1	A B C D E
Bitter	1.9	0.5	A B C D E
Sweet	2.4	0.5	A B C D E
Taste Acceptable	3.1	2.6	A B C D E
Hard	4.1	13.5	A B C D E
Cohesive	3.2	0.1	A B C D E
Chewy	4.4	10.4	A D C B E
Texture Acceptable	3.4	0.9	A B C D E
After Taste Objectionable	5.7	4.6	B A C D E
Sample Acceptable	3.5	3.3	A B C D E

Curing System B - 5°C, 95% R.H.
Parching - 1 - Low Temperature (79°C)
Experimental Mean 1 - Extremely Acceptable
7 - Extremely Unacceptable

Storage Time in weeks - A - 0
B - 1
C - 3
D - 5
E - 7

APPENDIX 19. Comparison of Acceptability Score of Shallow Lake Rice Processed by Systems B and 2.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	3.3	17.1	A B C D
Dark Brown	6.4	2.2	A B C D
Split	2.2	1.5	A B C D
Mushy	5.2	31.2	A B C D
Appearance Acceptable	2.8	2.5	A B C D
Grainy (odor)	4.0	0.1	A B C D
Swampy	1.7	0.5	A B C D
Toasted	4.2	5.5	A B C D
Aroma Acceptable	2.7	1.8	A B C D
Burnt	2.3	2.2	A B C D
Moldy	1.9	0.7	A B C D
Grainy (taste)	3.5	3.4	B A C D
Earthy	1.7	0.5	A B C D
Bitter	1.9	0.9	A B C D
Sweet	2.2	1.2	A B C D
Texture Acceptable	2.7	1.8	A B C D
Hard	4.6	8.8	A B C D
Cohesive	3.5	1.2	A B C D
Chewy	4.7	9.8	A B C D
Texture Acceptable	3.6	0.1	
After Taste Objectionable	5.9	0.1	A B C D
Sample Acceptable	3.2	0.9	A B C D

Curing System B - 5°C, 15% R.H.
Parching System 2 - High Temperature (135°C)
Experimental Mean 1 - Extremely Acceptable
7 - Extremely Unacceptable

Storage Time in weeks - A - 1
B - 3
C - 5
D - 7

APPENDIX 20. Comparison of Acceptability Score of Paddy Rice Processed by Systems B and 1.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	3.0	6.8	A B C D E
Dark Brown	3.6	10.1	A B C D E
Split	3.3	1.5	A B C D E
Mushy	5.1	4.1	A B C D E
Appearance Acceptable	3.7	2.4	A B C D E
Grainy (odor)	3.8	1.7	A B C D E
Swampy	3.0	5.8	A B C D E
Toasted	3.2	5.9	A B C D E
Aroma Acceptable	3.9	2.8	A B C D E
Burnt	2.7	3.2	A B C D E
Moldy	2.5	1.1	A B C D E
Grainy (taste)	3.6	0.4	A B C D E
Earthy	2.2	1.4	A B C D E
Bitter	2.6	1.2	A B C D E
Sweet	2.1	0.3	A B C D E
Taste Acceptable	4.1	0.9	A B C D E
Hard	4.3	2.4	A B C D E
Cohesive	3.4	2.3	A B C D E
Chewy	4.9	0.3	A B C D E
Texture Acceptable	3.4	0.3	A B C D E
After Taste Objectionable	5.0	0.8	A B C D E
Sample Acceptable	4.1	1.7	A B C D E

Curing System B - 5°C, 95% R.H.
Parching System 1 - Low Temperature (79°C)
Experimental Mean 1 - Extremely Acceptable
7 - Extremely Unacceptable

