THE UNIVERSITY OF MANITOBA

THE PROCESSING SYSTEMS OF MANITOBA LAKE AND PADDY WILD RICE

BY

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The Processing Systems of Manitoba Lake and Paddy Wild Rice.

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TO MY PARENTS

ABSTRACT

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Colour, flavour, percent breakage and cleanliness are the main criteria for judging the quality of finished wild rice. The present study is an attempt to investigate some of the problems in the wild rice industry today. The study was designed to evaluate the optimum processing system for Manitoba lake and paddy wild rice. Results indicated that good quality wild rice was obtained when low temperature curing and parching processing were used. In addition, the hulling study indicated that extended curing periods and hulling after storage would increase the breakage of the rice. Above all, the percent yield can be maximized if the processing system is carefully controlled. The flavour characteristics of wild rice were also investigated in this study, and 24 sensory characteristics were identified. Specific sensory characteristics such as swampy odour, mouldy and strong, earthy taste and mushy texture were noted to be the main factors which contribute to unacceptability of finished wild rice.

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I. INTRODUCTION

Wild rice is an aquatic cereal, native to North America. The species common to Manitoba are annual pollinated grasses. This rice has been used by Indian Tibes of the tall grass prairie region as a staple food for over 300 years. Paddy production of wild rice was not started until the white man decided to expand the wild rice industry in the mid-1960's. Since then, the production of paddy rice has increased to two or three times that of the lake wild rice. Wild rice, including its several varieties has an extensive distribution in eastern North America, reaching from the northern end of Lake Winnipeg eastward along the northern shores of the Great Lakes and the St. Lawrence river to eastern New Brunswick, from the central Dakotas, western Nebraska and eastern Texas, to the Atlantic Ocean, and along the coast as far as central Florida (34,33). Among these areas, Minnesota, Manitoba, Wisconsin and Northern-Western Ontario are estimated to have the highest production.

Wild rice is a nutritious food when compared to the other cereal products. Wild rice is relatively high in protein and low in fat content (33). The first recorded analysis of wild rice was made in 1862 by Peters (6,29) who reported that the seed contained 6.71 percent of protein, and was made up of 12 percent hulls and 88 percent hull free kernels. Woll, in 1899 (6,37) stated that wild rice was richer in both protein and nitrogen-free extract than other cereals and hence should have a higher food value. The protein content of the wild rice sample studied by Woll averaged about twice that reported by Peters. Kennedy, in 1929 (20) showed that wild rice resembled other grains by the fact that it was relatively rich in vitamin B and relatively deficient in vitamin A and some other minerals. In 1942, Nelson and Palmer, (28) further showed that parched rice could be regarded as a good source of thiamine, riboflavin and nicotinic acid. Recent studies (15,12) showed that 100 grams of raw wild rice contained 353 calories, 6.2 mg of niacin and 14.10 gm of protein.

At the present time, wild rice is no longer used as a staple food by the Indians, however, it still remains as a most important supplementary food and a source of much needed income for them. The price of the rice has been raised from 10 cents a pound before the First World War to approximately $6.00 per pound in 1972 (36). Due to the high cost, not many people can afford to consume the rice. In spite of this, the white man has introduced about 45 recipes for the preparation of wild rice, ranging from game-bird stuffings to tempting desserts (33). The common way to prepare wild rice is by cooking it in boiling water until the rice becomes tender.

In the wild rice industry today, quality standards have not been established for the finished product. Wild rice that appears on the markets usually has a poor appearance, lacks proper colour and is without a standard grading size.

The present study examines the different methods of wild rice processing and has the following purposes: (a) To evaluate the different methods of wild rice processing by using different periods of time and temperatures. (b) To determine which method will improve the overall quality of the finished wild rice. (c) To study the effect of curing and parching on the yield and ease of hulling of wild rice. (d) To characterize the flavour of finished wild rice.

II. LITERATURE REVIEW

Carr (6,9), in 1895 reported that wild rice served the Indian both as food and revenue; hence was of great importance to the various tribes of the Great Lakes region. Although the Indian had started to process wild rice many years ago, there was no literature written about their skill of practice and the economic importance of wild rice production. The earliest literature and records indicated that extensive harvesting of wild rice has been carried on for only three to five hundred years (33). This source of information was based on the culture of some Indian tribes. When white man migrated to the wild rice regions around the mid-18th century, records revealed that he had to depend upon this crop as a staple and winter food. Before the 20th century, the Indians harvested the rice, hand processed the crop and sold the finished rice to the white man. However, since the turn of the century, the white man has started to harvest and process wild rice.

An increased demand for the product since World War I has placed a much higher requirement on production. Mechanical harvesting methods and semi-mechanical processing methods were introduced. There has been a greatly increased production of wild rice in the past two decades especially after the wild rice industry was modernized by utilizing paddy production. The first true commercial paddies were developed in Minnesota in 1964, and since then, the paddy development expanded rapidly into Wisconsin, Manitoba, and some areas in Ontario, Saskatchewan, Alberta and Michigan. Paddies are usually built in those regions where wild rice grows naturally. After ten years of paddy production, problems such as lateness of maturity, susceptibility to helminthosporium disease and uniformity of type and non-shattering of seed are still troublesome for the growing of paddy wild rice (5).

2.1. Methods of wild rice processing.

Harvesting of wild rice usually takes place in late August and can be done either by hand or by machines. Two or three gatherings are made during the harvesting season, extending over a period of 15-20 days. After harvesting the wild rice has to be processed before it becomes a marketable product. The purposes of processing wild rice are to change the overall quality and yield of the rice as well as to allow the final product to have a longer storage life.

All methods of wild rice processing include the following steps:

(a) Curing: A stage in which the immature grains are allowed to pass into a riper stage of maturity. Many soft grains become firm accompanied with the development of a darker colour (14) and product flavour is enhanced. The degradation of hulls through curing will facilitate hull removal in the later stage of the process (13). During the curing period, the rice kernels not only change their colour but also become less fragile (35). Curing can be done by spreading the rice on the floor in open air or by storing it in a controlled atmosphere. The former one is called natural curing and the latter one is called controlled curing.

(b) Parching: In this second stage of the process, all the chemical, physical and biological changes that have been taking place in the rice during the curing procedure will be stopped by this drying process. The purpose of parching is to lower the moisture content of the rice to an acceptable level which is between 7%-10% moisture content. This level of moisture content will help the rice to have a longer shelf life and a higher hulling efficiency. Like curing, parching will also effect the fragility and flavour of the product (13).

(c) Hulling and cleaning: Hulling is a process that separates the outer hull from the hard rice kernel. After parching, the kernels are firm and hard and lie loosely within their dry and brittle hulls. It is the rubbing and beating action that separates the hulls from the hard kernels. Different machines have been designed to hull rice and they all follow the same principle. During this process, breakage and scarification will occur in the rice. Care must be maintained when operating the hullers, because breakage of rice will cause a lower yield of head rice (whole rice) and scarification of rice will change the cooking characteristics of the rice (35). The hulling and cleaning process takes place at the same stage. Once the hulls are separated from the rice kernels, a counter-current air stream blows the hulls off into a collecting pan.

2.1.1. Old methods of wild rice processing.

In the past, harvesting and processing of wild rice were done by the Indians. Their methods of processing were simple, primitive but practical. No mechanical method was involved. During the curing process, the freshly harvested grains were allowed to dry under the sun. In some Indian tribes, curing was done by means of small fires (6,18). After this process, the dry grains were kept until it was convenient to do the parching. When parching, a small amount of rice was put into a copper or iron kettle over a small fire and heated rather strongly for 15 minutes to half an hour until the hulls became dry and brittle. The rice was stirred from time to time with a wooden paddle so as to prevent any rice being overheated. The rice was allowed to cool after parching.

It was then placed in shallow holes lined with clay and with animal skins around the side to serve as a mortar. A man who acted as the pestle would stand on the rice and tread the rice by a rhythmic movement of his whole body coupled with shuffling of the feet. This action caused the rice to rub against one another and the husks were then rubbed off (34). Different Indian tribes used different processing methods. However, the idea was the same.

2.1.2. Current methods of wild rice processing in Manitoba.

In the present wild rice industry, the techniques of wild rice processing are highly varied. Each processor has developed his own technique and designs his own equipment for the process. In Manitoba, the equipment used by the different processors are similar. Harvesting of wild rice is mostly done by the Indians from a nearby reserve. In certain areas of Manitoba such as Lac du Bois, machines have been constructed to do the harvesting (14). The freshly harvested wild rice is packed in cloth bags and transported to processing plants for immediate processing (Figure 1). Curing of wild rice takes place in open air. The green rice is spread out on the ground piling up to a height of about one to one and a half feet. Some processing plants even pile up the rice to a height of about three feet so as to accelerate the curing process. During curing, the rice is turned over or stirred at least once a day and water is added to the rice frequently. The purpose of doing this is to prevent any heat accumulation in the rice bed. The temperature of the rice bed usually ranges between 37.7 C to 48.8 C depending upon the bed depth. The rice is then kept under natural conditions for a certain period of time until the rice turns to a darker colour.

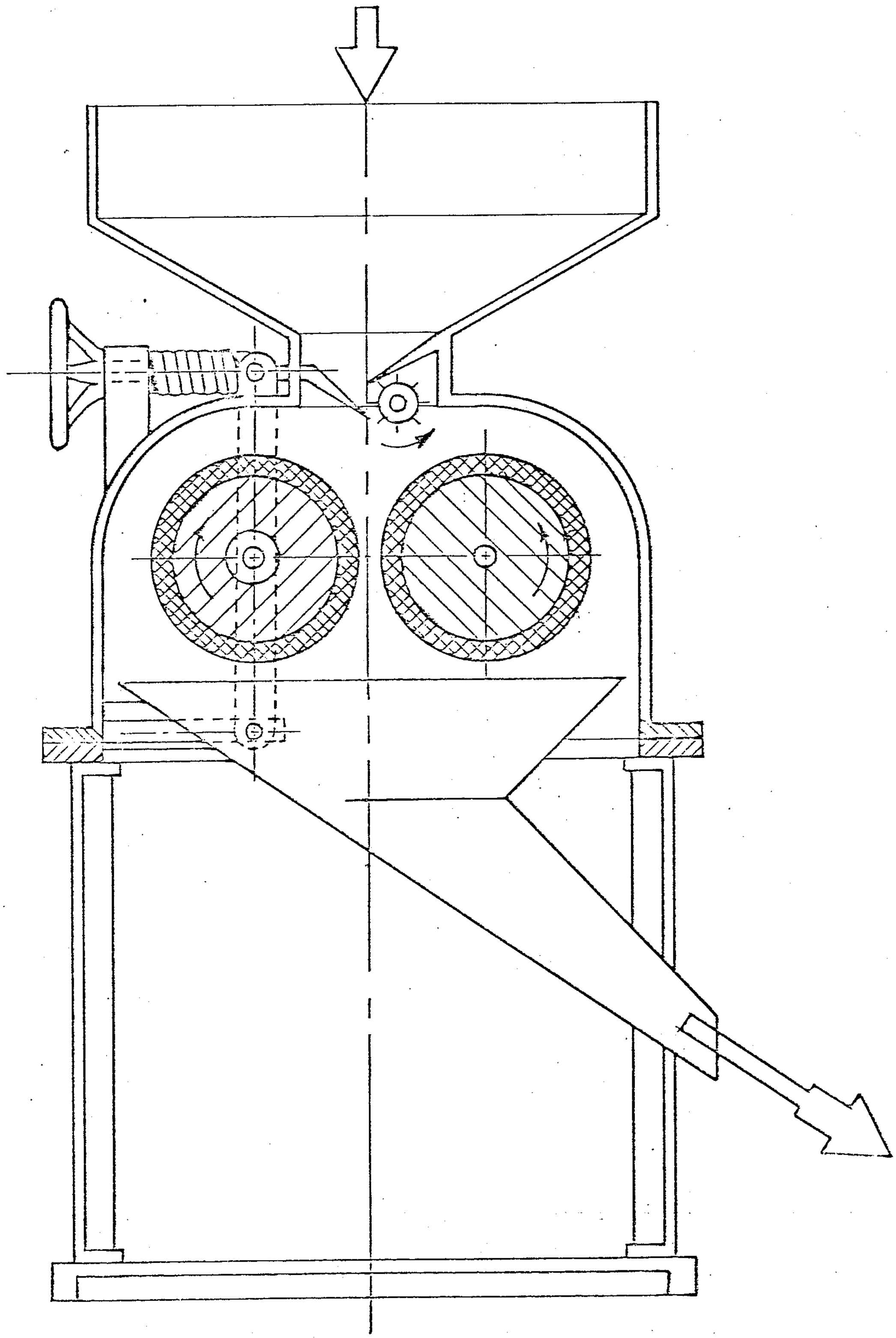
Figure 1. A Flow Diagram on Wild Rice Processing

Harvesting → Washing → Curing → Parching → Hulling → Cleaning → Packaging

After curing, the rice is parched in ovens which are cylindrical in structure. Gas heating is applied from below. The oven rotates during parching to provide agitation of rice so that certain portions of the rice will not be overheated. Upon completion of drying a conveyor belt carries the parched rice from the oven to the huller. The huller is also a cylindrical container mounted in a stationary position and the axle of the huller to which flails covered with pieces of rubber hose are attached, is rotated by motor power (14). The speed of the flails is carefully adjusted, so that breakage of the kernels caused by hulling can be minimized. The beating action of the flails on the rice and the rubbing action between the rice causes the hulls to be separated from the hard kernels.

Another type of huller, which is not currently used in Manitoba, is the Kyowa huller (Figure 2). This huller is manufactured in Japan and is designed for hulling white rice (31). In 1971, this huller was effectively adapted to the wild rice industry (30). Referring to Figure 2, dried rice gravity-feeds down between rubber surfaced rollers which turn in opposite directions and at different speeds. The pressure between the two rollers is regulated by a pneumatic cylinder and can be varied. This is one advantage for using this huller, because different varieties of rice require different shelling pressures. The efficiency of the huller is about 92% (31).

After hulling, the rice is cleaned and size graded by the normal seed-cleaning operations adapted from the grain industry. The average yield for Manitoba wild rice is 40%-45%. This percentage indicates that 40-45 lbs. of finished wild rice is obtained from 100 lbs. of green rice. The average for paddy wild rice is 10-20%. Although the present methods of wild rice processing are accepted commercially, some



KYOWA HULLER

FIGURE 2

ADDAPTED FROM RICE CHEMISTRY AND
TECHNOLOGY

improvements in both the equipment and techniques are required if production and quality of wild rice are to be improved.

2.2 Laboratory research on wild rice processing.

Since the mid-1960, people have paid more attention to the quality of finished wild rice than ever before. Workers from various Universities have recently started research on wild rice processing and have tried to establish a standard processing method to improve the quality of the final product. The expectation is to produce a uniform final product which will satisfy the consumer demand. The University of Wisconsin started the research on wild rice processing in 1969. The specific goal of their research was to provide a better economic base for the people of the wild rice region through a sound product, processing and marketing program (35). Their program is still continuing.

2.2.1. Curing studies

The University of Wisconsin team initiated studies on the curing of wild rice. They tested three systems, namely, the dry, wet and cooler methods (35). Wooden bins were used to store the rice during curing. Their results indicated that the wet method showed a small increase in yield during curing, while the yield for the dry and cooler methods remained constant except for a slight decrease in the fifth week. Extended curing for all treatments resulted in decreased yield. This was due to excessive slimy formation which led to caking of the rice on the surface of the parcher and resulted in kernel damage through scorching and popping. In addition, respiration of the rice, microbial degradation and kernel fragility contributed to the loss.

After three years' study on curing, they found that the dry method and non-turning of wild rice during curing could not be recommended because of the development of an excessive amount of mold and kernel damage which occurred during extended storage. This led to severe off-flavour and a potential mold-toxin health hazard in the finished product. The wet and cooler methods produced acceptable finished rice. An exception was noted for paddy-raised non-shattering wild rice which developed an excessive amount of slime during the ambient wet method of curing. It was suggested that the use of cooler methods (50^{o} F, 10^{o} C) for curing was beneficial in slowing down the rate of microbial action. This delayed the onset of kernel degradation and thereby extended the optimum processing time for wild rice. They further pointed out that microbial action began to degrade the protective hull after a period of time. This depended on the temperature and moisture content of the fermenting pile. Rapid degradation occurred at a high temperature and moisture. The partially degraded hulls became easier to remove during hulling, thus increasing yields by reducing kernel breakage in the huller. As curing progressed a point was reached where the microbes actually began to penetrate and to degrade the kernels themselves. This caused the kernels to become more fragile, and resulted in easily broken and pulverized kernels during hulling. The net result was a decrease in yield (35).

In 1972, they started using a controlled environment chamber for the curing of wild rice (13). This was an attempt to control the temperature and relative humidity of the environment through-out the entire period of curing. Metal bins were used to hold the wild rice for curing. Ambient temperature (cycled between 10^{o} C and 27^{o} C) and cooler temperature (10^{o} C) were used along with a constant relative humidity of 95% (13). Data showed that the yield of wild rice cured at ambient conditions decreased progressively through the five weeks' curing while the yield of the cooler stored sample remained relatively constant for the first two weeks and then progressively decreased. Their yield data appeared to be in agreement with years past. However, a difference in pile temperature was observed between the two studies. A relatively higher pile temperature was recorded in the curing studies of 1970 and 1971 while, in 1972's curing study, a relatively lower pile temperature was observed. The reasons were due to the immaturity of the 1972 rice and improved aeration of the 1972 rice during curing. Other changes such as colour and odour were observed in the curing rice (13). Lake rice was darker initially than paddy rice and continued to develop darker kernels much faster than paddy rice. Swampy odours were detected during the later stages of the curing process.

The main objective of the 1973 study at Wisconsin was to evaluate the different techniques that could be used to extend the curing time for wild rice (29). One important result was the report of botulism-type organisms on the rice pile cured under an anaerobic condition. Their results indicated that aeration was an important factor for curing. It did not only effect the pile temperature of wild rice but also the pH of the rice. Both temperature and pH affected the type of micro-organisms found on the rice.

Kernel fragility is one of the main factors that effect the quality of wild rice. It was found that the length of the curing time did not markedly affect this factor. Freezing treatment before curing, however, increased kernel fragility (29). This was due to stress development during rapid freezing.

The Wisconsin study demonstrated that the temperature used in the curing process and the length of time that rice is held in curing storage will affect the yield of finished rice. Their data indicated that the percentage yield of rice cured at a lower temperature will have its percentage yield decreased in a slower rate than rice cured at a higher temperature (29).

2.2.2. Parching studies

Parching studies on wild rice have been carried out at the University of Wisconsin since 1970. The purpose of their studies was not only concerned with how to dry the rice in the least possible time, but also with how to obtain the maximum whole rice yield after hulling (13). Their studies indicated that the design of the parchers, drying time and temperature effected the quality of the final product.

Wild rice was susceptible to popping and fragile kernels resulted if the rice was not agitated during parching. In addition, rice cured for an extended period of time was easily burnt if a temperature of 82.2^{o} C or above was used. Their data on wild rice texture indicated that scorched or burnt rice took up water faster during cooking. This change of cooking characteristics altered the texture of the cooked rice (13). Paddy rice was the most difficult among all the types of wild rice to parch. An advantage of parching, as reported by the researchers, was that it weakened the hulls of wild rice through scorching and thus promoted easier hulling (6).

Results of the 1972 studies demonstrated that the yield increased as drying time decreased (13). However, the high rate of drying was not considered a good method for practical purposes (4). The advantage in using this method was that it turned out a large volume of grain in a shorter period of time even when using a small holding capacity dryer (4).

Wisconsin workers further showed that, for slow drying, the yield was decreased because low temperatures were used (13). This low temperature was below gelatinization temperature (62^oC - 65^o C) (23) and consequently a more fragile kernel resulted. As a consequence most of the kernels cracked during hulling.

The height of the rice bed in the parching operation had an effect on the percentage yield of the rice (9). A stationary rice bed depth of six inches was recommended in order to prevent any yield loss (13). A study on drying of seeds by Nellist and Hughes (27) revealed that the use of excessive heat during the drying of seed would lead to internal cracks and discolouration of the product. Ban (4) also reported that sudden drying or high rate drying was the major cause of rice cracking.

2.2.3. Hulling studies

The percentage head rice is considered as a quality and economic factor of the finished rice. Head rice, as defined by the wild rice industry is the percent of whole and unbroken kernels in a sample (35). Most kernel breakages occurred during the hulling process. A portion of the breakages occurred due to improper operation of the machinery and the rest are a result of improper curing and parching. The different designs of hullers are believed to effect the percentage yield of head rice (35,13). In 1971, Matthews, Veal and Deobale (26) showed that the laboratory Mcgill huller broke slightly more rice than the commercial Kyowa huller.

In 1973 a laboratory model Kyowa huller was used in the University of Wisconsin to hull small samples of wild rice (29). Data indicated that 90-95% of hulls were removed in a single pass. This figure is an indication of huller performance. The huller performance is evaluated in terms of huller efficiency.

In addition to rice breakage, as reported by the Wisconsin workers, hulling also led to scarification of wild rice. These two factors subsequently effected the cooking characteristics of the product (13).

2.2.4. Evaluation of appearance, flavour and texture.

The many methods of wild rice processing give rise to final products with many variations in appearance, flavour and texture. Some of these variations are generally unacceptable. Therefore it is important to study how the different types of flavour develop throughout the process and how the process effects the appearance and texture of the product, in order to have controls on the process.

Sensory evaluation of wild rice was first started in 1970 (35) at the University of Wisconsin. The taste of wild rice was described at that time as bland, grassy, moldy, swampy, bitter, toasted, medicinal and starchy. More information was obtained from 1971's and 1972's study (13). Taste panel data showed patterns of wild rice flavour development. The ambient temperature curing yields full flavoured wild rice after one week and only limited moldy flavour developed after five weeks. The cooler temperature curing yielded a more consistent product with a less intense tea-like flavour. A slightly earthy flavour became apparent after two week's holding, and even after five week's holding the flavour was not highly pronounced. On the other hand, the tea-like and grainy flavour became less pronounced as curing progressed. Data also showed that parching process added toasted flavour to the product and this flavour was partly due to the slimy nature of the rice after extended curing time. This phenomenon is more likely to happen on paddy rice.

In addition to flavour evaluation, a study on appearance and textural qualities was also reported by the researchers at the University of Wisconsin (13). This study revealed that the time for the conversion of the greenish-black colour of the kernel to a brownish-black colour was one to two weeks for ambient curing conditions and three or four weeks for cooler conditions. The other appearance characteristics rice such as kernel breakage, splitness and curliness were mainly affected by the parching and hulling processes. The texture of wild rice did not appear to be affected by curing, unless severe mold damage to kernels occurred. In such cases the kernels took up water more rapidly and became split, soft and overcooked. Similar to the appearance character, the texture was mostly affected by the parching and hulling processes.

Paddy rice behaved similarily with lake rice in most of these characteristics except that a lack of flavour development was noted (13). This was due to the immature nature of the rice.

Further research on wild rice flavour was carried out in 1973 (30). Most of the data showed agreement with previous results except the development of a toasted flavour as mentioned before. Data showed that parching of wild rice did not contribute a toasted flavour to the wild rice. Moldy flavour was controlled by curing the rice at a lower temperature (4.4 C). A study on chemical treatment of wild rice showed that wild rice treated with chemical such as chlorine or sorbate before curing yielded a strong chemical and medicinal flavour which was highly undesirable (30).

2.3 Other factors that affect the process and the product qualities.

Colour, flavour and percentage breakage are the main criteria for judging the qualities of finished wild rice. These quality characters are not only affected by the different curing, parching and hulling techniques, but can also be affected by factors such as seed maturity, freezing of seeds before processing and moisture content.

2.3.1. Seed maturity.

Due to the fact that wild rice matures unevenly, part of the immature wild rice is harvested for processing. During the curing process, the immature wild rice does not undergo the same changes as mature wild rice, and this results in a great variety of quality in the final product (13,29). Capen and LeClerc in 1947 (6) showed that the immature seed was only slightly poorer in protein and was somewhat higher in sulfer than mature seed. They further reported that the mature wild rice was one-third heavier than the immature rice. A study on premature grains shows that immature grains reduces both yield and quality of the product and is low in starch content (24). In addition, immature kernels are subjected to easy breakage (25) and lack flavour (13). During the curing procedure, a higher pile temperature was recorded for mature wild rice and this enabled the rice to change its overall quality and immature rice did not appear to react the same (13).

2.3.2. Frozen storage before processing.

More than a century ago, Scharling observed that when starch pastes were frozen and thawed they form a spongelike mass (19). Current research by Jones (19) on white rice showed that freeze-processing structurally changed the final product. Further results indicated that freeze-processed rice was found to be more resistant to attack by the enzyme beta-amylase (19). Hustrulid (17), in his study on wheat drying, revealed that frozen storage had no effect on the drying process.

In 1970, it was reported from the University of Wisconsin, that laboratory holding of freezing green wild rice showed very few changes had occurred over a year's storage. However, the freezing-process might alter the microbial populations and subsequently affect the curing process (35). Further research in 1973 (13), had showed that freeze-processed wild rice was lower in yield and had a poor hulling efficiency. The product demonstrated excessive cracking and had white centers. However, this method of processing showed no effect on the flavour of the rice (30).

The literature review reveals the current knowledge on the commercial and laboratory wild rice processing. Unfortunately, information concerning the quality standard of wild rice is not available at the present time. As the popularity of wild rice increases, a grading system for the product is highly desirable. Food scientists at the University of Wisconsin have noted that, in the establishing of grades for the wild rice, it would be ideal if all descriptions could be in concrete and measurable terms (35). They have further suggested that when grading wild rice, factors such as kernel size, kernel damage, broken kernels, chalky kernels (opague centers) and colour are needed to be considered. However, even with modern day instruments, it is impossible to measure all quality factors in a positive or numerical value. More positive descriptions will be available in the future as more economical, precise quality measuring equipment are developed (35). The present study extends the knowledge on processing systems with specific emphasis on methods and materials.

III. METHODS AND MATERIALS

3.1. Experimental Design:

3.1.1. Introduction.

The Department obtained 1,000 pounds green lake rice and 300 pounds green paddy rice from the Indian Rice Producers co-op Limited in late August, 1973. This lot of wild rice was processed in early 1974 after 6 months storage at a temperature of -32^{o}F. In September, 1974, the Department purchased another 500 pounds of green lake rice from Eileen Lake and 500 pounds of green paddy rice from Sprague. This rice was processed immediately after harvesting. All wild rice either for frozen storage or for direct processing were thoroughly washed in order to remove sand, worms and plant debris. About 100 pounds of cured lake rice was purchased from Northland Wild Rice Company, Winnipeg, for preliminary studies on parching.

Two controlled environment cabinets with internal measurement of 5'6" x 7'6" x 8" high were purchased from P.M. Industries, Winnipeg, and were installed in the Department (Figures 3 + 4). A fan was designed for air exchange between the inside and the outside air. The air was changed at a rate of 1,270 c.f.m..

A two-burner Jabez Burns coffee roaster was purchased second hand from Clubhouse Coffee in Toronto for our parching studies. Each of the two units were capable of holding a maximum of one pound of rice. The units were heated with gas jets and rotated at a speed of 55 r.p.m. (Figure 5). The motor used to rotate the units was 1/6 h.p..

A single roller huller designed by a technician in the Department of Plant Science was used for hulling studies. The metal roller was covered with rubber (Figure 6). A 1/6 h.p. motor was used for turning

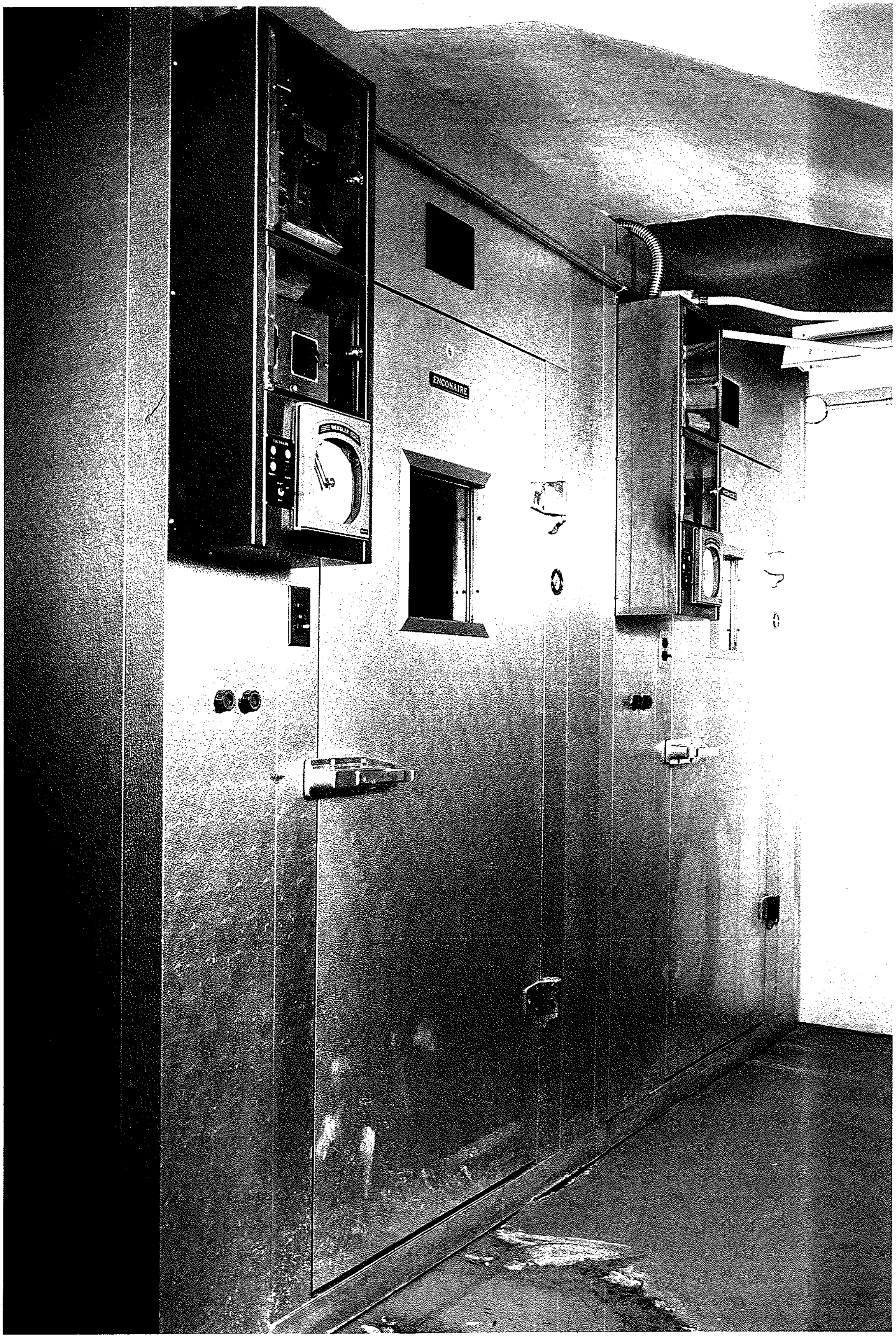
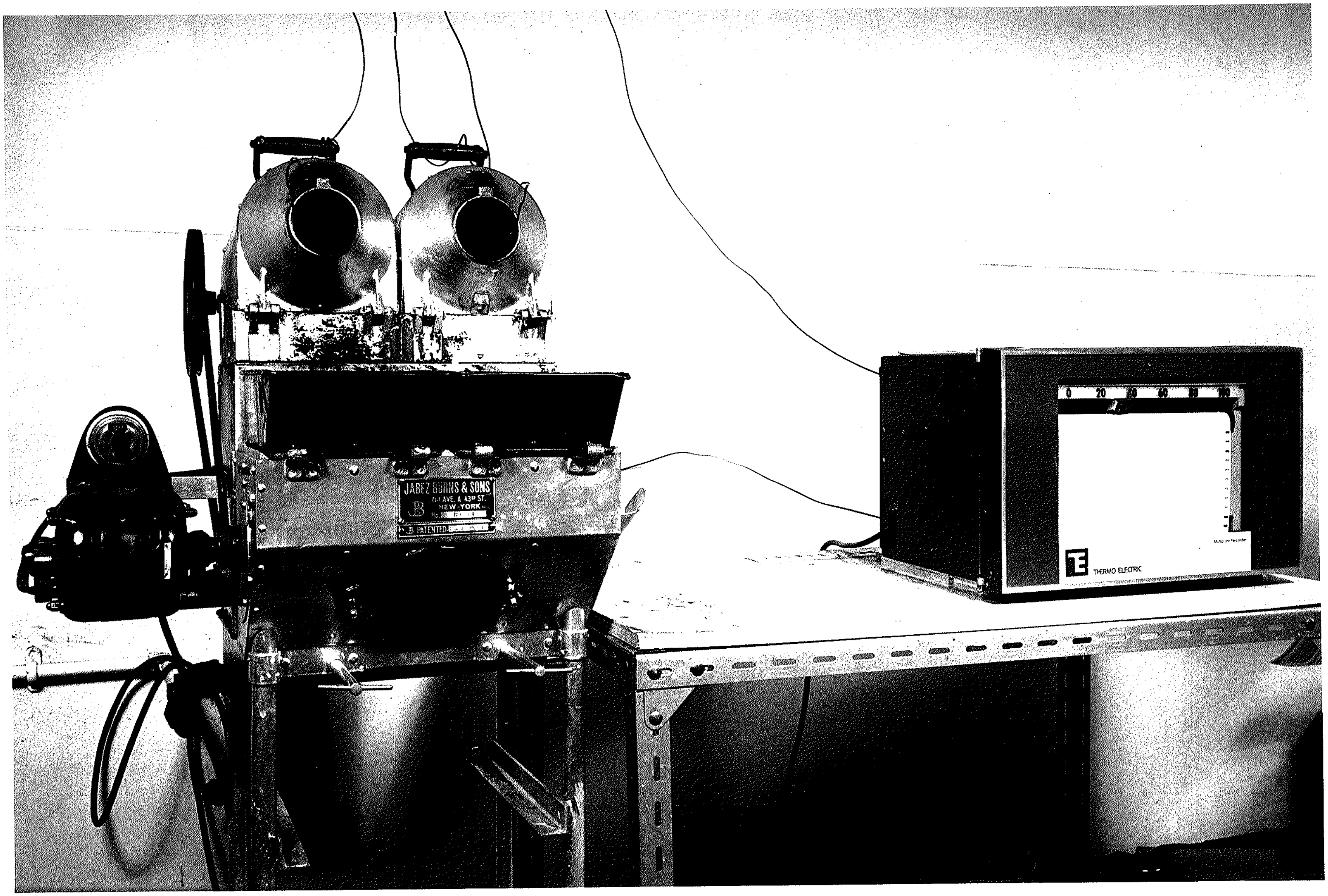


Figure 3. Controlled Environment Cabinets

Figure 4. An interior View of the Cabinet

Figure 5. Jabez Burns 2 Unit Coffee Roaster with Thermocouples Hooked to the Multipoint Recorder



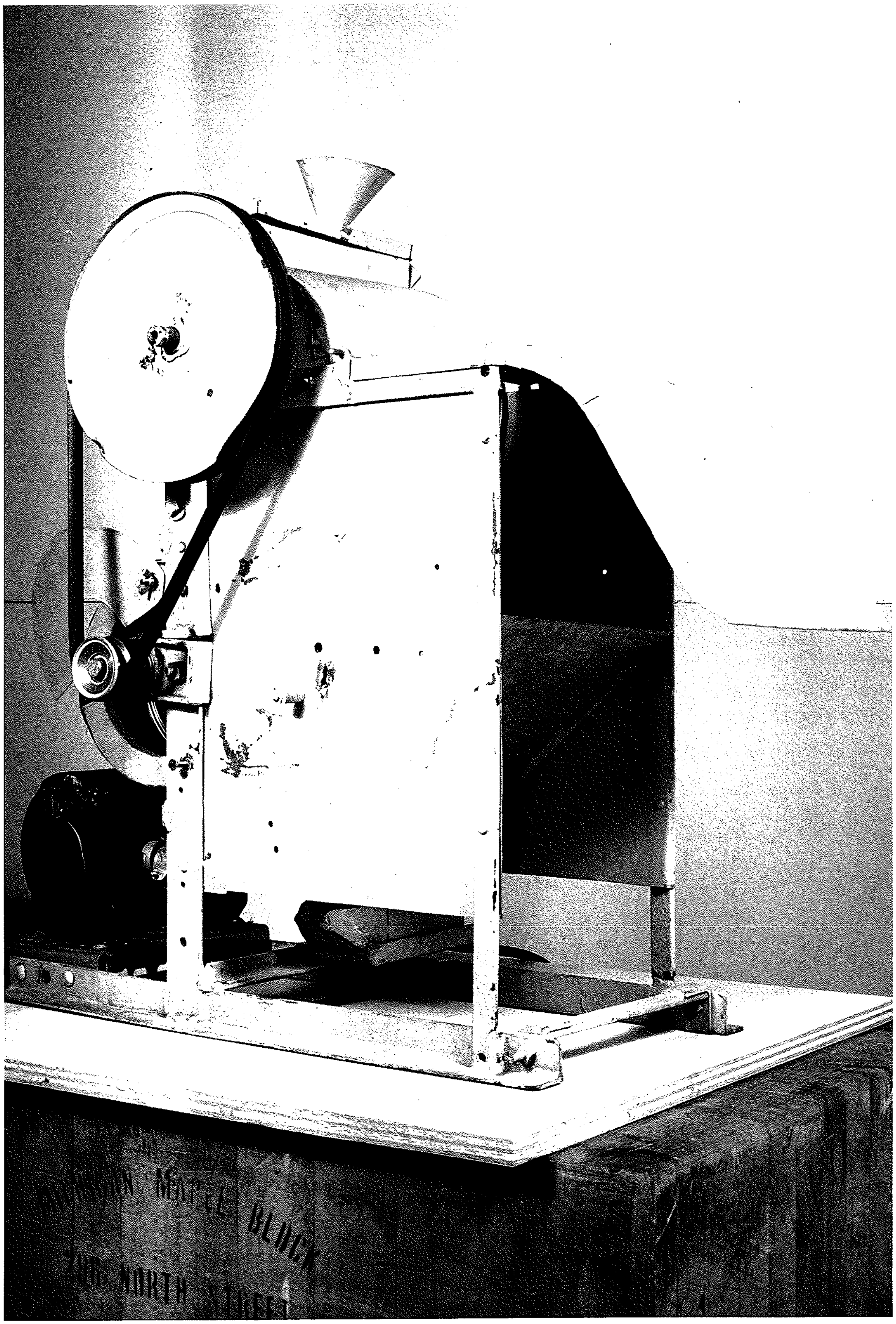


Figure 6. A single Roller Huller

the roller and the fan for hulling and cleaning purposes. The efficiency of the huller varied and was dependant upon the treatment of the rice prior to dehulling.

The parched and hulled wild rice was cleaned and separated into broken and unbroken grains by passing the rice through a clipper cleaner, manufactured by A.T. Ferrell & Co., Saginaw, Michigan. The finished wild rice was quality evaluated for three main characteristics, colour, kernel breakage and flavour since they were considered to be the major factors affected by the various processing systems. The raw data was analysed statistically utilizing the randomized blocks design and the means were evaluated by the Duncan Multiple Range test.

3.1.2. Design of curing and parching studies.

Mixed lots of lake and paddy wild rice harvested in late August were obtained by the Department in early September 1973. The rice was thoroughly washed, packed in cloth bags and was stored for six months at a temperature of $-32^{\circ}F$ before processing. In September, 1974, another lot of lake and paddy wild rice was obtained by the Department. This rice was processed immediately after washing. The curing and parching environments for these two seasons' wild rice were the same:

a) Treatment 1: The curing temperature was $10^{\circ}C$ with a relative humidity of 95%. One randomized sample was removed each week for a period of 9 weeks. This sample was parched using 2 different times and temperatures as follows;

1. Low temperature parching: Initial temperature of the rice was the same as room temperature and was gradually raised to $79.5^{\circ}C$. The entire parching time was 50 minutes.

2. High temperature parching: Initial temperature of the rice

was the same as room temperature and was gradually raised to 135° C. The entire parching time was 25 minutes.

b) Treatment 2: The curing temperature was 21.1° C with a relative humidity of 95%. One randomized sample was removed each week for a period of 5 weeks and parched with the same conditions as mentioned above.

c) Treatment 3: The curing temperature was 32.2° C with a relative humidity of 95%. One randomized sample was removed every 5 days for a period of 15 days for lake rice and 10 days for paddy wild rice. The parching conditions were the same as mentioned above.

The reasons for selecting these treatments were as follows. Firstly, the 10° C temperature curing showed good success according to the results from Wisconsin. Secondly, the 21.1° C temperature curing reflected the approximate ambient curing condition used by wild rice processors in Manitoba. Thirdly, the 31.1° C temperature curing was selected because we wished to compare high speed curing with other two curing treatments and some Manitoba wild rice processors use this high temperature environment in their operation. The purpose of using two different temperatures for parching was to compare the advantages and disadvantages of the two conditions. The low temperature used was just above gelatinization temperature of wild rice and the high temperature is just below the maximum recommended parching temperature (23).

3.1.3. Design of hulling study.

This study involved a comparative study and a storage study on the ease of hulling of wild rice. The former one was to compare the ease of hulling of wild rice cured at different periods of time and also to compare the rice cured at different temperatures. The latter one was to study the affect of storage of parched rice on the ease of hulling. In these studies the parameter used for measuring (ease of hulling) was the percentage hulled rice after passing one time through the huller. For the comparative study, wild rice samples stored at the lower temperature ($10^{o}C$ and $21.1^{o}C$) were taken out weekly while those stored at a higher temperature ($31.1^{o}C$) were taken out every five days for evaluation.

For the storage study, a randomized sample of about 5 pounds was taken out mid-way through each of the different curing treatments. One hundred grams of rice was hulled immediately after parching and the rest was stored at room temperature. That same size of sample was hulled every 5 days for a period of 80 days.

3.1.4. Design for sensory evaluation.

The main objective of this study was to develop profiles for characterization of the appearance, texture and flavour of wild rice. These profiles were used to evaluate the product that was obtained from the processing studies. It was anticipated that these profiles would be a guide line for wild rice consumers, processors and for later research. A ballot of 24 7-points scales was designed for these studies. The scales represented the 24 sensory characteristics of wild rice as selected by the panel. These scales were classified under 5 categories such as appearance, aroma, taste, texture and aftertaste. A group of 6 panel members were asked to evaluate the rice samples sensorially according to the scales. The results were subsequently used to build up the profiles which represented the product from each processing system. In addition, the results were also analysed statistically to obtain more precise information concerning the difference among the different processing systems.

3.2. Experimental procedure.

This section deals with the appropriate experimental procedures used in each of the studies conducted. Four different lots of wild rice were utilized for these studies, namely, the 1973's and 1974's lake and paddy wild rice. All the lots were tested with the same conditions for all studies.

3.2.1. Sample preparation for processing.

The lake rice and paddy wild rice harvested in August,1973, were received by the Department and thoroughly washed with water. These 2 lots were then packed in cloth bags and stored at a temperature of -32^{o} F for 6 months before being processed. Those lots harvested in August, 1974, were treated the same way except that they were processed without frozen storage.