Storage Time in weeks - A - 0
B - 1
C - 3
D - 5
E - 7

APPENDIX 21. Comparison of Acceptability Score of Paddy Rice Processed by Systems B and 2.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	3.7	17.8	A B C D E
Dark Brown	4.7	5.0	A B C D E
Split	3.3	0.9	A B C D E
Mushy	4.5	2.5	A B C D E
Appearance Acceptable	3.8	3.5	B A C D E
Grainy (odor)	3.2	3.4	B A C D E
Swampy	2.9	1.9	A B C D E
Toasted	3.7	11.4	A B C D E
Aroma Acceptable	4.2	3.7	B D C A E
Burnt	3.1	13.1	A B C D E
Moldy	2.7	6.7	A B D C E
Grainy (taste)	3.0	0.7	A B C D E
Earthy	2.6	1.7	A B C D E
Bitter	3.4	3.1	A B C D E
Sweet	2.0	1.4	A B C D E
Taste Acceptable	4.8	2.7	A B C D E
Hard	4.5	11.2	A B C D E
Cohesive	3.3	0.8	A B C D E
Chewy	4.6	6.7	A B C D E
Texture Acceptable	6.2	1.1	A B C D E
After Taste Objectionable	4.8	1.8	A B C D E
Sample Acceptable	5.0	7.3	A B C D E

Curing System B - 5°C, 95 % R.H.
Parching System 2 - High Temperature (135°C)
Experimental Mean 1 - Extremely Acceptable
7 - Extremely Unacceptable

Storage Time in weeks - A - 0
B - 1
C - 3
D - 5
E - 7

APPENDIX 22. Comparison of Acceptability Score of Shallow Lake Rice Processed by Systems C and 1.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	2.3	1.4	A B
Dark Brown	5.8	0.9	A B
Split	1.9	2.1	A B
Mushy	4.6	1.9	A B
Appearance Acceptable	3.1	0.5	A B
Grainy (odor)	4.3	2.6	A B
Swampy	5.2	5.3	A B
Toasted	2.1	2.8	A B
Aroma Acceptable	4.7	5.1	A B
Burnt	2.0	2.4	A B
Moldy	3.9	4.2	A B
Grainy (taste)	3.6	1.3	A B
Earthy	2.9	0.6	A B
Bitter	3.1	0.9	A B
Sweet	1.8	0.7	A B
Taste Acceptable	5.3	4.8	A B
Hard	3.8	1.3	A B
Cohesive	4.0	0.9	A B
Chewy	4.2	1.8	A B
Texture Acceptable	4.1	0.7	A B
After Taste Objectionable	2.8	4.8	A B
Sample Acceptable	5.7	4.2	A B

Curing System C - 38°C, 95% R.H.
Parching System 1 - Low Temperature (79°C)
Experimental Mean 1 - Extremely Acceptable
7 - Extremely Unacceptable

Storage Time in days - A - 2
B - 6

APPENDIX 23. Comparison of Acceptability Score of Paddy Rice Processed by Systems C and 1.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	2.5	1.8	A B
Dark Brown	3.0	4.2	A B
Split	3.2	2.8	A B
Mushy	4.5	2.6	A B
Appearance Acceptable	3.6	0.3	A B
Grainy (odor)	3.4	2.3	A B
Swampy	4.0	4.8	A B
Toasted	2.4	2.9	A B
Aroma Acceptable	5.2	4.1	A B
Burnt	1.7	3.4	A B
Moldy	3.6	2.5	A B
Grainy (taste)	2.9	1.4	A B
Earthy	2.8	0.3	A B
Bitter	3.2	0.9	A B
Sweet	2.3	1.0	A B
Taste Acceptable	5.0	4.3	A B
Hard	3.8	1.8	A B
Cohesive	3.4	1.3	A B
Chewy	4.1	1.3	A B
Texture Acceptable	3.5	0.4	A B
After Taste Objectionable	4.2	4.5	A B
Sample Acceptable	5.2	3.6	A B

Curing System C - 38°C, 95% R.H.
Parching System 1 - Low Temperature (79°C)
Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

Storage Time in days - A - 2
B - 6

APPENDIX 24. Comparison of Acceptability Score of Eileen Lake Rice Cured by System D.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	4.3	22.5	A B C D E F G
Dark Brown	4.2	9.5	A B C D E F G
Split	1.8	3.4	A B C D E F G
Mushy	3.9	8.7	A B C D E F G
Appearance Acceptable	4.3	6.6	A B C D E F G
Grainy (odor)	3.5	0.8	A B C D E F G
Swampy	1.9	1.3	A B C D E F G
Toasted	3.6	9.7	A B C D E F G
Aroma Acceptable	3.9	3.9	A B C D E F G
Burnt	3.1	16.5	A B C D E F G
Moldy	2.1	1.3	A B C D E F G
Grainy (taste)	3.5	0.6	A B C D E F G
Earthy	2.1	1.4	A B C D E F G
Bitter	3.1	3.8	A B C D E F G
Sweet	1.8	0.7	A B C D E F G
Taste Acceptable	4.6	1.9	A B C D E F G
Hard	3.1	9.2	A B C D E F G
Cohesive	3.6	0.8	A B C D E F G
Chewy	3.6	9.3	A B C D E F G
Texture Acceptable	4.0	2.6	A B C D E F G
After Taste Objectionable	4.7	2.6	A B C D E F G
Sample Acceptable	4.7	6.6	A B C D E F G

Curing System D - 15°C, 95% R.H.
Parching Systems A - 3 - 65°C
B - 4 - 79°C
C - 5 - 93°C
D - 6 - 107°C
E - 7 - 121°C
F - 8 - 135°C
G - 9 - 149°C

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 25. Comparison of Acceptability Score of Shallow Lake Rice Cured by System D.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	3.3	33.4	A B C D E F G
Dark Brown	5.7	0.8	A B C D E F G
Split	1.8	2.6	A B C D E F G
Mushy	4.5	2.0	A B C D E F G
Appearance Acceptable	3.4	4.3	A B C D E F G
Grainy (odor)	4.2	0.8	A B C D E F G
Swampy	2.4	1.3	A B C D E F G
Toasted	3.2	10.9	A B C D E F G
Aroma Acceptable	3.5	1.5	A B C D E F G
Burnt	2.7	12.3	A B C D E F G
Moldy	2.5	1.9	A B C D E F G
Grainy (taste)	3.2	2.1	A B C D E F G
Earthy	2.7	0.8	A B C D E F G
Bitter	3.0	2.1	A B C D E F G
Sweet	1.9	0.6	A B C D E F G
Taste Acceptable	4.3	4.7	A B C D E F G
Hard	3.6	4.5	A B C D E F G
Cohesive	3.8	0.7	A B C D E F G
Chewy	4.1	3.5	A B C D E F G
Texture Acceptable	3.7	2.5	A B C D E F G
After Taste Objectionable	5.5	1.1	A B C D E F G
Sample Acceptable	4.1	3.2	A B C D E F G

Curing System D - 15°C, 95% R.H.
Parching System - A - 3 - 65°C
B - 4 - 79°C
C - 5 - 93°C
D - 6 - 107°C
E - 7 - 121°C
F - 8 - 135°C
G - 9 - 149°C

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 26. Comparison of Acceptability Score of Wild Rice Processed by Systems D and 1.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	2.7	3.2	A B C
Dark Brown	3.6	12.9	A B C
Split	2.3	1.5	A B C
Mushy	4.3	0.9	A B C
Appearance Acceptable	3.8	1.2	A B C
Grainy (odor)	2.1	2.6	A B C
Swampy	5.0	14.5	A B C
Toasted	1.3	0.3	A B C
Aroma Acceptable	5.0	4.2	A B C
Burnt	1.6	0.7	A B C
Moldy	4.7	13.8	A B C
Grainy (taste)	2.2	2.6	A B C
Earthy	3.3	0.8	A B C
Bitter	3.7	1.1	A B C
Sweet	2.0	0.5	A B C
Taste Acceptable	5.6	4.7	A B C
Hard	4.0	1.9	A B C
Cohesive	3.9	0.8	A B C
Chewy	4.2	0.7	A B C
Texture Acceptable	3.6	1.0	A B C
After Taste Objectionable	2.3	2.8	A B C
Sample Acceptable	5.5	4.3	A B C