3.2.2. Processing.

Cylindrical metal containers measured 2 feet high and 1 foot in diameter were used to hold the rice during curing. Sixteen 1/8" holes were drilled on the bottom of each container for draining and aeration purposes. As mentioned on the previous section, three different curing trials were used for all rice samples. For each trial and for each lot, four containers (four replicates) holding 18 lbs. of wild rice each (representing a depth of 12 inches), were used

Before the start of each curing trial, six samples of 250 gms each representing green wild rice were taken out randomly from the four containers. The temperature of the rice bed in each of the four containers was also recorded. After these procedures were finished, the containers were placed into the controlled environment cabinets. The cabinets had been operating for approximately 1 week prior to use at the desired temperature and relative humidity.

The temperature and relative humidity of the cabinets were carefully monitored every day. The temperature of the rice bed was recorded each day by means of a thermometer. This thermometer was inserted into the centre of the rice pile in each container until a constant temperature was observed. The rice was also turned over daily. About 350 ml of fresh water was added to each container three times every week.

Each week, six samples of 250 gm each were taken out randomly from four containers. When the 10^{o} C environment was used, this practice continued for 9 weeks and when the 21.1^{o} C environment was used the time period was 5 weeks. For the 31.1^{o} C temperature curing, samples were taken out every 5 days in the same manner for a period of 15 days.

All samples were processed and analysed as follows:

1. Moisture content of the rice was immediately analysed.
2. The 6 samples were separated into 2 groups of 3 replicates. One of the groups was parched by the high temperature system and the other by the low temperature system. These systems were specified in section 3.1.2. The temperature inside each unit of the coffee roaster was monitored throughout the entire period of drying. Copper and constantan thermocouples were used for temperature measurement. The temperature was recorded on a multipoint recorder which had been standardized by means of a minimite with reference to a Thermocouple Temperature Millivote Table before use. Both the multipoint recorder and the minimite were manufactured by The Thermo Electric Company. By the end of the drying time, approximately 10 gm of rice was removed and placed in a thermo

cup for instant temperature measurement. This temperature was measured by inserting a thermometer into the centre of the rice bed.

3. Moisture content of the rice was measured again after parching.
4. The samples were then weighed before and after hulling.
5. The hulled rice was cleaned by means of a clipper.
6. The Hunter Lab D25 Colour Difference Meter was used to measure the colour of the finished rice.

3.2.3. Hulling analysis:

The purpose of this study was to evaluate the effect of the different processing system on ease of hulling. All samples were weighed and hulled separately after parching. Each sample was allowed to pass through the huller once. The hulled and unhulled rice were then separated by hand and weighed. These measurements were used for study of the effect of the processing systems on the ease of hulling the rice.

The following procedure was used to obtain the percent yield of finished rice. The samples used to evaluate the ease of hulling were continued in this study as follows. The unhulled portion of the rice sample was put back through the huller until the entire sample was hulled. The total hulled rice was weighed. This measurement was used to represent the yield of the rice from a particular process.

$$\text{Percent yield of finished rice} = \frac{\text{wt. of hulled rice (broken and whole kernels)}}{\text{wt. of cured rice (250 gm)}} \times 100$$

The hulled rice obtained from the above procedure was cleaned and separated into two portions by passing the rice through the clipper previously referred to in Section 3.1.1.. The size of the two screens used was 8/64" x 3/4" and number 8. The portion of rice with longer kernel length (1 cm or longer) was considered as whole rice and the other portion was considered as broken rice (35).

The effect of storing parched rice for a period of time prior to hulling was evaluated in a second study. A sample of five pounds of rice was taken out randomly from the four containers mid-way through each of the different curing treatments. All rice samples were parched by the high temperature system. One hundred grams of rice were randomly removed from each sample and hulled immediately after parching. This was repeated at 5 day intervals for 80 days.

Each sample was allowed to pass through the huller once. Hulled rice and unhulled rice was separated by hand and each portion was weighed. The percent hulled rice was calculated as follows:

$$\text{percent hulled rice} = \frac{\text{wt. of hulled rice (broken \& whole kernels}}{\text{wt. of rice before hulling}} \times 100$$

$$\text{percent unhulled rice} = \frac{\text{wt. of unhulled rice}}{\text{wt. of rice before hulling}} \times 100$$

3.2.4. Sample preparation for sensory analysis.

A total of 80 samples were collected from the 10° C curing environment, 48 samples from 21.1° C curing environment and 32 samples from the 31.1° C environment. This gave a total of 160 samples for the sensory evaluation. It was not necessary to evaluate all of these and therefore specific samples were selected for these studies. The samples selected for the sensory evaluations are presented in Table 1. These samples were selected on the basis of the preliminary study on the flavour and acceptability of wild rice. The preliminary study revealed that wild rice cured at high temperatures such as 21.1° C and 31.1° C were highly unacceptable after an extended curing time.

All samples were cleaned and stored at room temperature until they were ready for the taste panel. There were three replicates for each

Table 1. Methods of sampling for sensory analysis of finished wild rice. These methods were common for both Lake and Paddy wild rice and for Low and High Temperature parching.

Length of curing time

Curing Temperature	Weeks of curing									
10^{o} C	$\boxed{0}$	1	2	$\boxed{3}$	4	5	$\boxed{6}$	7	8	$\boxed{9}$
21.1^{o} C	$\boxed{0}$	1	$\boxed{2}$	3	$\boxed{4}$	5				
	Days of curing									
31.1^{o} C	$\boxed{0}$	$\boxed{5}$	$\boxed{10}$	15						

$\boxed{}$ Samples used in the Taste Panel sample except for paddy rice which had only two replicates because of the lower yield of the rice. All samples and replicates were taken out randomly for the taste panel and were prepared as follows:

MATERIALS: Three gourmet double boilers manufactured by Corning, a 500-ml measuring cylinder, sieves.

METHOD: 1. Three samples of 40 gm each were weighed out for each taste panel.

2. Each rice sample was washed three times with clean water.

3. For 40 gm of rice, 280 ml of water were used for cooking (13).

4. The water in the boiler was heated to boiling before the rice was added. The cooking time was 45 minutes.

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

6. After 45 minutes cooking time, excessive water was drained away with a sieve.

7. A spoonfull of rice from each sample was put into a 2 oz. lily cup and was served immediately. This ensured that the rice was still warm while being tasted.

Three different rice samples were presented to each judge for evaluation at each taste panel. They were asked to evaluate the samples according to the instructions on the ballot (Appendix 1). For each panel session, the judges were the same for all the trials used.

3.3 Evaluation of the product.

3.3.1. Moisture content measurement.

Standard vacuum oven method as described in AOAC (2,3).

3.3.2. Colour Measurement.

In the wild rice industry, suitable colour development has been established as one of the primary quality factors involved in market value of wild rice (13). Unfortunately, no standard method has been established for colour measurement. The Hunter Model D25 colour difference meter has been widely used for the measurement of the colour of grains. It has been used to measure the colour of white rice in the rice industry (31) and has also been used for the evaluation of wheat class and grade (11).

A description of colour measurement has been presented in Chan-Gerbasi's Theses (10,16).

For measuring the colour of wild rice, the three colour values were used to calculate the total colour difference of each rice sample compared to a colour standard. The total colour difference (ΔE) indicates the difference in colour between the specimen and the colour standard. The larger the ΔE value, the larger is the colour difference between the specimen and the colour standard. A good finished wild rice should have a colour of dark brown to black. This was why a white colour standard tile was selected as the reference having the following value: L = 93.8, aL = -1.1, bL = 2.3. The difference of each colour component has a value of ΔL, ΔaL and ΔbL. These values are used to calculate ΔE where:

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

$$\Delta L = L \text{ standard} - L \text{ sample}$$

$$\Delta aL = aL \text{ standard} - aL \text{ sample}$$

$$\Delta bL = bL \text{ standard} - bL \text{ sample}$$

3.3.3. Sensory analysis.

A group of 10 students and staff from the Department were trained to identify the flavour of wild rice. They were also asked to describe its texture and appearance. A series of training sessions and panel discussions were held in the summer of 1974. Commercial wild rice purchased from Lac Du Bois, Northland wild rice company and The Indian Rice Producer Co-op Ltd. and wild rice processed in the Department were used during the training sessions. The purpose of using wild rice from different processing plants was two-fold; first, to acquaint the panelists with wild rice processed under different techniques, and secondly, to make them aware that the taste, texture and appearance of wild rice were different depending on the source.

Panel training was held twice a week followed by discussion for a period of 4 months. After the training period, all panelists were able to recognize the different types of flavour and distinguished the wild rice from different sources. The panelists held a discussion period after each training session during which the various sensory characteristics were discussed and recognized. Many descriptive words used to characterize the flavour, texture and appearance of wild rice were created through the taste panels. Among these words, twenty four were picked out and were classified into appearance, aroma, taste, texture and after taste of wild rice. This classification was constructed as the format of the ballot used for sensory analysis of all wild rice samples. All the results were analysed statistically by the randomized blocks design (1).

IV RESULTS AND DISCUSSION

The studies on the processing of wild rice were carried out between October, 1973 and December, 1974. Lake and paddy wild rice grown in 1973 and 1974 were utilized in this study. The main objectives of this research were to evaluate the effect of the different processing systems on the yield, flavour and colour of the final product. A second objective was to characterize the flavor of finished wild rice. It was also possible to compare the effect of two growing seasons on the processing of wild rice and the quality of the final product.

4.1. General observations of the curing of wild rice.

During the curing process, many changes occurred in the wild rice which we were able to observe visually or by means of measurements. Many of these changes could be readily observed in wild rice cured at 31.1°C. Wild rice cured at this temperature showed rapid colour and odour changes. Physical breakdown apparently was accelerated by the high temperature. Wild rice cured at 21.1°C showed similar changes except that the physical breakdown occurred at a relatively slower rate. Wild rice cured at these two temperatures developed a very unacceptable appearance and odour part way through the curing studies. Wild rice cured at the cooler temperature (10°C) was a success in terms of visual observation. The physical appearance, colour and odour were acceptable throughout the entire curing studies. Sprouting occurred after six weeks with lake rice but this did not happen with paddy wild rice. This phenomenon indicated that lake rice was still physiologically active at the later stages of curing.

4.1.1. Rice bed temperature

The bed temperature of the rice cured at $10^{\circ}C$ showed little fluctuation from the control temperature throughout the entire curing storage. This temperature ranged from $10.5^{\circ}C$ - $13^{\circ}C$ for both 1973 and 1974 rice and it remained almost constant after two-thirds of the curing period (Figure 7). For the $21.1^{\circ}C$ and $31.1^{\circ}C$ curing temperatures, a higher bed temperature was recorded for the 1974's lake rice (Figures 9, 11). The temperature ranged from $18^{\circ}C$ to $34^{\circ}C$ for the $21.1^{\circ}C$ curing study and ranged from $24^{\circ}C$ to $44^{\circ}C$ for the $31.1^{\circ}C$ curing study. In the later stages of curing, the rice bed temperature tended to rise at both $21.1^{\circ}C$ and $31.1^{\circ}C$.

In general, paddy wild rice had a higher rice bed temperature than lake rice. This might be due to the fact that paddy wild rice was smaller in size with less air space between the rice. This resulted in more heat accumulation in the rice pile. When comparing the two seasons' paddy wild rice data, the bed temperatures were nearly the same except that more fluctuation occurred in 1974's (Figures 8, 10, 12). Unlike lake rice, the bed temperature of paddy wild rice decreased during the later stages of the curing period. This decrease in temperature might indicate that paddy wild rice was physiologically less active than lake wild rice at this period of time.

Wild rice has to be well handled during curing to give high quality final product. Well cured rice has to have the following attributes; 1. high yield; 2. acceptable colour; 3. acceptable flavour. These 3 factors will be more fully discussed later.

Bed temperature was an important indicator of good control during the curing process. Factors that contributed to the bed temperature