Curing System D - 15°C, 95% R.H.
Parching System - 1 - Low Temperature (79°C)
Experimental Means - 1 - Extremely Acceptable
7 - Extremely Unacceptable

A - Harrop
B - La Ronge
C - Paddy

APPENDIX 27. Comparison of Acceptability Score of Wild Rice Processed by Systems D and 2.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test
Straight	2.8	1.2	A B C
Dark Brown	4.2	3.7	A B C
Split	2.5	0.9	A B C
Mushy	4.3	4.5	A B C
Appearance Acceptable	3.3	1.1	A B C
Grainy (odor)	3.5	0.8	A B C
Swampy	4.5	1.2	A B C
Toasted	2.8	1.0	A B C
Aroma Acceptable	4.8	1.7	A B C
Burnt	2.2	0.5	A B C
Moldy	4.3	14.8	A B C
Grainy (taste)	3.0	1.2	A B C
Earthy	3.3	6.9	A B C
Bitter	3.3	4.3	A B C
Sweet	1.9	0.3	A B C
Taste Acceptable	4.8	3.9	A B C
Hard	4.2	0.9	A B C
Cohesive	3.4	1.5	A B C
Chewy	4.1	1.0	A B C
Texture Acceptable	4.0	0.5	A B C
After Taste Objectionable	3.4	1.9	A B C
Sample Acceptable	5.8	2.3	A B C

Curing System D - 15°C, 95% R.H.
Parching Temperature System 2 - High Temperature (135°C)
Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

A - Harrop
B - La Ronge
C - Paddy

APPENDIX 28. Comparison of Acceptability Score of Crowduck Lake Rice Processed by System E, F, and 6.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test 55% R.H.	Duncan's Multiple Range Test 75% R.H.
Straight	2.6	4.6	A B C	B A C
Dark Brown	5.1	0.9	A B C	A B C
Split	1.9	1.2	A B C	A B C
Mushy	4.2	2.7	A B C	A B C
Appearance Acceptable	2.7	3.0	A B C	A B C
Grainy (odor)	3.8	0.8	A B C	A B C
Swampy	2.2	0.8	A B C	A B C
Toasted	2.1	0.3	A B C	A B C
Aroma Acceptable	2.7	1.0	A B C	A B C
Burnt	1.7	1.5	A B C	A B C
Moldy	2.2	1.8	A B C	A B C
Grainy (taste)	3.3	0.7	A B C	A B C
Earthy	2.0	1.0	A B C	A B C
Bitter	2.2	1.0	A B C	A B C
Sweet	2.9	1.2	A B C	A B C
Taste Acceptable	3.0	0.8	A B C	A B C
Hard	3.3	1.5	A B C	A B C
Cohesive	3.4	1.3	A B C	A B C
Chewy	4.0	1.2	A B C	A B C
Texture Acceptable	3.0	0.7	A B C	A B C
After Taste Objectionable	5.8	0.7	A B C	A B C
Sample Acceptable	2.9	2.0	A B C	A B C

Curing System E - 10°C, 75% R.H.
Curing System F - 10°C, 55% R.H.
Parching System 6 - (107°C)

Storage Time in weeks - A - 1
B - 3
C - 4

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 29. Comparison of Acceptability Score of 75 Paddy Rice Processed by Systems E, F and 6.

Characteristics	Experimental Mean	F. Value	Duncan's Multiple Range Test 55% R.H.	Duncan's Multiple Range Test 75% R.H.
Straight	3.1	0.4	A B C	A B C
Dark Brown	3.6	1.8	A B C	A B C
Split	2.4	2.3	A B C	A B C
Mushy	4.3	2.8	A B C	A B C
Appearance Acceptable	3.7	0.5	A B C	A B C
Grainy (odor)	3.3	0.4	A B C	A B C
Swampy	3.0	3.2	A B C	A B C
Toasted	1.9	1.5	A B C	A B C
Aroma Acceptable	3.5	6.7	A B C	A B C
Burnt	1.6	0.6	A B C	A B C
Moldy	2.9	6.4	A B C	A B C
Grainy (taste)	2.8	0.4	A B C	A B C
Earthy	2.3	1.1	A B C	A B C
Bitter	2.0	2.0	A B C	A B C
Sweet	2.2	0.2	A B C	A B C
Taste Acceptable	3.4	4.1	B A C	B A C
Hard	3.8	1.2	A B C	A B C
Cohesive	3.3	0.9	A B C	A B C
Chewy	4.2	0.8	A B C	A B C
Texture Acceptable	3.7	3.8	A B C	A B C
After Taste Objectionable	4.9	4.9	A B C	A B C
Sample Acceptable	3.8	2.1	A B C	A B C

Curing System E - 10°C, 75% R.H.
Curing System F - 10°C, 55% R.H.
Parching System 6 - (107°C)

Storage Time in weeks - A - 1
B - 3
C - 4

Experimental Mean - 1 - Extremely Acceptable
7 - Extremely Unacceptable

APPENDIX 30. Wild Rice Selection by Color Preference
(Samples Selected as First Choice on the Basis of Color)

Rice Type	Number of Respondents	Percent
Shallow Lake	45	64.3
Harrop Lake	17	24.3
Lac La Ronge	6	8.6
Paddy	2	2.8
	70	100.0

Note: Rice color in descending order of darkness was Shallow Lake, Harrop Lake, Lac La Ronge and Paddy.

APPENDIX 31. Wild Rice Selection by Size Preference

Rice Type	Average Length of Kernels in cm.	Number of Respondents	Percent
Lac La Ronge	2.5	29	41.4
Shallow Lake	2.0	23	32.9
Harrop Lake	1.5	15	21.4
Paddy	1.0	3	4.3
		70	100.0

N.B. Diameter (width) of rice kernels approximately 0.2 cm.

APPENDIX 32. Characteristics of Respondents (2)

Characteristics	Number of Persons per Household					
	(1 - 2)		(3 - 4)		(5 - 7)	
	Number	Percent	Number	Percent	Number	Percent
Professionals	5	41.7	28	68.3	13	76.5
White Collar	4	33.3	6	14.6	4	23.5
Blue Collar	1	8.3	5	21.2	-	-
Student	2	16.7	2	5.9	-	-
Totals	12	100.0	41	100.00	17	100.00

Characteristics	Number of Times Wild Rice is Served at Home							
	Once/month		Once/year		2-3 times/year		More than 4 times/year	
	No.	%	No.	%	No.	%	No.	%
Professionals	7	70	8	80	14	53.8	16	66.7
White Collar	3	30	2	20	7	26.9	3	12.5
Blue Collar	-	-	-	-	3	11.5	3	12.5
Student	-	-	-	-	2	7.8	2	8.3
Totals	10	100.0	10	100.0	26	100.0	24	100.0

Number of Times Wild Rice is Served at Home	Number of Persons per Household					
	(1 - 2)		(3 - 4)		(5 - 7)	
	No.	%	No.	%	No.	%
Once/month	2	16.7	4	9.8	5	29.4
Once/year	2	16.7	4	9.8	3	17.7
2-3 Times/year	3	25.0	18	43.9	5	29.4
>4 Times/year	5	41.6	15	36.5	4	23.5
Totals	12	100.0	41	100.0	17	100.0