Figure 7. Rice Bed Temperature of Lake Wild Rice Cured at 10°C

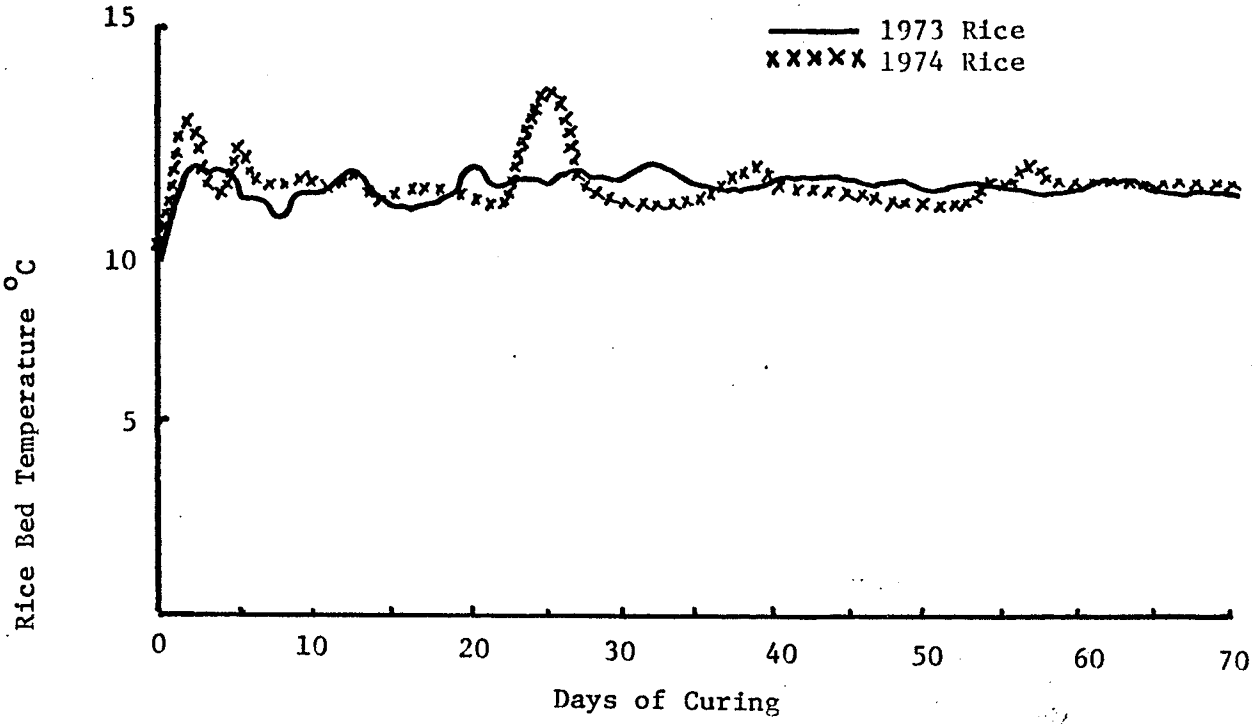


Figure 8. Rice Bed Temperature of Paddy Wild Rice Cured at 10°C

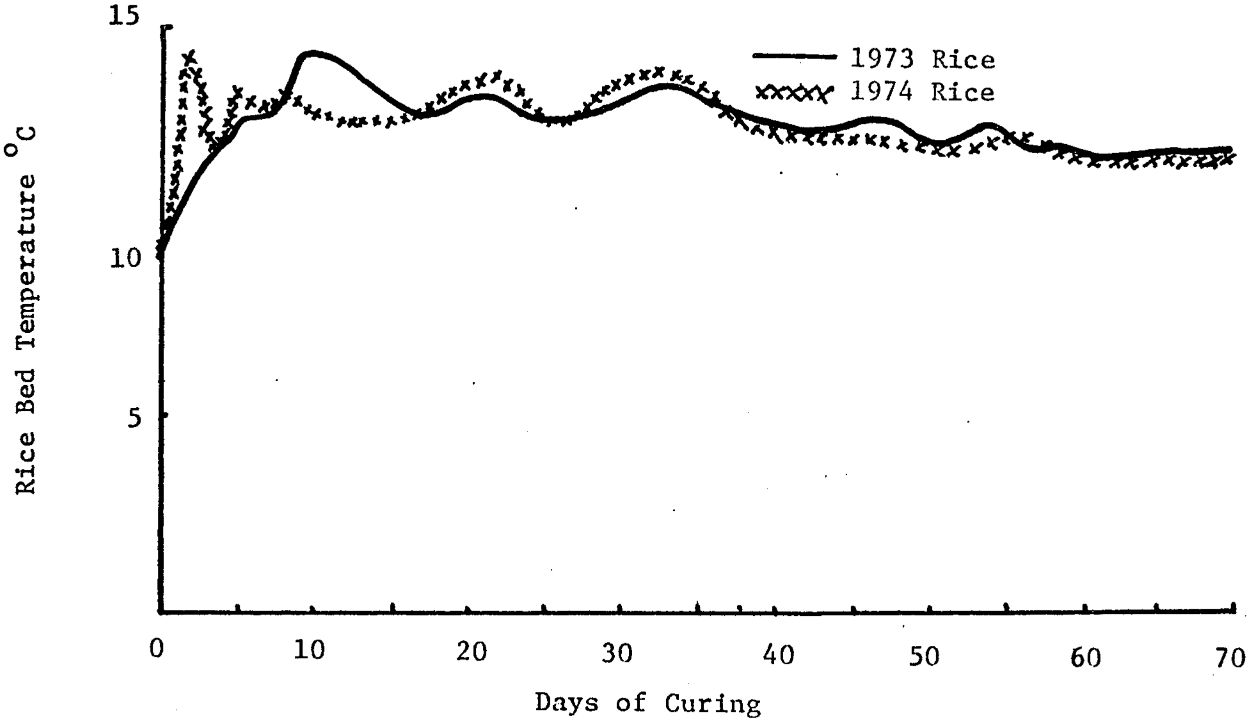


Figure 9. Rice Bed Temperature of Lake Wild Rice Cured at 21.1°C

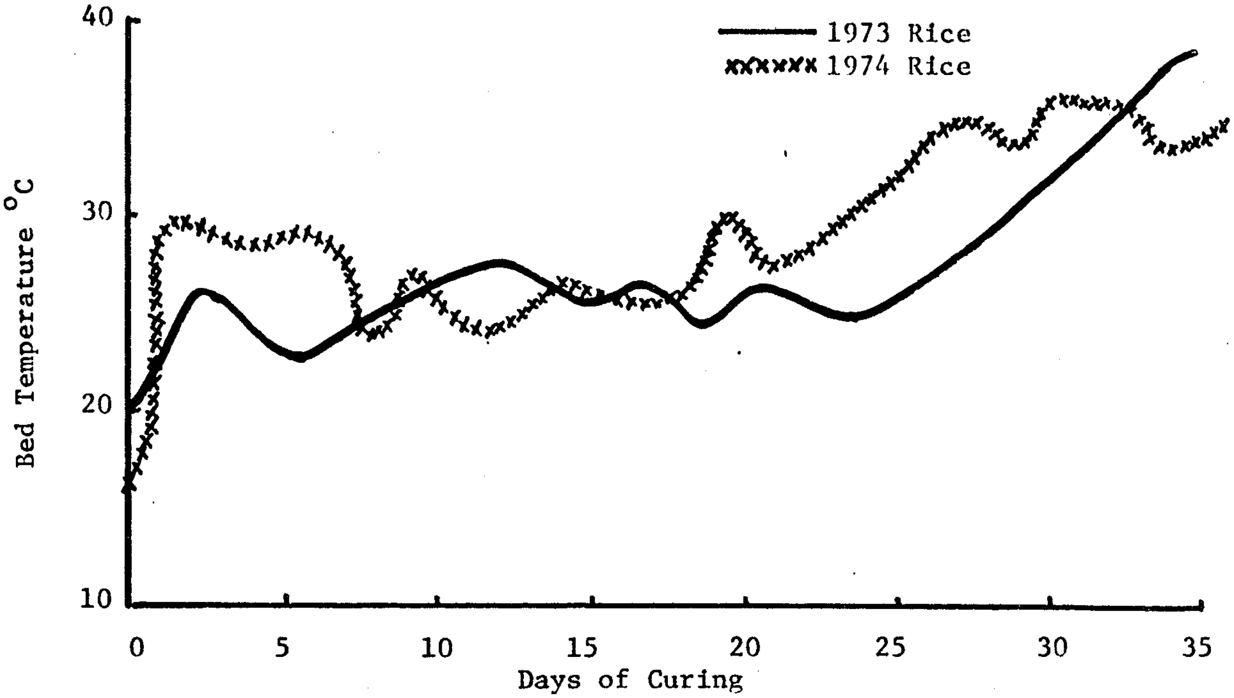


Figure 10. Rice Bed Temperature of Paddy Wild Rice Cured at 21.1°C

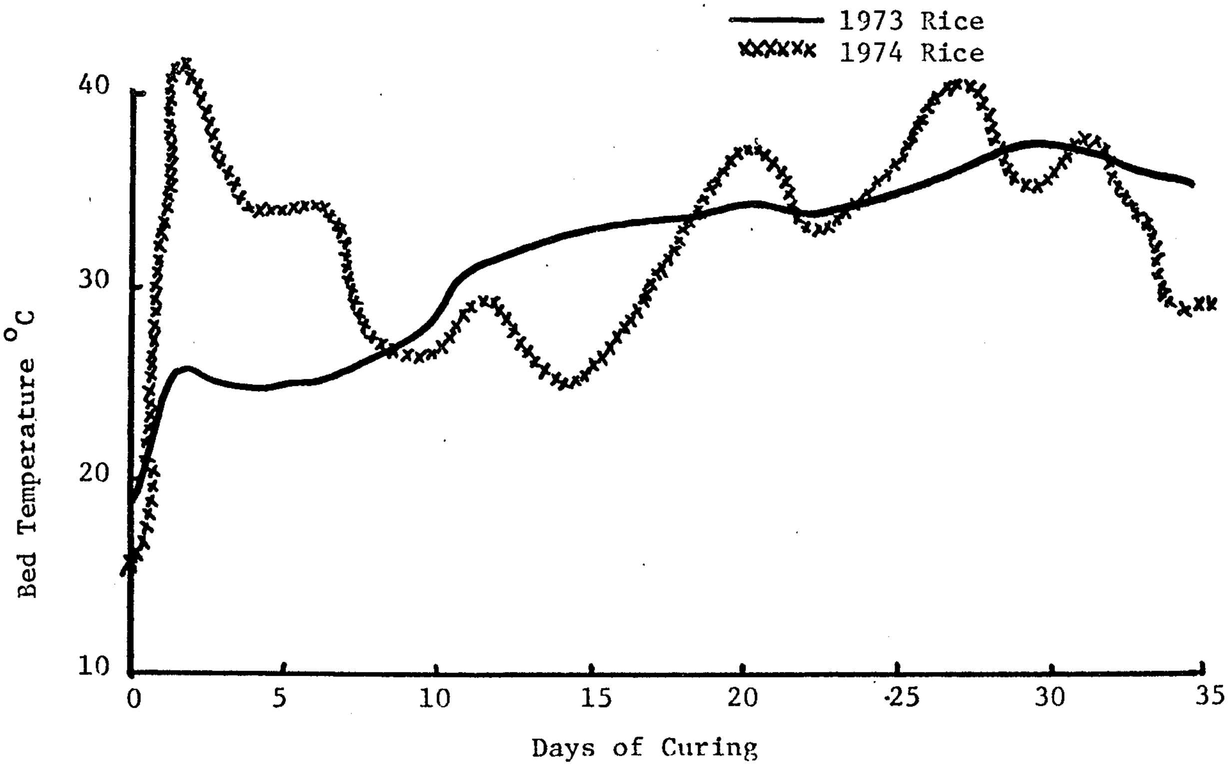


Figure 11. Rice Bed Temperature of Lake Wild Rice Cured at 31.1°C

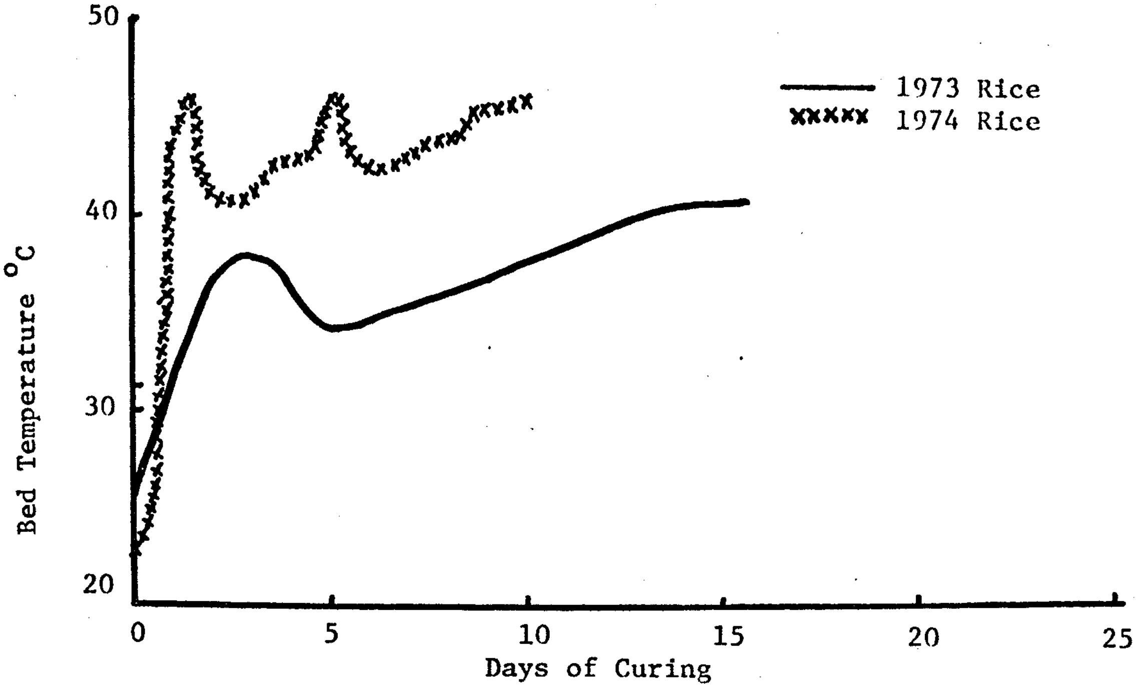
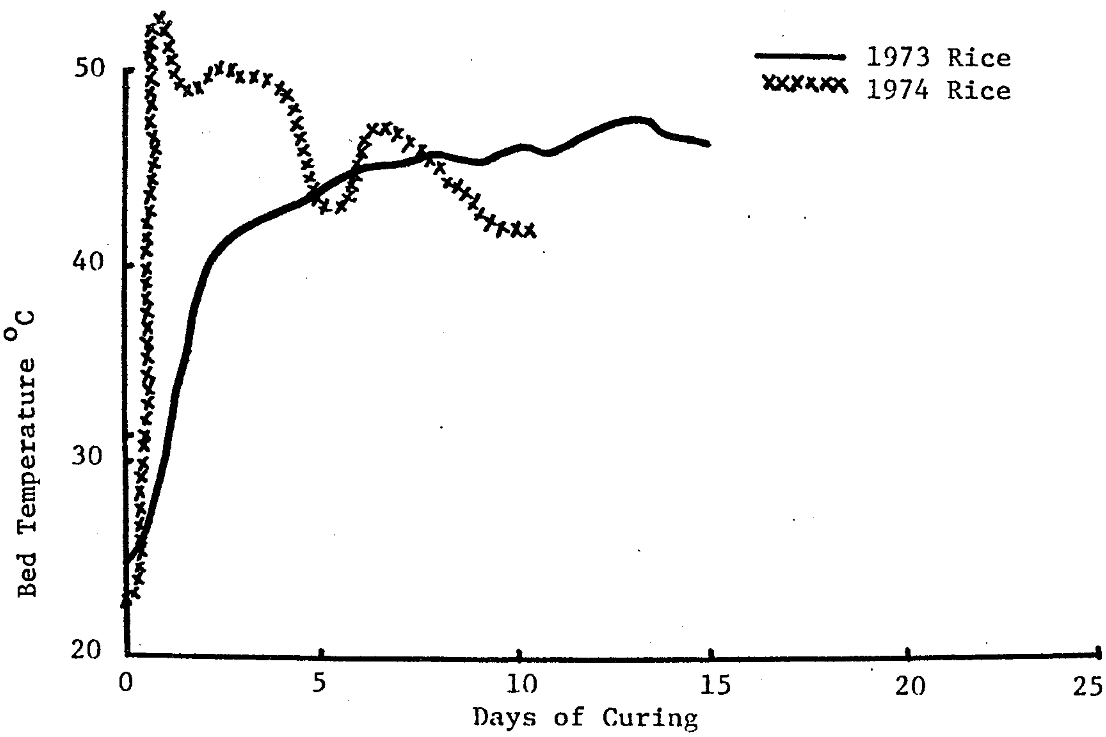


Figure 12. Rice Bed Temperature of Paddy Wild Rice Cured at 31.1°C



include type of rice, i.e. lake, paddy; specific genotype of rice; "maturity of the rice"; rice size; curing environment; method of handling during curing, i.e. turning and watering.

Many of those factors were not controlled in our studies, were not controlled by commercial processors and were 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. The lower the temperature of the curing environment, the easier it was to control the temperature of the rice bed (Figures 7 - 12 inclusive).

Rapid increase in temperature during the final stages of curing at 21.1°C and 31.1°C indicated physiological deterioration of the rice. This did not develop when rice was cured at 10°C. In summary, rice was easier to handle when cured at low temperature (10°C).

4.1.2. Colour, odour and other visual changes

Freshly harvested lake and paddy wild rice usually are green in colour. After harvesting, the green colour starts to change to a darker appearance. For the samples used in these studies, the rate of colour change was more rapid for lake rice than for paddy rice. This colour change was observed during the shipment, storage and curing of both types.

The rate of colour change in wild-rice was proportional to the curing environments (Figure 13 - 15). This change occurred rather slowly with low temperature curing (10°C) and more rapidly at higher temperature curing. The pattern of colour change for lake rice was the same for all treatments. The colour change was as follows; green

Figure 13. The Colour Change of Lake Wild Rice Cured at 10 ^{o}C

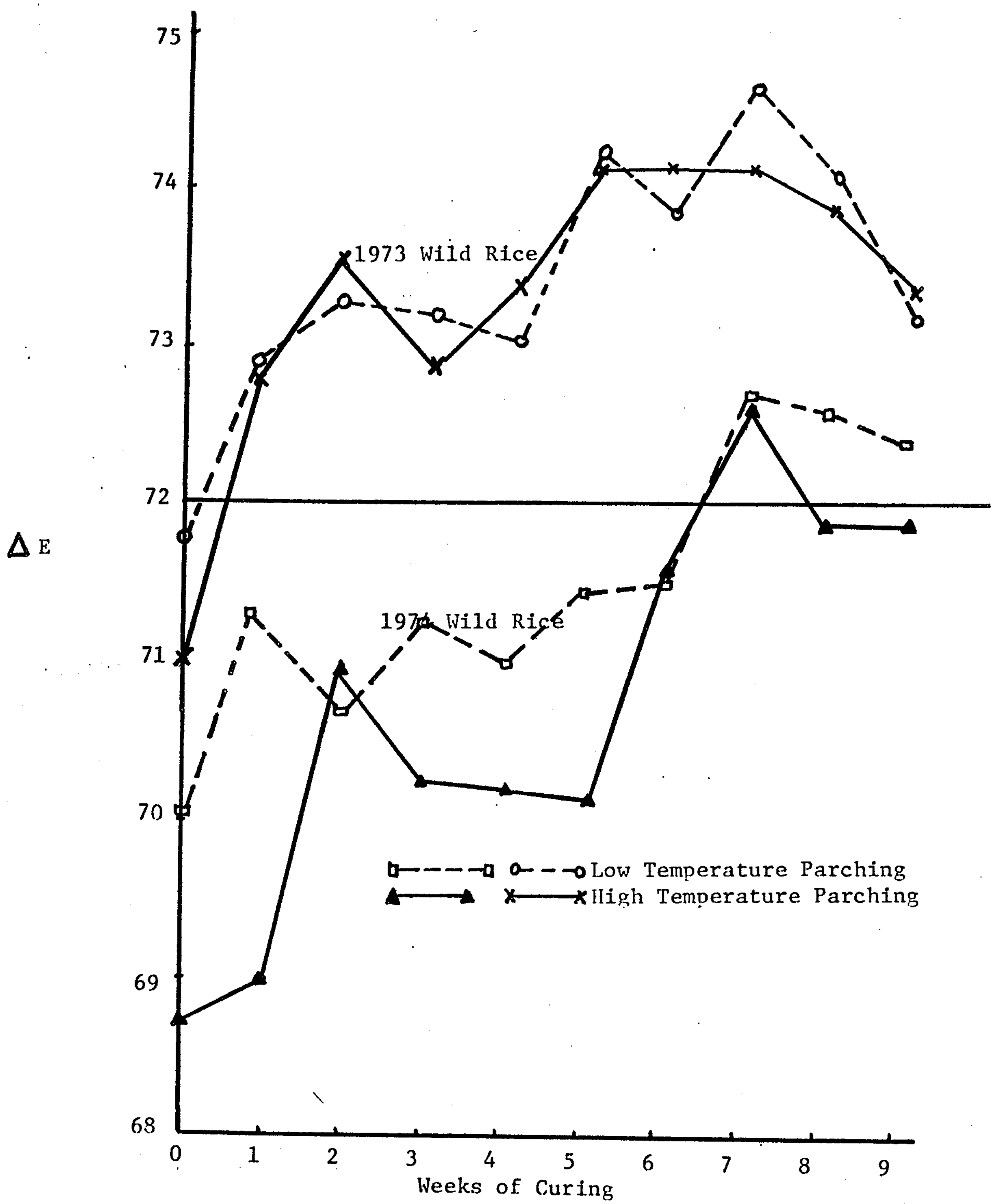


Figure 14. The Colour Change of Lake Wild Rice Cured at 21.1°C

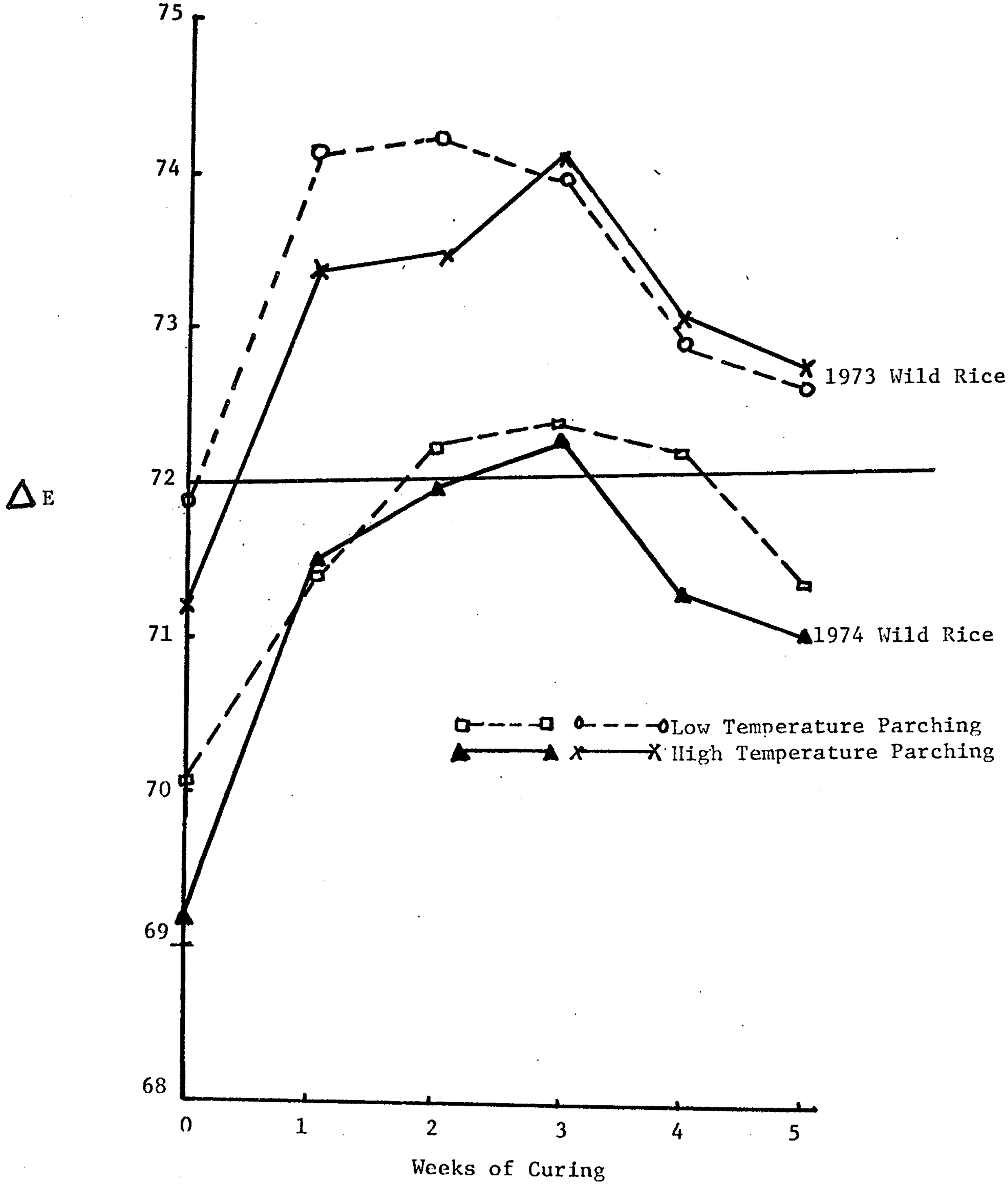
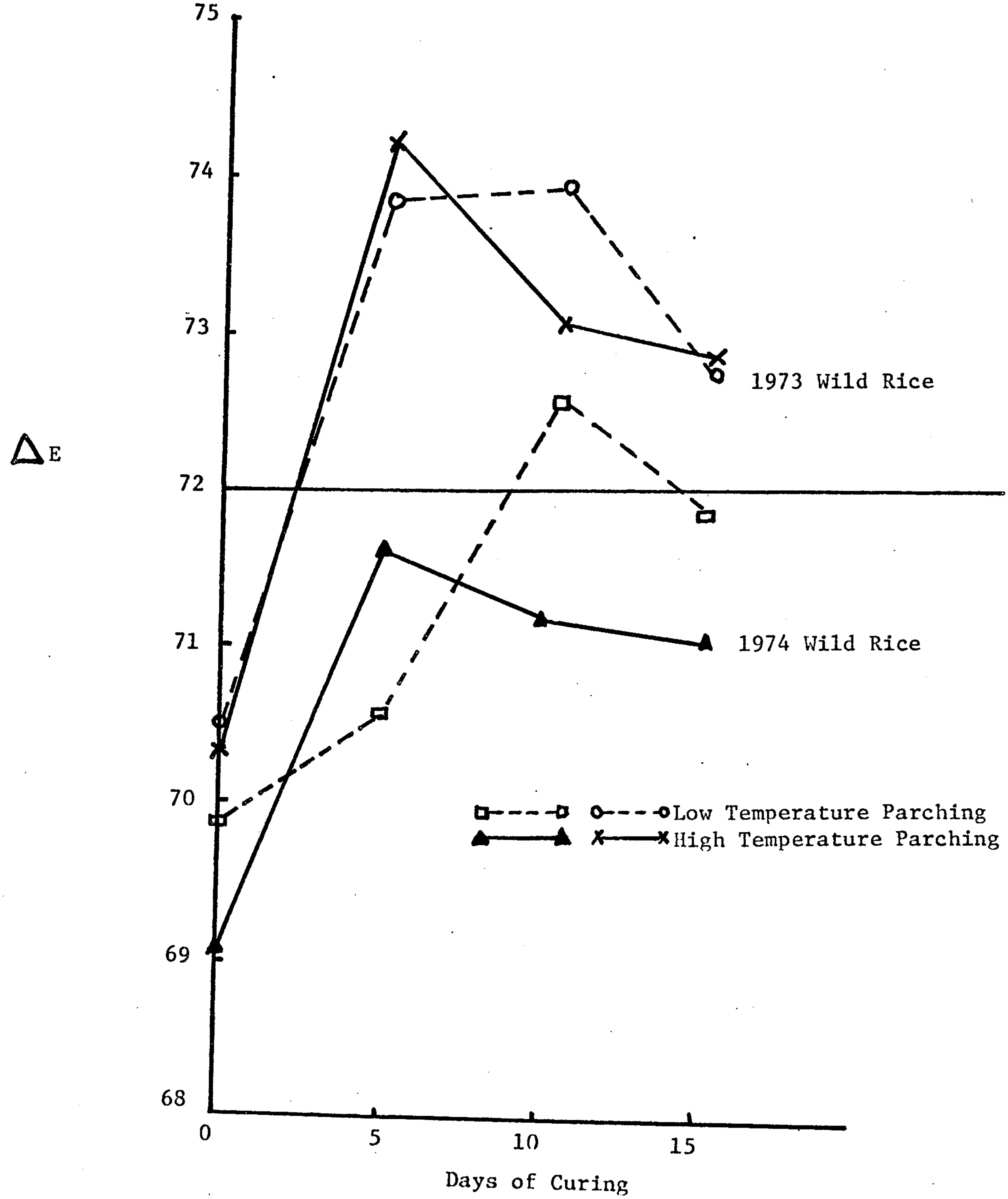


Figure 15. The Colour Change of Lake Wild Rice Cured at 31.1°C



to brownish green, deep brownish green, and then deep brown. The final colour tended to fade towards the end of each curing treatment and became a brownish yellow.

For paddy wild rice, the pattern of colour development was different from lake rice. The colour changed from green to yellowish green, then to brownish yellow. It was very possible that some essential components for the development of a darker colour were not present in paddy wild rice.

The development of odour in curing lake wild rice was similar for all treatments. The green rice was dominated by a grassy odour. The texture of the rice was firm and appeared clean. Gradually the odour changed to a fishy character and the colour began to develop. As the colour deepened, an earthy odour developed. This earthy odour lasted for about 1/3 of the curing period. During this stage the rice kernel had the darkest appearance and firmest texture indicating that this was the optimum time to carry out parching. By the end of this stage, a strong earthy odour was dominant and gradually changed to a swampy odour indicating that the lake rice had started to deteriorate. This phenomenon occurred about 2/3 of the way through the curing trial. The deterioration of lake rice was characterized by the following:

1. High bed temperature
2. Strong swampy odour
3. Slimy texture
4. Dirty in appearance
5. Colour fading
6. Soft kernels
7. Reduced volume of rice
8. Higher moisture content

Paddy wild rice had a similar odour development to lake rice. However, the other changes such as colour and texture were different. The texture of paddy wild rice was soft and it started to deteriorate much more rapidly than lake rice. Slimy texture and strong swampy odour dominated the later stage of curing paddy wild rice.

4.2. Quality Evaluation of Wild Rice

4.2.1. Colour

The colour of the finished rice samples were measured by The Hunterlab Colour Difference Meter Model D25 in terms of L, aL and bL values. The E values were calculated and are graphically presented in Figures 13 - 18. The results indicated that the colour of wild rice kept fluctuating while curing and it also showed that there were two observations which were common in all studies. The first was that the rice started to lose its colour towards the end of each curing period. This change of colour may be partly due to physical breakdown of the rice and partly due to the lack of energy supply for the continued development of proper colour pigments. The second assumption was based on reports from the University of Wisconsin. They indicated that the chlorophyll and polyphenolic fractions and the relative concentrations of each of the derivatives were primarily responsible for the desirable colour changes of wild rice during curing (13). The second observation was that there was no significant effect on colour of final product by using the low or high temperature parching system.

A comparison of data between lake and paddy wild rice demonstrated that lake rice developed a darker colour in all curing environments (Figures 13 - 18).

The wild rice grown in 1973 (lake and paddy) produced a darker coloured final product than the 1974 wild rice (Figures 13 - 18). The following factors could be involved in this phenomenon. The

Figure 16. The Colour Change of Paddy Wild Rice Cured at 10°C

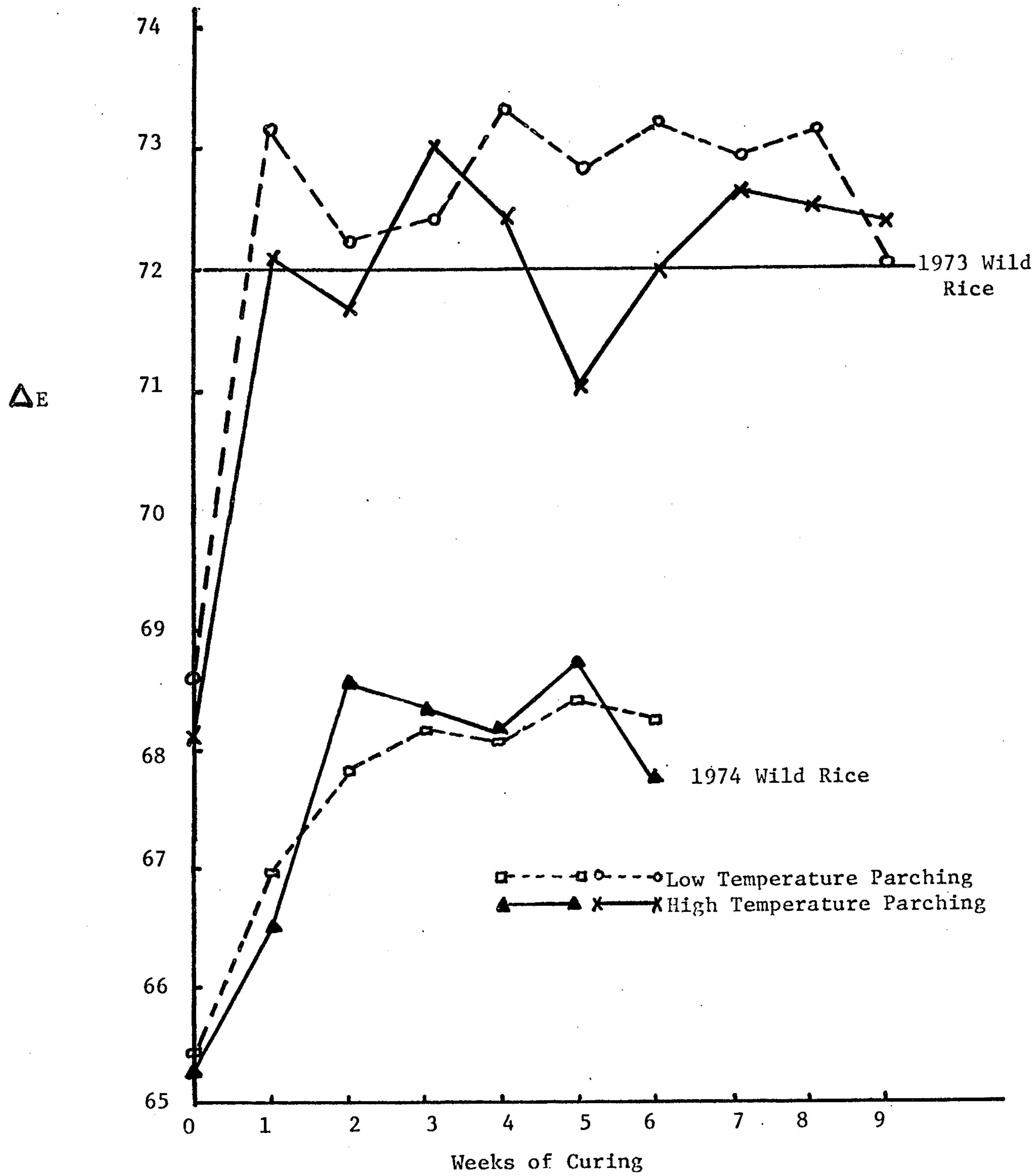


Figure 17. The Colour Change of Paddy Wild Rice Cured at 21.1°C

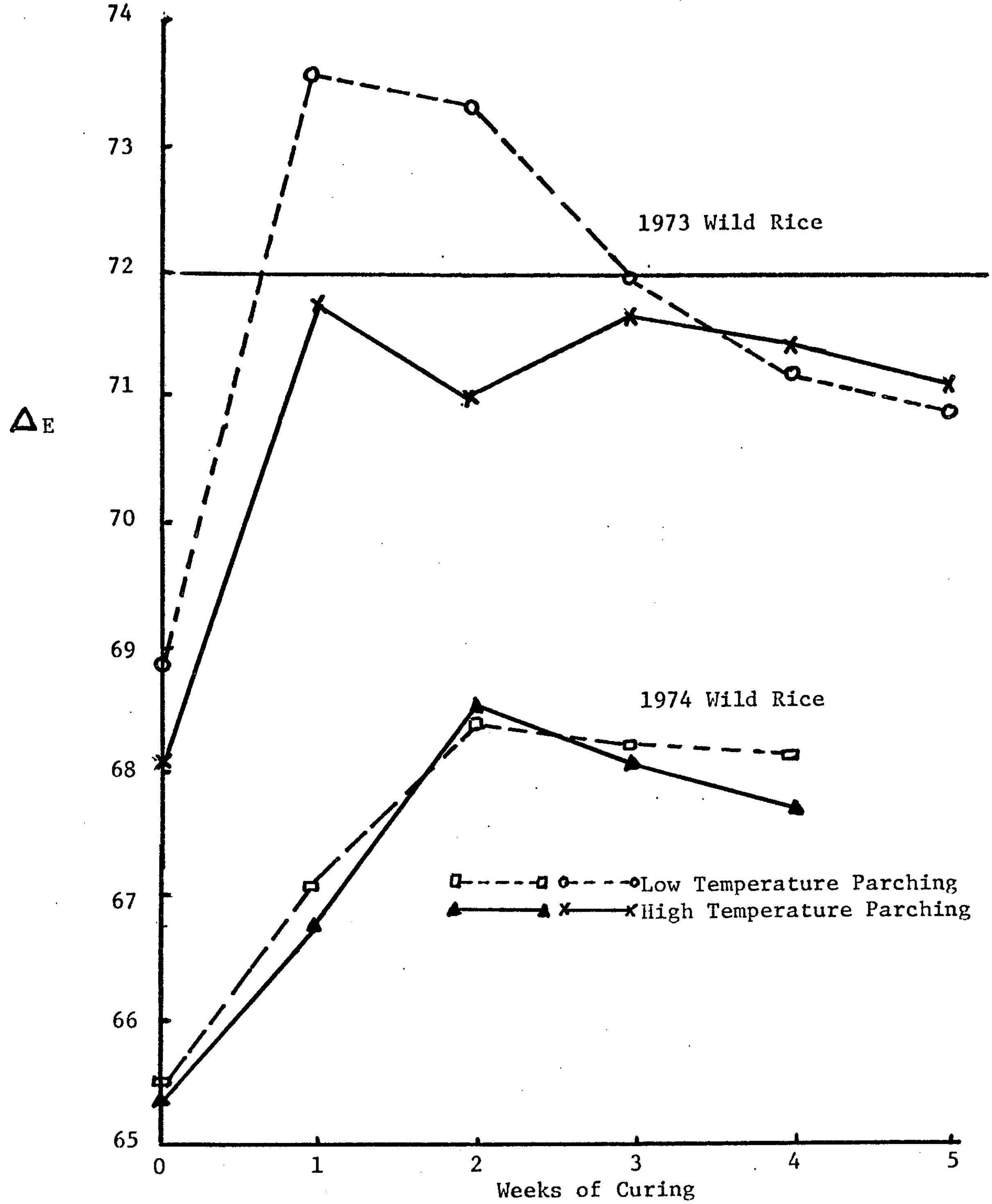
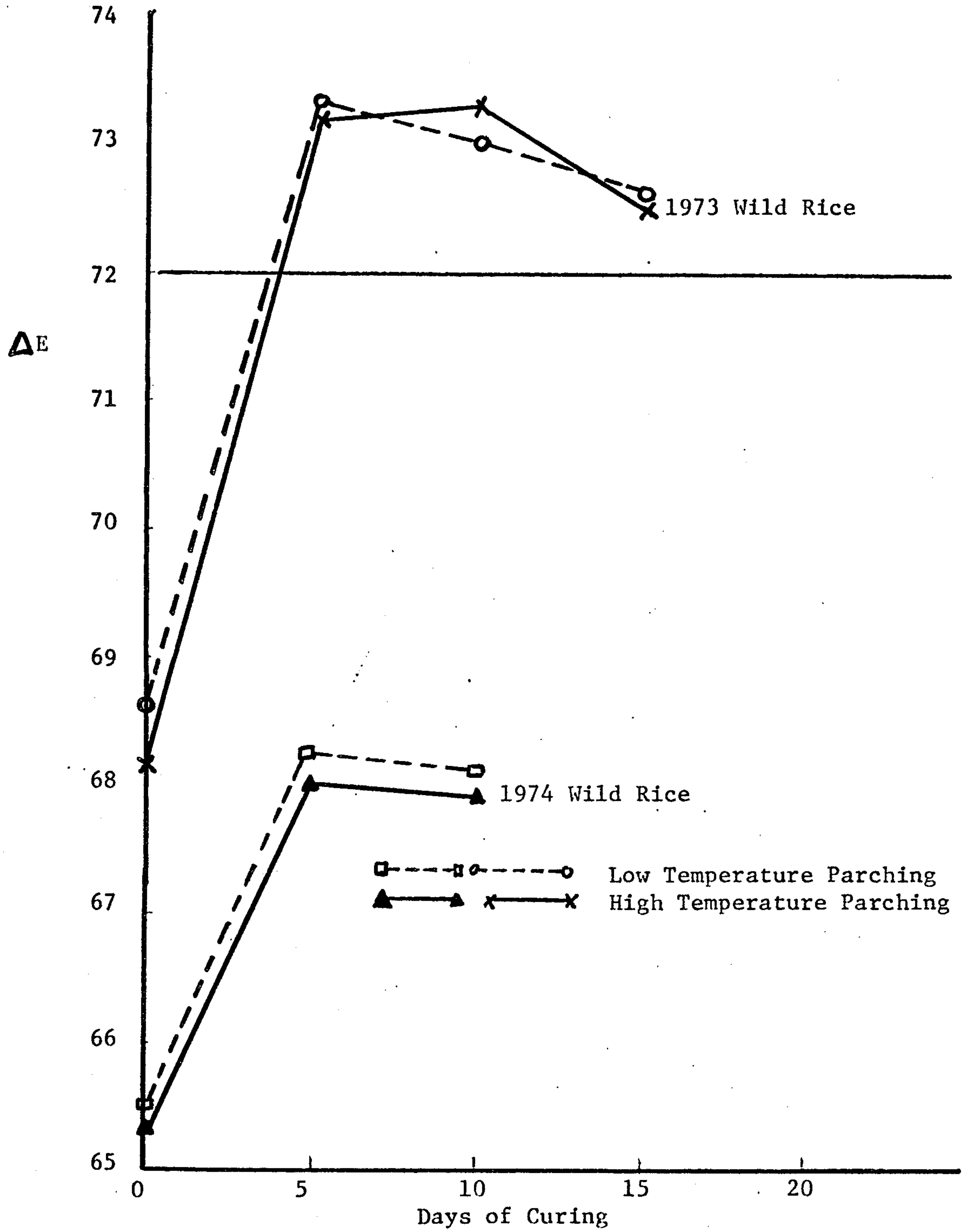


Figure 18. The Colour Change of Paddy Wild Rice Cured at 31.1°C



1973 wild rice was held in frozen storage and the rice from the two crop years came from different locations, therefore were different wild rice genotypes. The growing seasons for the two years were quite different. In addition, physiological activity of rice played a major role in colour development. Recent research at the Department of Food Science, University of Manitoba, indicated that freezing may also play a significant role in colour development.

The rate of colour change at higher curing temperatures (21.1°C and 31.1°C) appears to correlate with the rate of the temperature change in the rice bed during curing (Figures 9, 10, 11, 12, 14, 15, 17, 18). The sudden change of colour (from an unacceptable colour to an acceptable colour) during the early stages of curing was accompanied by a sudden rise of bed temperature. It may be possible to use this sudden rise of bed temperature as an indicator for the sudden change of colour in curing wild rice when high temperature curing environments are used.

Highly acceptable colour could be developed under all conditions of curing provided that the correct type of rice was used; for example, some of the 1974 rice did not develop good colour. The rate at which colour developed was dependent upon the curing environment; for example, at 31.1°C, less than 5 days were required, at 21.1°C this required less than 1 week, and at 10°C it was approximately 1 week. The length of time that good colour remained in the wild rice samples while being cured also depended upon the curing environment. Colour could be held in rice cured at 10°C for 7 weeks before fading, while at 21.1°C this was only 3 weeks before fading started and at 31.1°C fading occurred after 5 days (Figures 13 - 18). It appeared that low temperature curing gave the processors better control in the curing process (Figures 7 - 12) and this resulted in better control of colour retention.

In the Figures 13 - 18 an arbitrary line at $\Delta E = 72$ has been drawn to indicate acceptable and inacceptable rice colour. Wild rice that had a ΔE value of 72 or above was considered to have an acceptable colour while values below 72 indicated an unacceptable colour. This determination was based on visual judgement according to discussion within the sensory panel.

The degree of darkness of wild rice depends upon several factors; the curing time, "rice maturity" - paddy versus lake, rice genotype, freezing of rice before curing. Not all factors can be controlled i.e. rice genotype, "rice maturity". However, the processors can through careful control of curing and parching produce a final product with highly acceptable colour.

4.2.2. Moisture Content

The moisture content of all wild rice samples were determined by the vaccuum oven method. Data showed that the moisture content of wild rice before parching was 40% - 45% for lake rice and 55% - 60% for paddy wild rice. At the latter stage of curing, the moisture content of lake rice rose by 5%, slime formed and the texture softened. Paddy wild rice did not have a significant change in moisture content during curing.

The moisture content of the finished lake and paddy wild rice parched at high and low temperature, was between 7% - 10%. The purpose for drying the rice down to this moisture level was three fold. The first reason was to increase the yield of the rice. This was because rice with a moisture content above 10% was difficult to hull and rice with a moisture content below 7% was fragile and easily broken when hulled. The second reason was to minimize the microbial degradation of the finished rice by reducing the water activity that was suitable for growing microorganisms. The third reason was that parched wild rice with moisture content below 5% might have hollow centres.

A study on the rate of moisture removal indicated that paddy wild rice took a little longer time to dry to the required moisture level than lake rice. This was due to the higher initial moisture content of paddy rice. Data presented in Figures 19 - 22 showed that the rate of moisture removed related to the drying time. Tables 2 - 5 showed the air temperature of the roaster and the corresponding bed temperature of the rice at each time interval. The final rice bed temperature recorded for each parching trial was capable of use to indicate the final moisture content of the rice. At a particular temperature range, the moisture content of the rice was between 7% - 10% (Table 6). The lower the temperature within the temperature range, the higher was the moisture content of the product. However, the moisture content of the product would not be above or below the acceptable moisture level, as long as the final bed temperature fell into the temperature range.

For example, when 250 gm of lake wild rice was parched at 135^{o}C for 25 minutes, and the final bed temperature of the rice was 87.7^{o}C, then the moisture content would be 7.7 ± 0.5%. The higher the bed temperature, the lower would be the final moisture content of the product (Table 6).

Figure 19. Rice Bed Temperature of Lake Wild Rice Parched at High Temperature

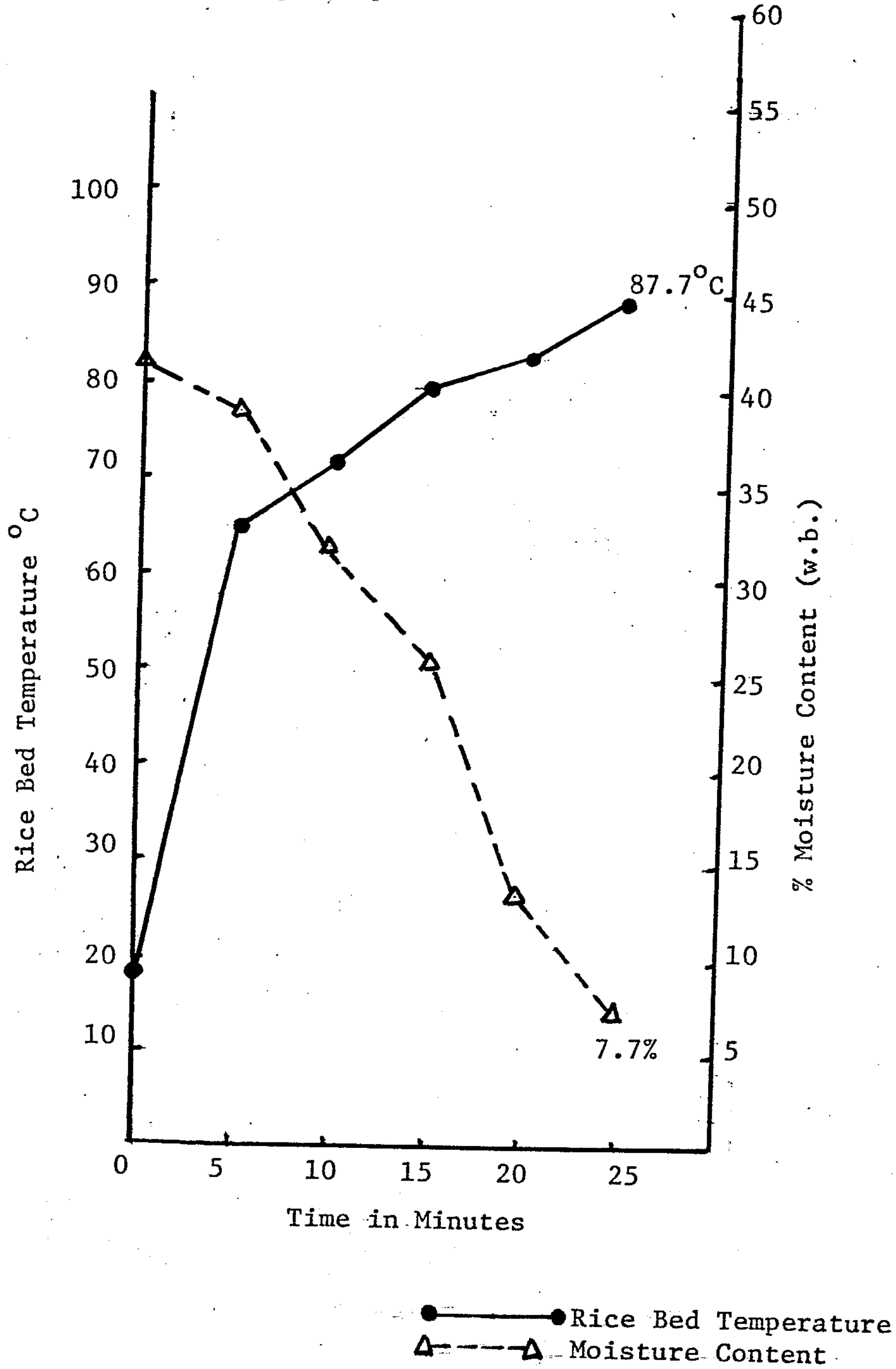


Figure 20. Rice Bed Temperature of Lake Wild Rice Parched at Low Temperature

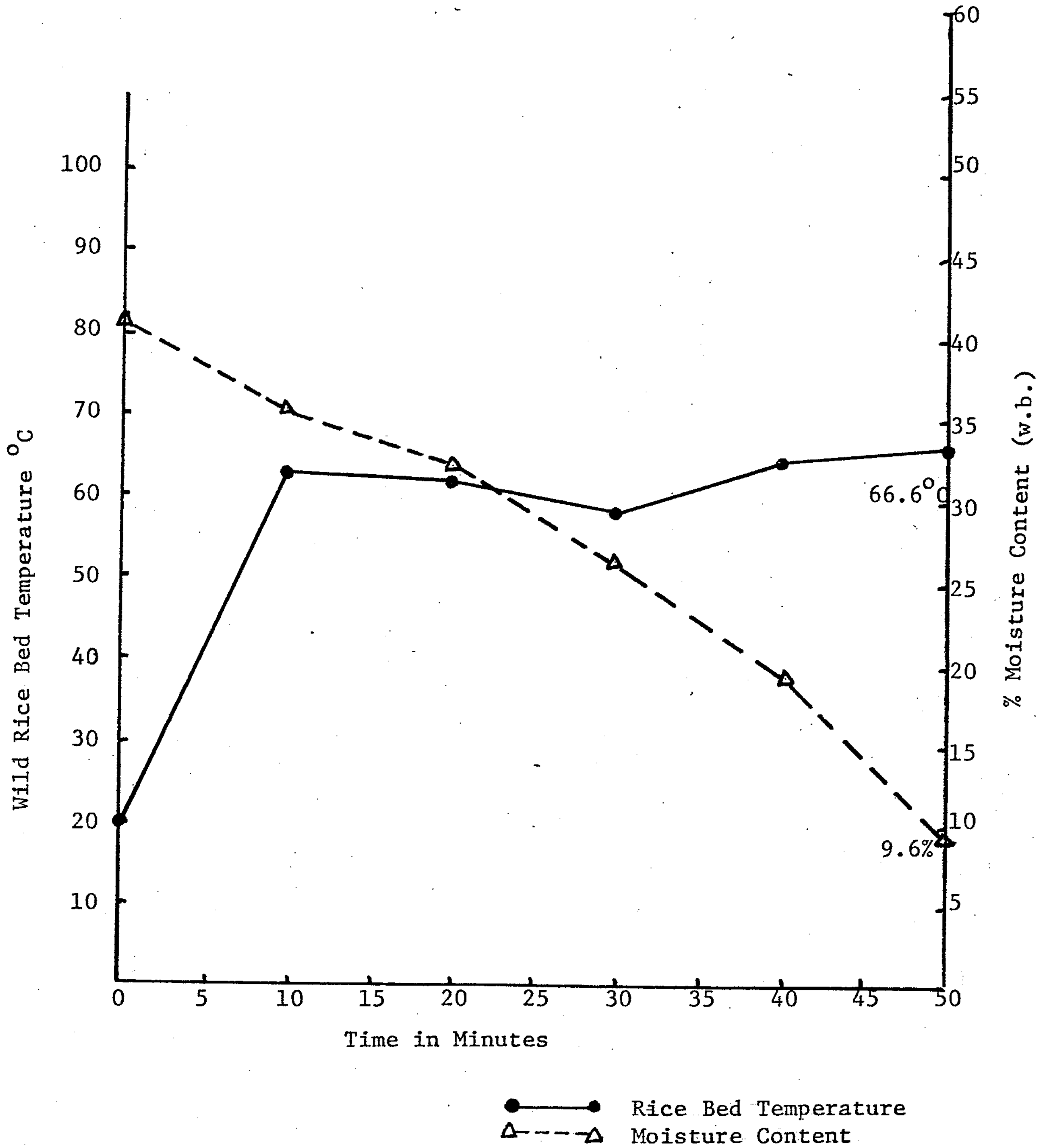


Figure 22. Rice Bed Temperature of Paddy Wild Rice Parched at High Temperature

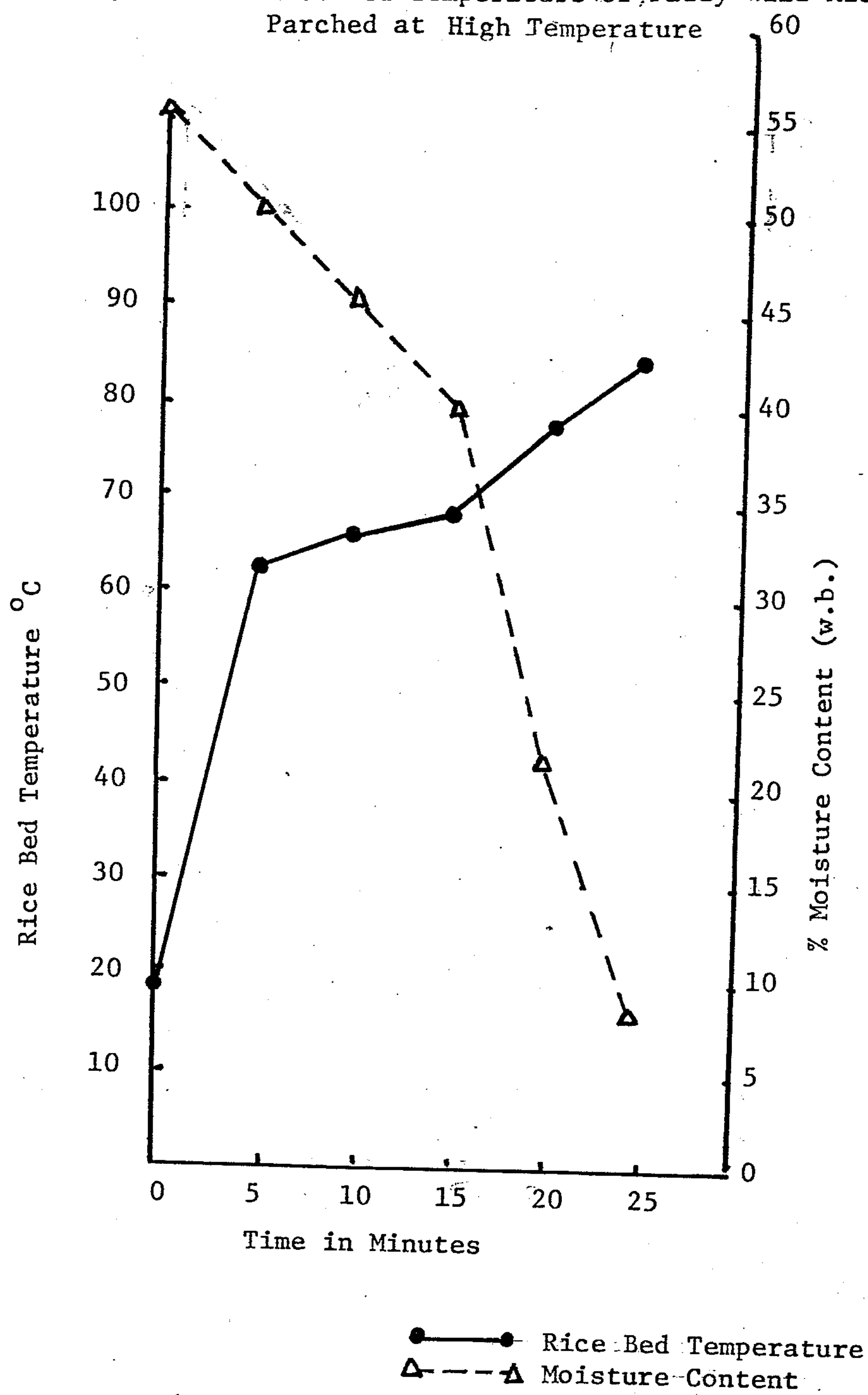


Figure 21. Rice Bed Temperature of Paddy Wild Rice Parched at Low Temperature

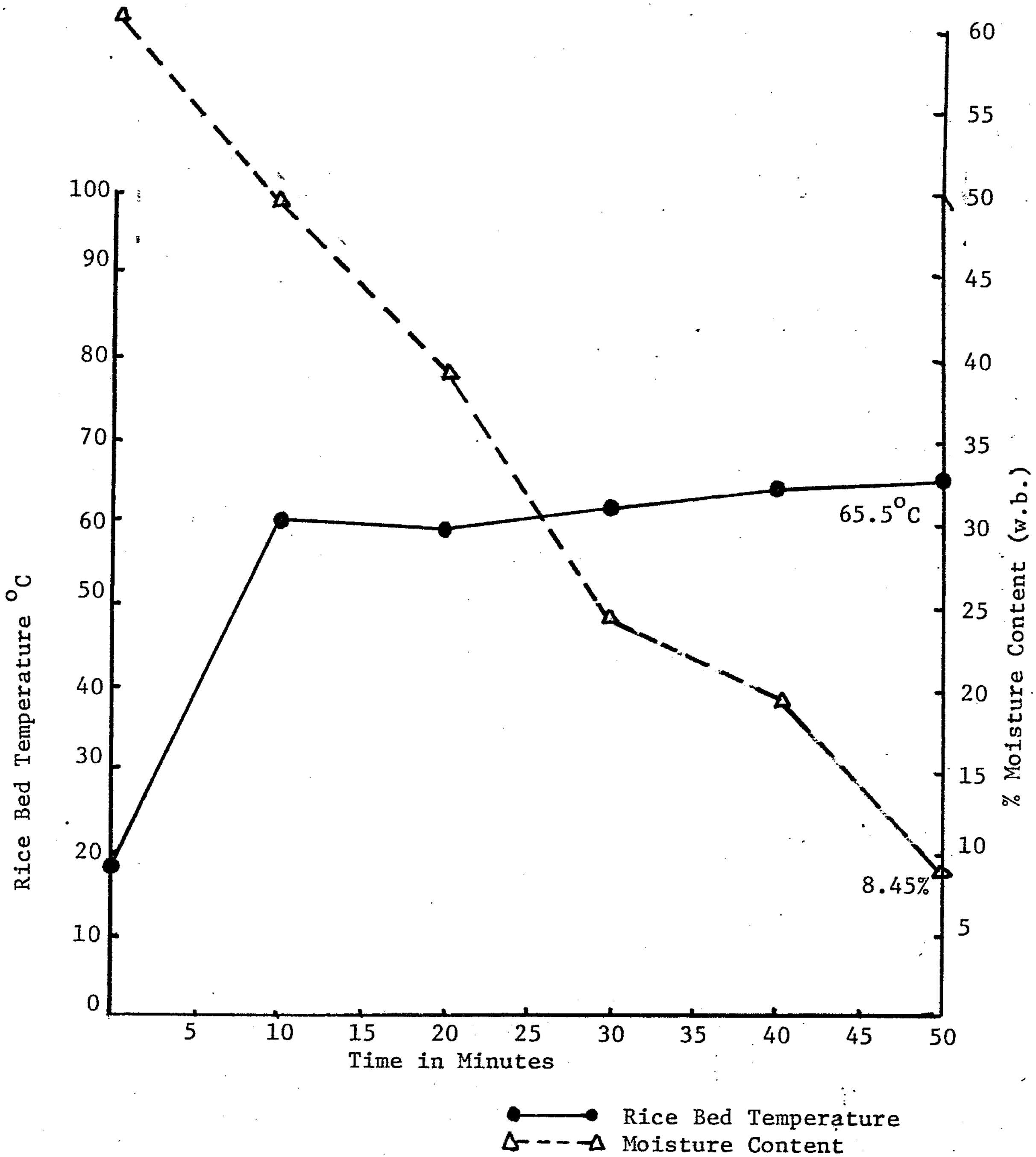


Table 2. Drying Rate of Lake Wild Rice

High Temperature Parching

Time	Air Temperature in ^{o}C	Rice Bed Temp. in ^{o}C	Moisture Content (%)
0	21.0	18.0	42.75
5	70.5	65.0	37.1
10	81.0	71.1	32.8
15	93.3	80.0	25.75
20	121.0	83.3	13.05
25	135.0	87.7	7.70

Table 3. Drying Rate of Lake Wild Rice

Low Temperature Parching

Time	Air Temperature in ^{o}C	Rice Bed Temp. in ^{o}C	Moisture Content (%)
0	20.5	19.0	41.80
5	65.5	62.2	35.45
15	67.5	61.1	33.75
25	69.0	58.8	26.10
35	76.0	65.0	17.20
45	80.0	66.6	9.6

Table 4. Drying Rate of Paddy Wild Rice

High Temperature Parching

Time	Air Temperature in ^{o}C	Rice Bed Temp. in ^{o}C	Moisture Content (%)
0	-	-	55.65
5	77.7	63.9	50.10
10	82.2	66.6	45.72
15	103.3	68.8	39.45
20	113.3	77.7	22.10
25	135.0	83.3	8.5

Table 5. Drying Rate of Paddy Wild Rice

Low Temperature Parching

Time	Air Temperature in ^{o}C	Rice Bed Temp. in ^{o}C	Moisture Content (%)
0	-	19.0	60.4
5	80.5	60.0	49.2
15	87.2	58.8	38.55
25	62.0	61.1	24.30
35	82.2	63.9	19.25
45	82.2	65.5	8.45

Table 6. Final Rice Bed Temperatures and the Corresponding Final Moisture Content of the Rice

Parching Conditions	Lake Wild Rice: Final Moisture Content (%)	Lake Wild Rice: Final Bed Temperature °C	Paddy Wild Rice: Final Moisture Content (%)	Paddy Wild Rice: Final Bed Temperature °C
High Temp. 135°C for 25 minutes	7.7±0.5-9.5±0.5	82.2-87.7	7.5±0.5-9.5±0.5	82.2-87.0
Low Temp. 78.3°C for 50 minutes	7.5±0.5-9.6±0.5	62.7-66.6	7.5±0.5-9.5±0.5	63.2-67.3

4.2.3. Finished Rice Yield

The percentage yield of wild rice (whole and broken kernels) varied with the different processing techniques. It was mainly affected by curing times and temperatures and parching temperatures. The percentage whole lake rice are rice kernels larger than 1 cm, which was the weight of whole kernels after hulling and cleaning, was also affected by these same factors. Yield data are presented in Figures 23 to 34.

The yield of finished wild rice was 40 - 54% for 1973 lake rice and 47 - 57% for 1974 lake rice cured at 10°C (Figures 23, 24). This range was 44 - 60% for 1973 and 1974 lake rice cured at 21.1°C (Figures 25, 26). The range at 31.1°C was 55 - 60% in 1973, while in 1974 it was 35 - 62% (Figures 27, 28). The higher yield was obtained in the early stages of curing for all the environments. The 1973 lake rice yield dropped approximately 7 - 8% after the 4th week in the 10°C environment (Figure 23). There was no noticeable yield drop in the 1974 crop at this temperature (Figure 24).

For lake rice cured at 21.1°C the yield dropped approximately 10% after 5 days (Figures 25, 27, 26, 28).

Data for the yield of finished paddy rice cured at 10, 21.1 and 31.1°C are presented in Figures 29 to 34. The yield did not fluctuate very much at 10°C ranging from 28 - 34% in 1973 and from 16 - 22% in 1974 (Figures 29, 32). When cured at 21.1°C the yield of finished rice ranged from 28 - 40% in 1973 and from 17 - 23% in 1974 and for rice cured at 31.1°C these figures were 30 - 40% for 1973 and 23 - 30% for 1974 (Figures 31, 32, 33, 34).

Figure 23. The Percent Yield of 1973 Lake Wild Rice Cured at 10°C

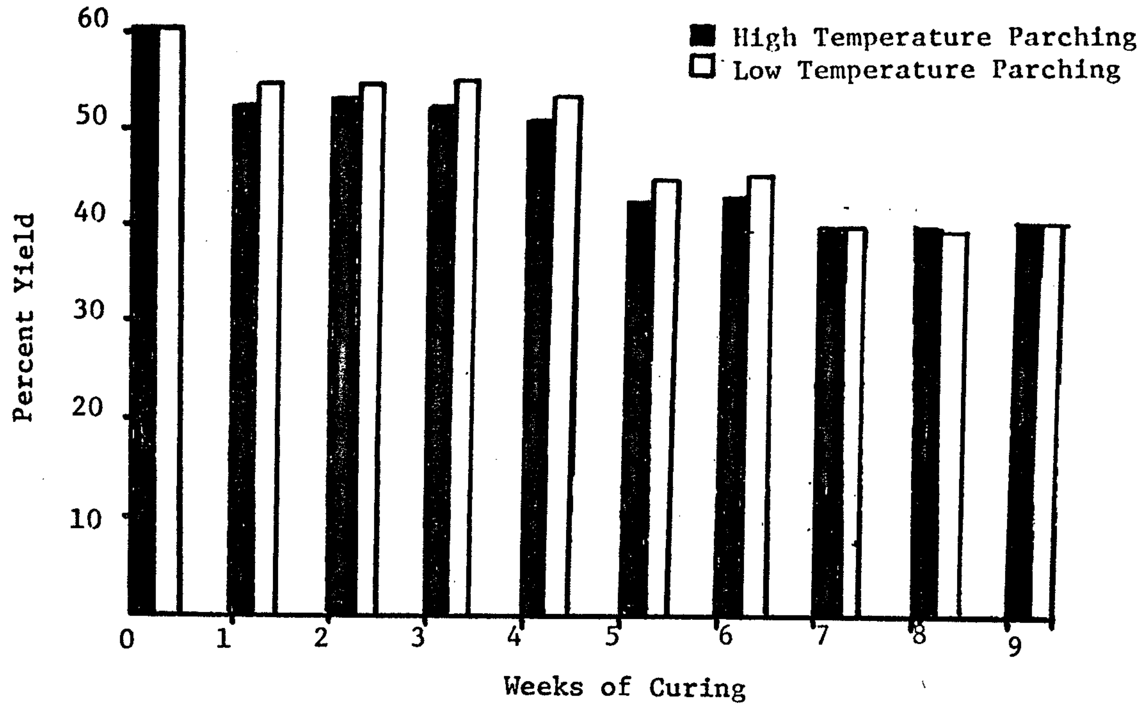


Figure 24. The Percent Yield of 1974 Lake Wild Rice Cured at 10°C

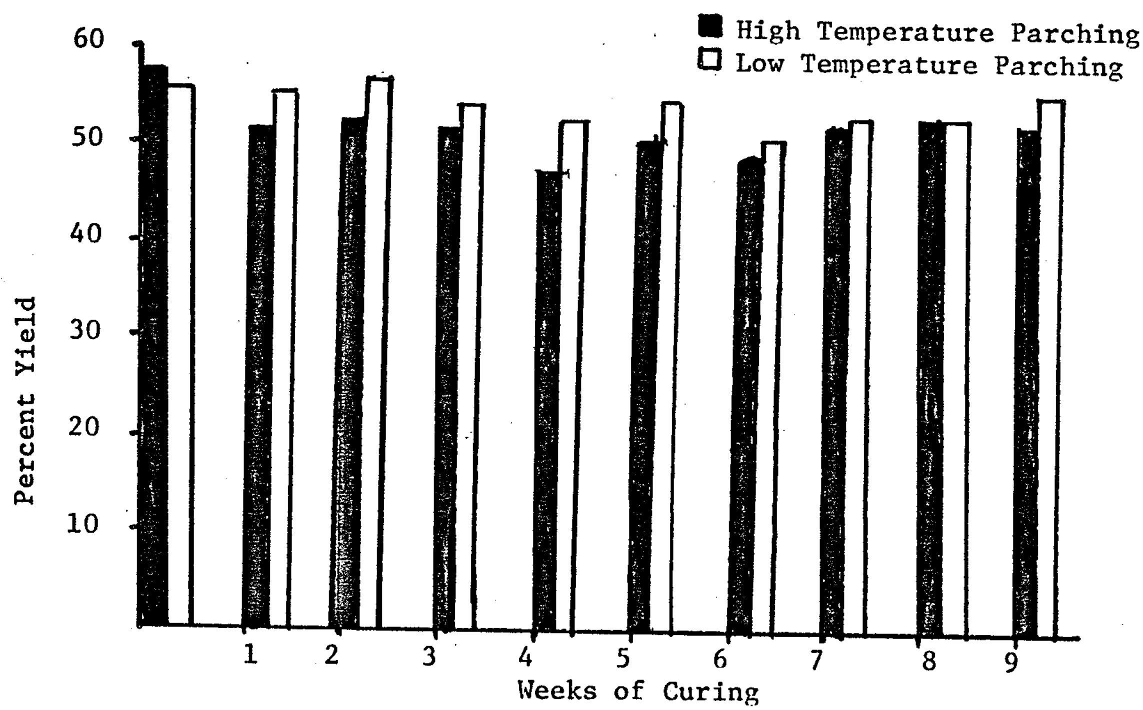


Figure 25. The Percent Yield of 1973 Lake Wild Rice Cured at 21.1°C

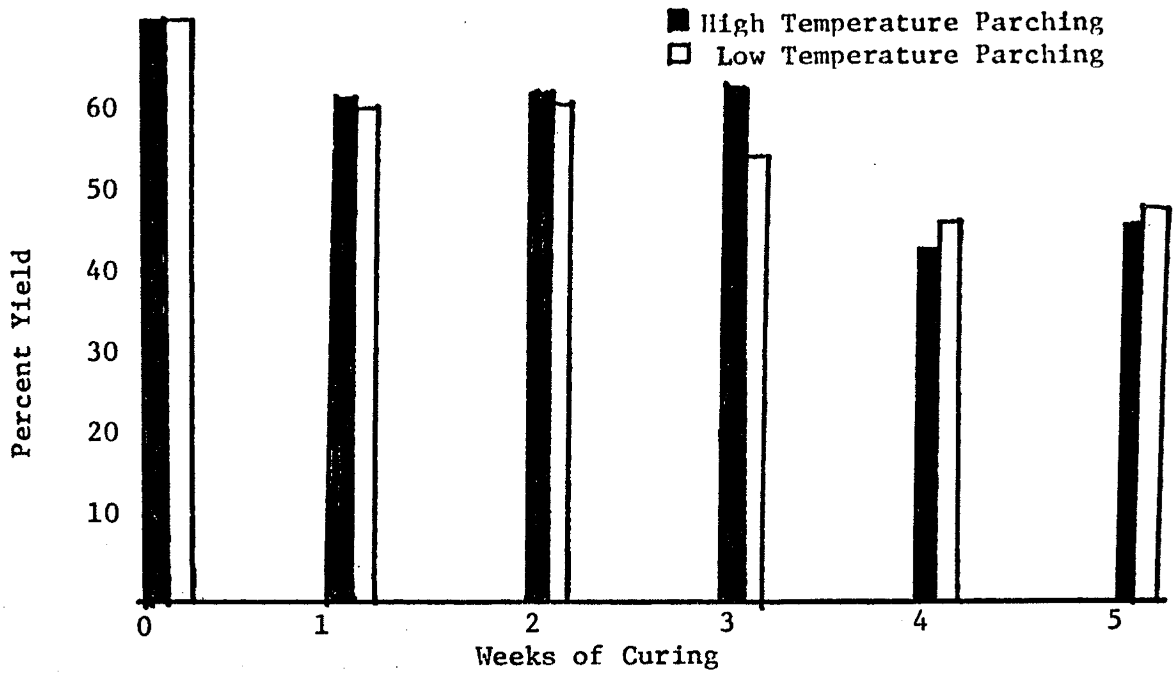


Figure 26. The Percent Yield of 1974 Lake Wild Rice Cured at 21.1°C

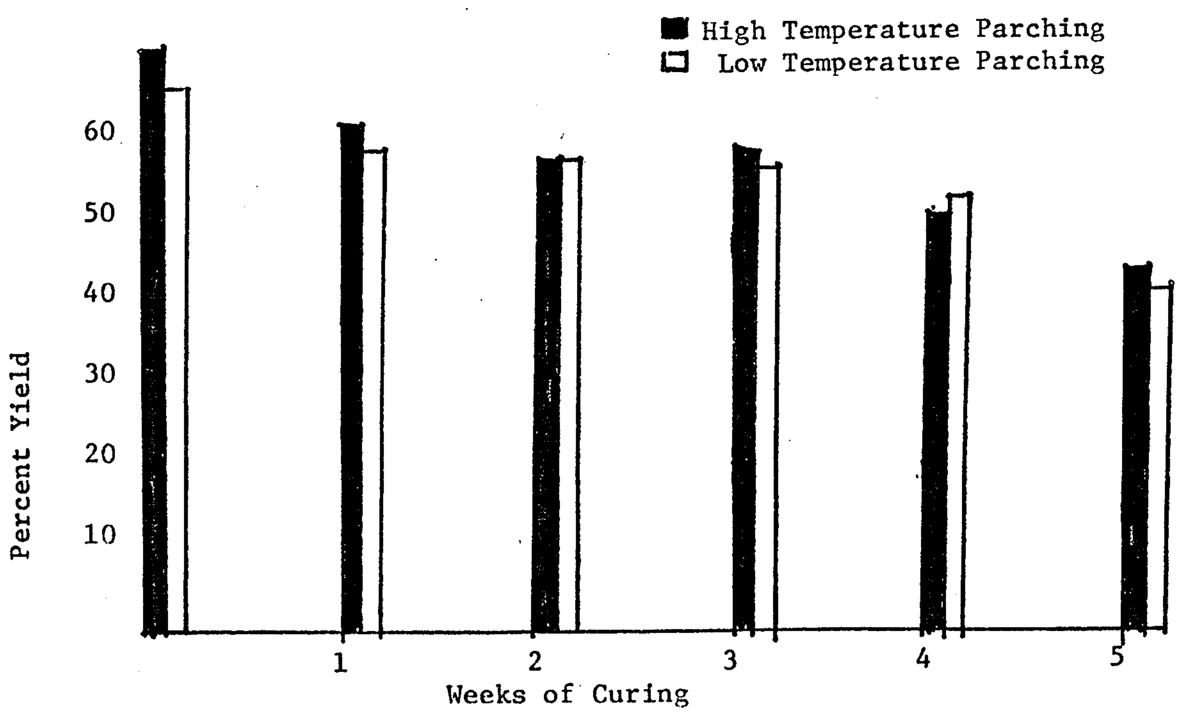


Figure 27. The Percent Yield of 1973 Lake Wild Rice Cured at 31.1°C

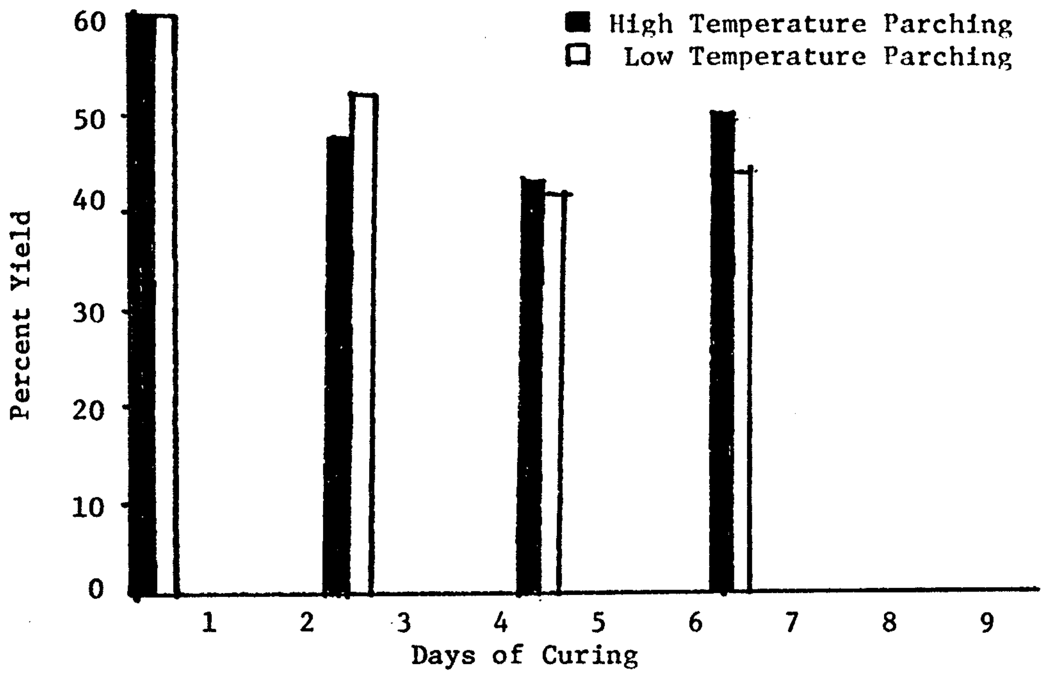
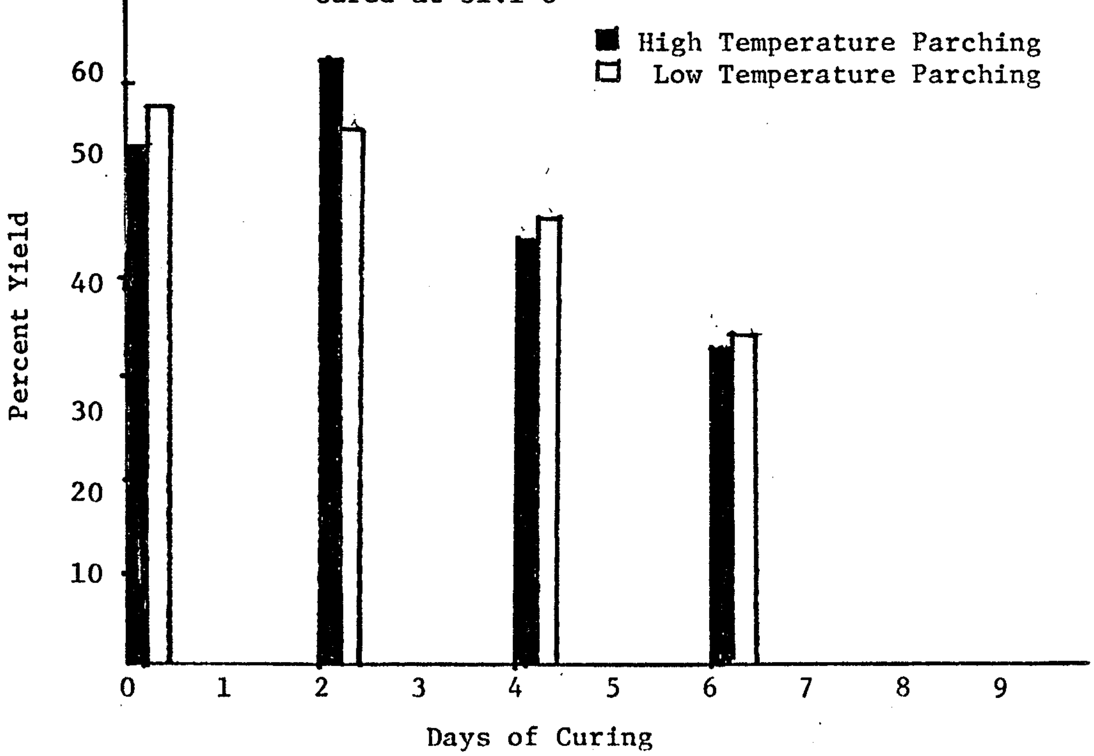


Figure 28. The Percent Yield of 1974 Lake Wild Rice Cured at 31.1°C



Figures 29. Percent Yield of 1973 Paddy Wild Rice Cured at 10°C

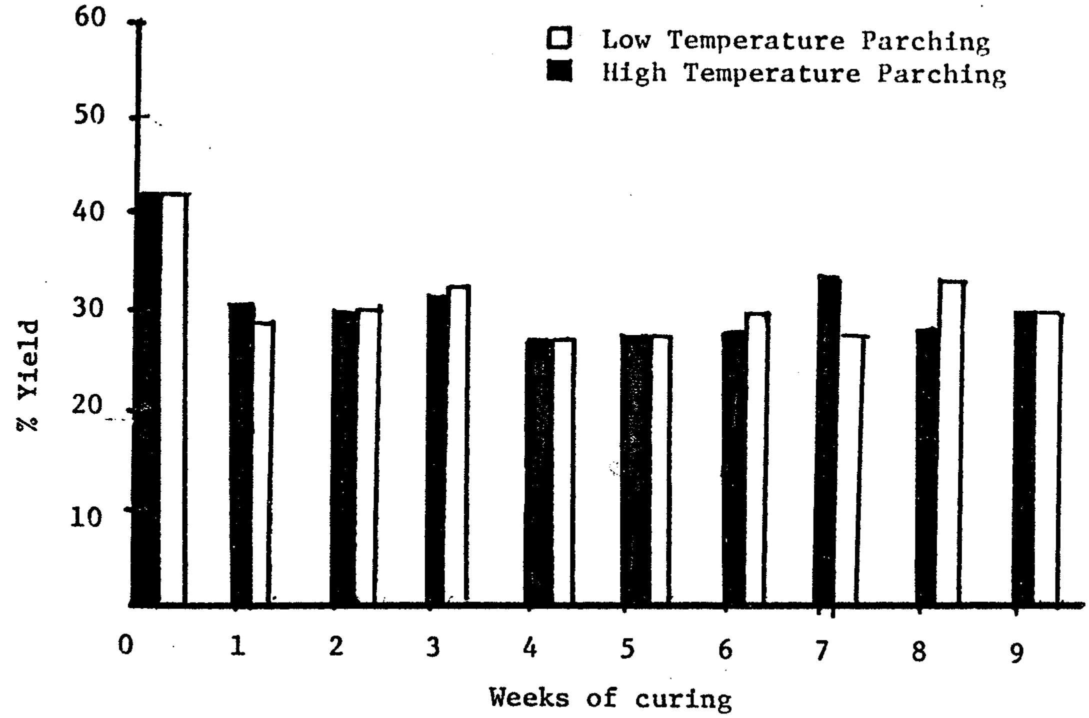


Figure 30. Percent Yield of 1974 Paddy Wild Rice Cured at 10°C

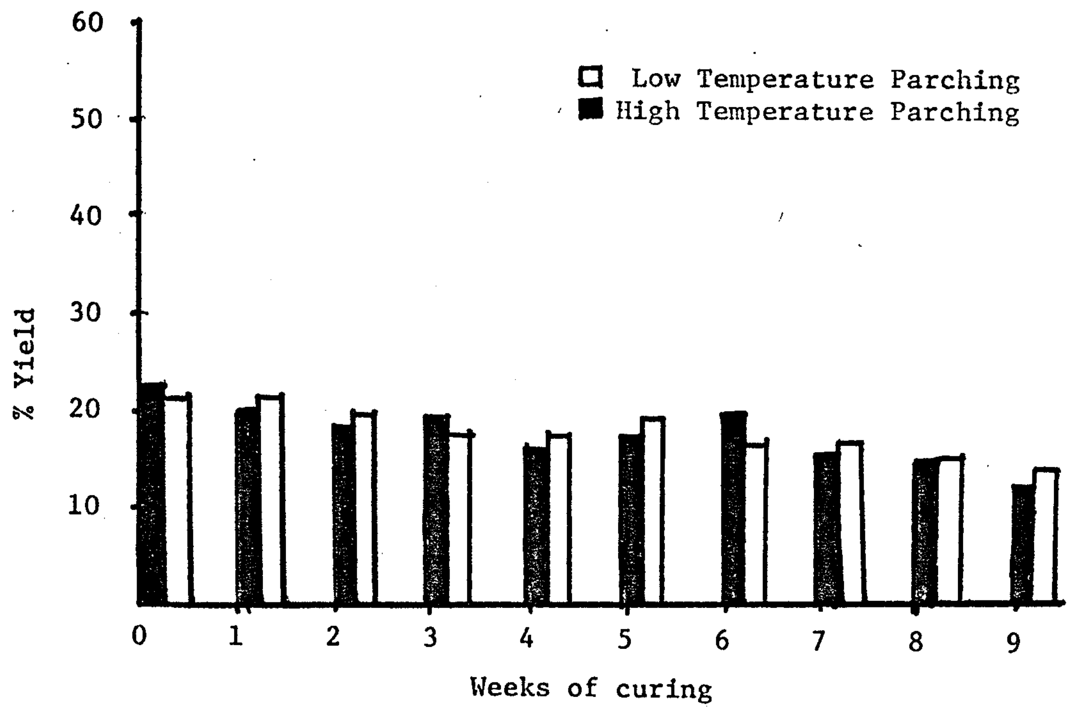


Figure 31. Percent yield of 1973 Paddy Wild Rice Cured at 21.1°C

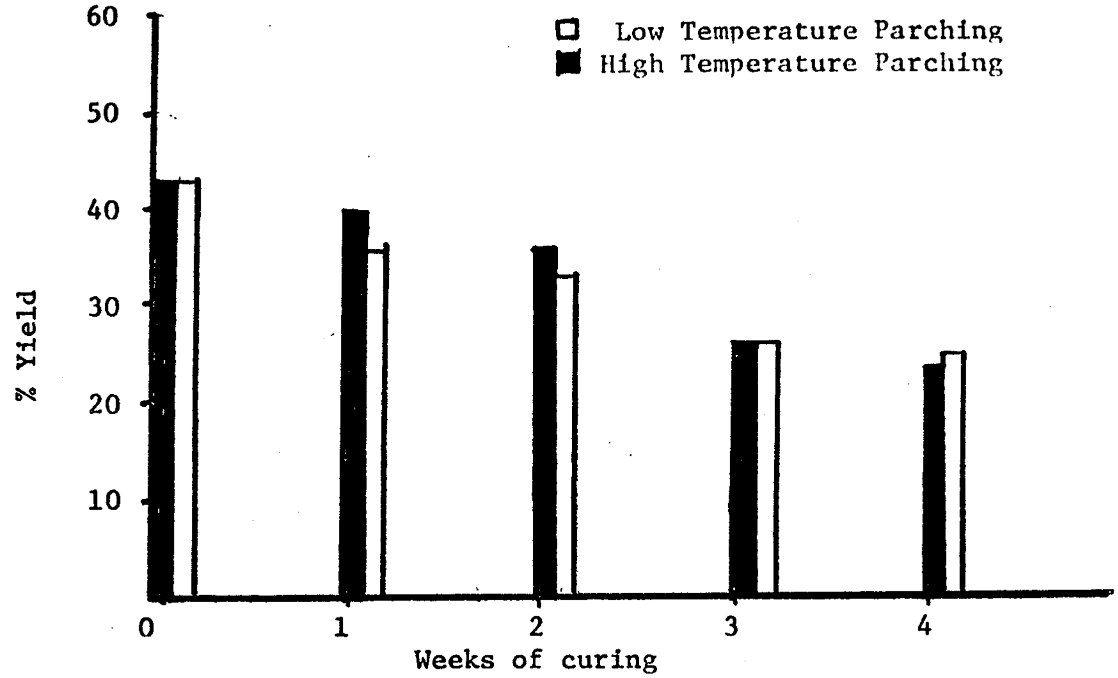


Figure 32. Percent Yield of 1974 Paddy Wild Rice Cured at 21.1°C

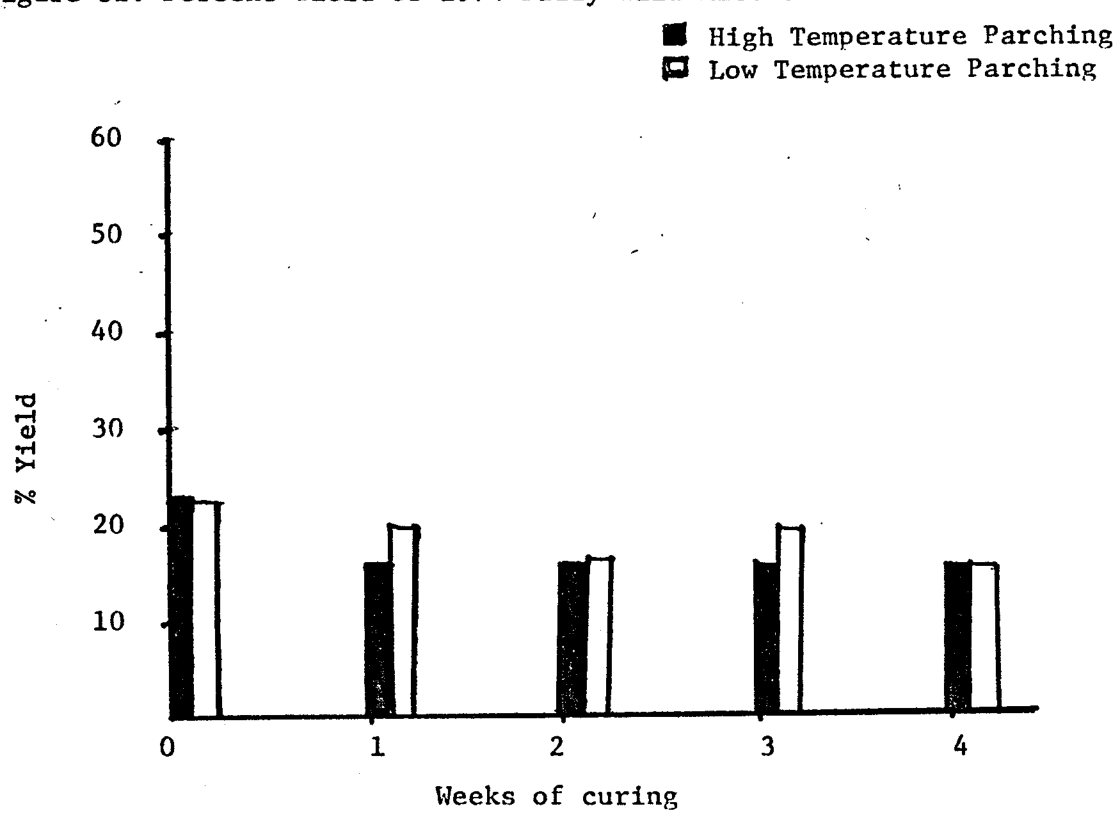


Figure 33. Percent Yield of 1973 Paddy Wild Rice Cured at 31.1°C

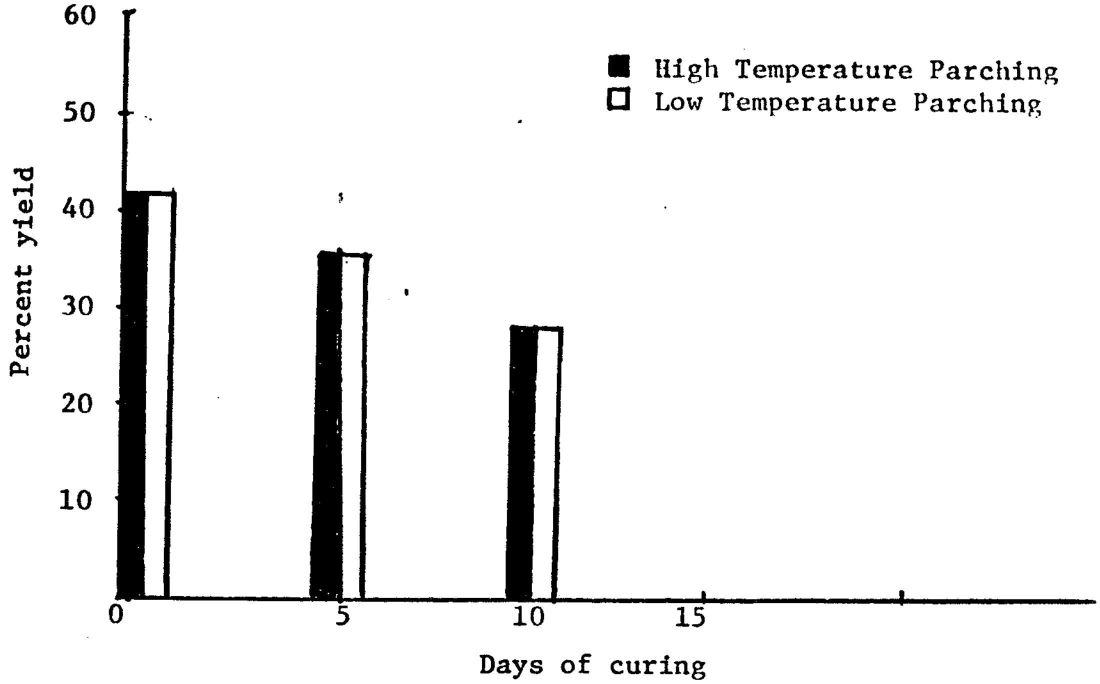
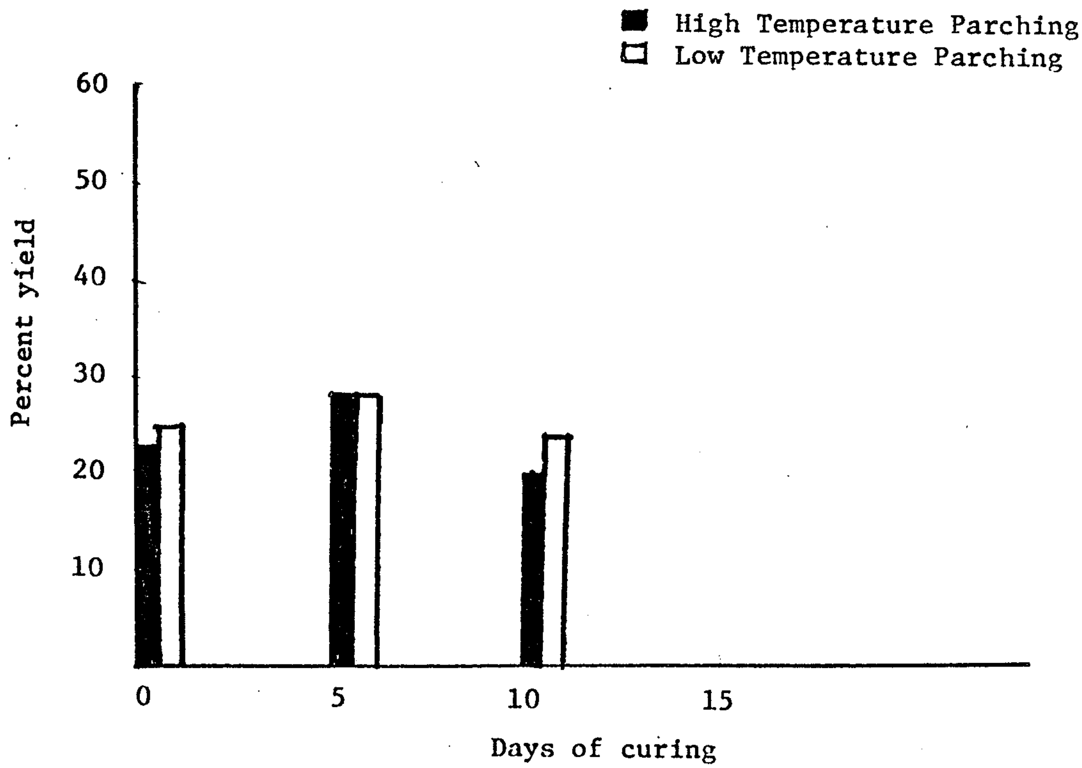


Figure 34. Percent Yield of 1974 Paddy Wild Rice Cured at 31.1°C



There was a significant difference in yield between lake and paddy wild rice. This was due to the inability of the variety Algot. Johnson Wild rice (which was used in paddy production in Manitoba) to develop to proper maturity under the growing conditions experienced in Manitoba. Because of this, many of the kernels in the curing waste away or did not develop properly into well cured finished kernels. This can only be improved when proper varieties are developed for paddy production.

The use of low temperature i.e. $10^{o}C$ for curing was the more desirable system for paddy and lake wild rice. This system gives the processor a more consistent high yield of finished rice. When higher temperatures i.e. $21.1^{o}C$ and $31.1^{o}C$ were used high yields are initially produced but if it was necessary to hold the rice for an extended period of time before further processing could be carried out, then the yield of finished rice will drop.

The parching temperature appeared to have an effect on the percentage yield of wild rice. The data indicated that low temperature parching had a higher yield than high temperature parching (Figures 23 - 34). This implied that the rice produced by low temperature parching weighed more than rice from high temperature parching. There might be two reasons to this. Firstly, in most cases in the parching trials, a high parching temperature resulted in a relatively lower final moisture content and this resulted in less weight in the final product. Secondly, high temperature meant faster rate of drying. The sudden induction of high temperature to the rice kernels caused centre part of the kernels (mainly carbohydrate) to shrink rapidly and become more fragile. Finally, the centre part would start to split from heat energy. Once the material at the rice centre had separated, the heat energy started to build up and forced the rice to expand in size. After parching, the rice kernels looked larger, but the centre part was hollow. Some rice even cracked on the outside. However, this phenomenon occurred only when the parching temperature was higher than the desirable temperature (135°C) or the parching process was not properly controlled. The kernels with hollow centres would certainly weigh less. High temperature parching not only brought about a lower yield of the rice but also brought about poor quality rice. This rice had a burnt flavour, absorbed more water during cooking and had a mushy texture and appearance after cooking. Low temperature parching was able to over come these problems. Rice parched at low temperatures dried slowly, gradually gelatinized and cooked to a desirable appearance and texture.

The yield of whole wild rice was also investigated in these studies. Any wild rice with a kernel length of 10 m.m. or longer was considered as whole rice regardless of whether it was broken or not. Any kernel less than 10 m.m. was considered broken. Figures 35 - 40 give the percentage yield of whole rice by weight. The data indicate that the crop year and the freezing treatment before processing had little effect on the yield of whole rice, but that, the curing time and temperature had a significant effect. The percent yield of whole rice started to decrease after 2/3 of the curing time for all the curing environments. These environments apparently produce more fragile kernels.

We were unable to obtain positive results for the percent yield of whole paddy wild rice. This was because all the paddy wild rice obtained from the past two seasons seemed to be quite "immature".

Figure 35. The Percent of 1973 Whole Lake Wild Rice Kernels Cured at 10°C

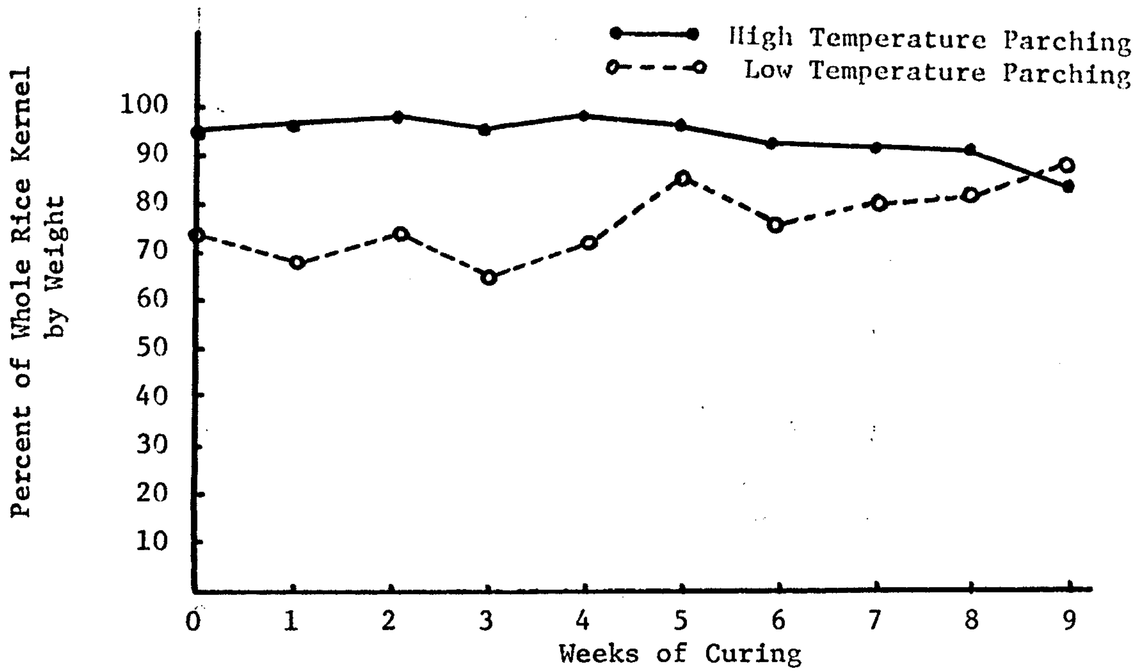


Figure 36. The Percent of 1974 Whole Lake Wild Rice Kernels Cured at 10°F

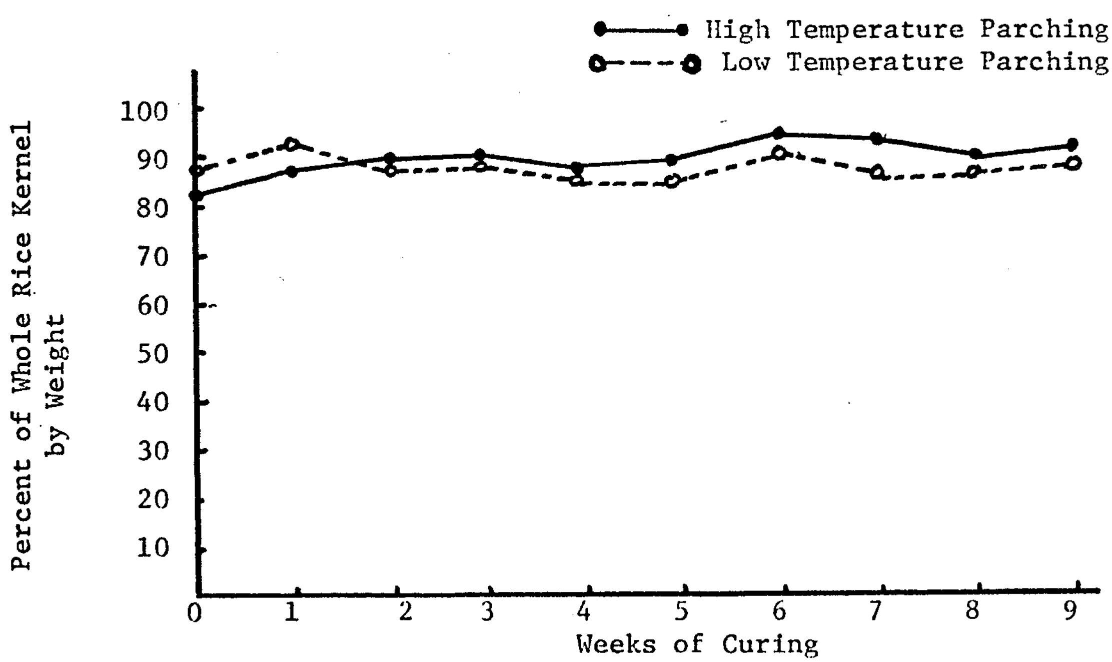


Figure 37. The Percent of 1973 Whole Lake Wild Rice Kernels Cured at 21.1^{o}C

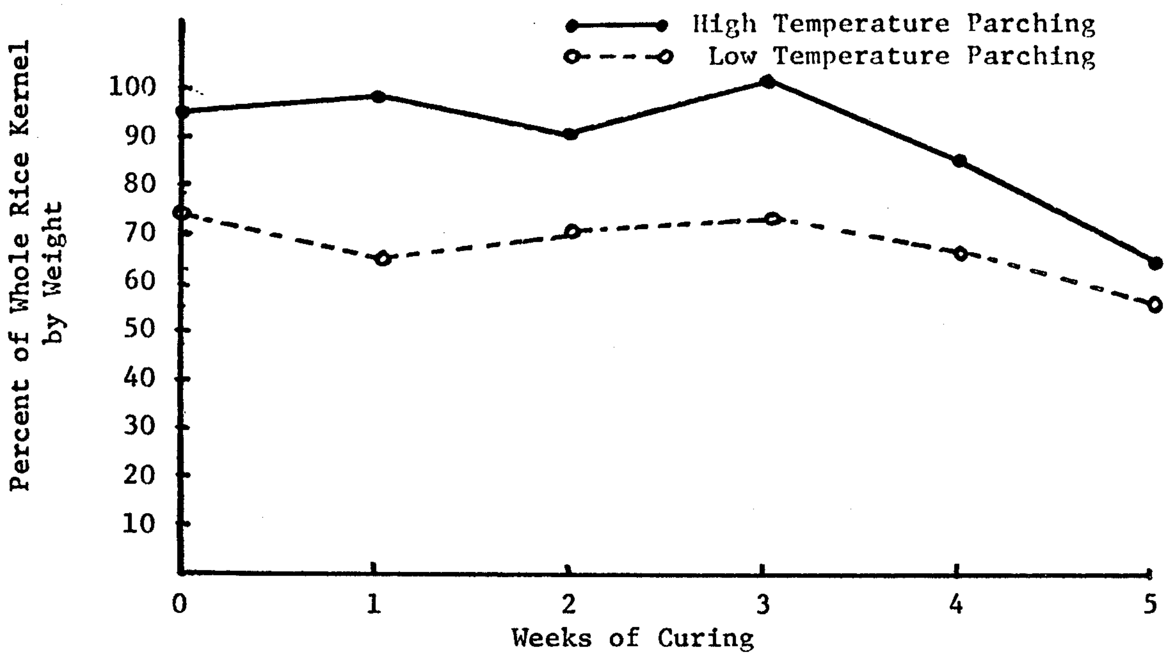


Figure 38. The Percent of 1974 Whole Lake Wild Rice Kernels Cured at 21.1^{o}C

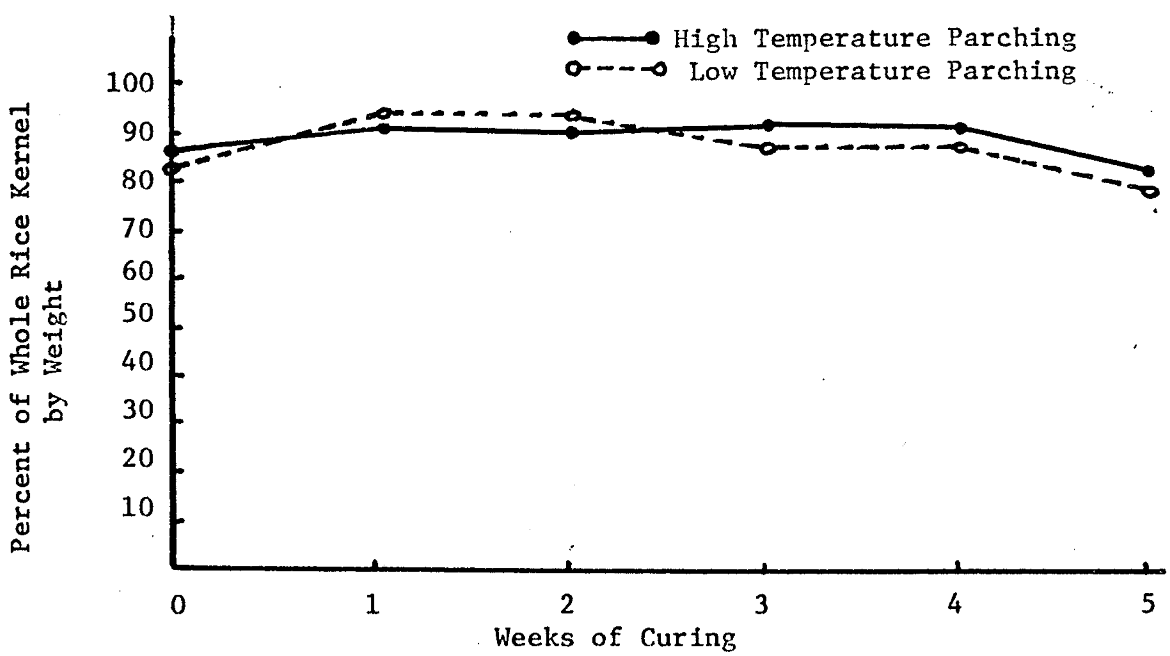


Figure 39. The Percent of 1973 Whole Lake Wild Rice Kernels Cured at 31.1°C

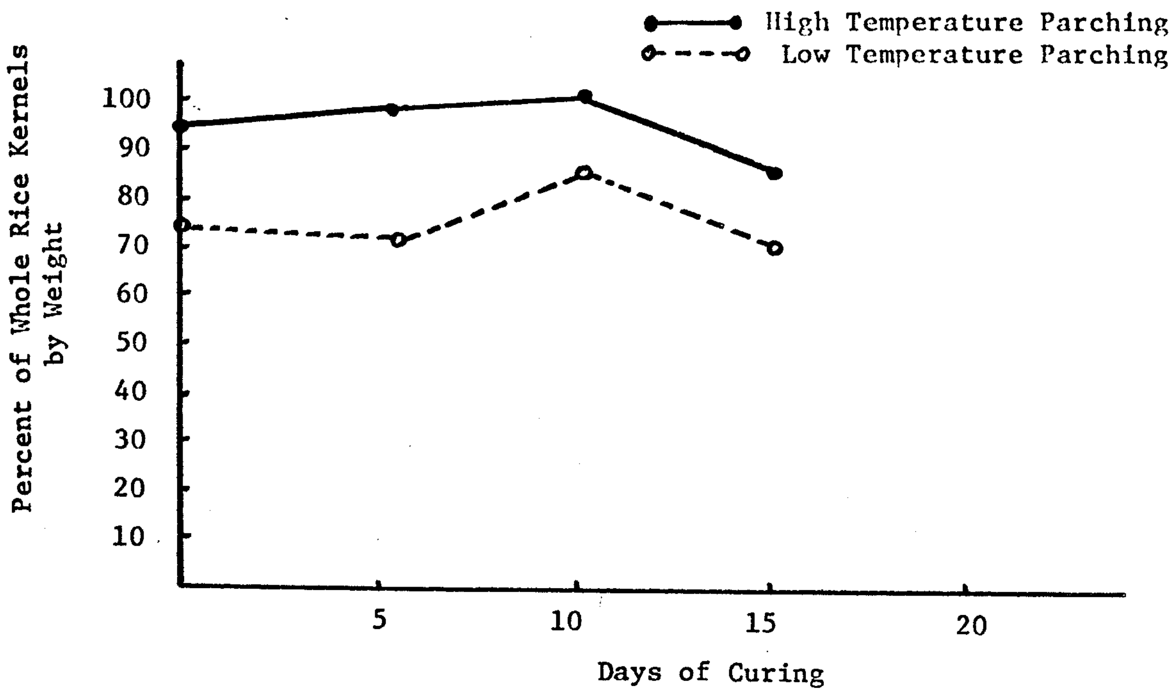
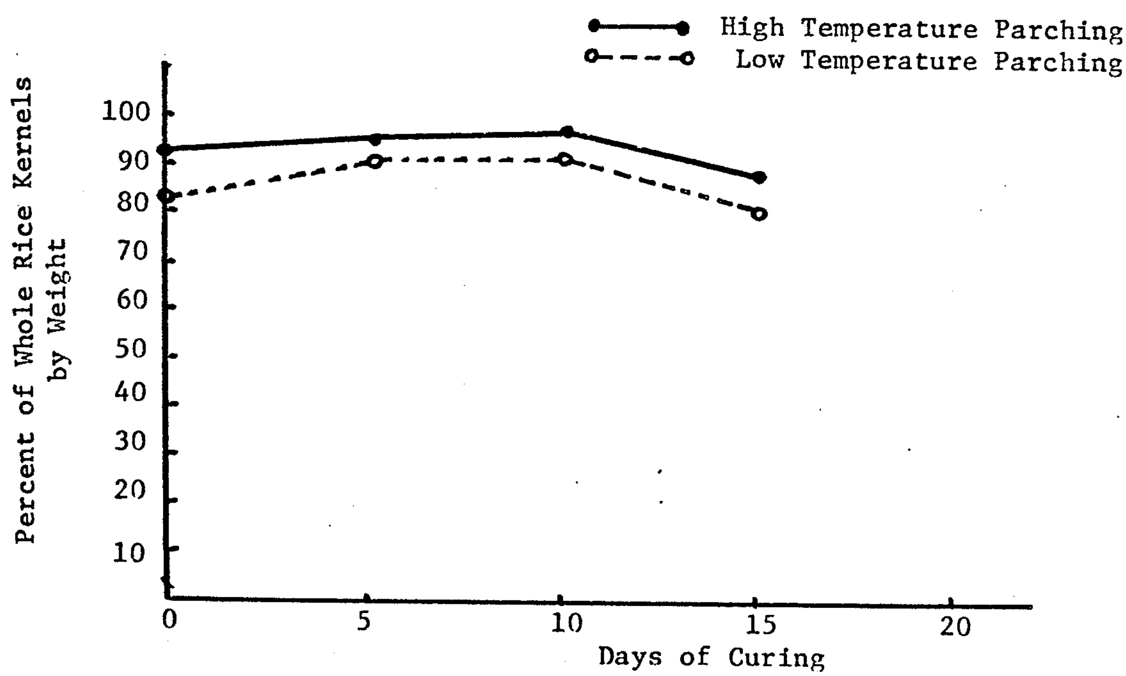


Figure 40. The Percent of 1974 Whole Lake Wild Rice Kernels Cured at 31.1°C



The kernels were thin and small. However, when comparing the two years' paddy wild rice visually, the 1973's finished rice had a longer kernel length.

4.2.4. Flavour, Appearance and Texture of Finished Wild Rice

The main objective of this study was to evaluate the effect of curing and parching on the appearance, flavour and texture of finished wild rice.

The experimental design of the sensory study was that of a randomized block. The data analyses were carried out on the University of Manitoba's IBM 360 system using the Stat 13 program (47). In addition to the analysis of variance on the data, Duncan's Multiple Range Test (1,21), was used to compare the means obtained for each test cured for different time periods. The results of the analysis and the flavour profile of wild rice are present in Appendices 3 - 37.

The sensory panel data showed a common pattern of flavour development by wild rice regardless of the curing environments used (Appendices 2 - 25). For example, in Appendices 2 to 7, the swampy odour was getting stronger as curing time progressed and the mouldy-like flavour was also intensified. The pattern of flavour development established by the panelists was given in Appendices 2 - 25, and the following pattern was used for judging the acceptability of wild rice.

1. The swampy odour and mouldy-like flavour were intensified as curing time lengthened. The panel considered this to be unacceptable.

2. The grainy odour and taste decreased as the rice became more "mature" and the colour darkened. A strong grainy flavour was not desirable.

3. The tea-like flavour became less intense towards the end of curing. A strong tea-like flavour was not desirable.

4. For high temperature parching, the burnt flavour was more easily detected during the later stages of curing. This might be due to the slimy texture of the wild rice which caused the rice to stick together and adhere to the inside walls of the roaster, thereby producing the toasted or burnt flavour. However, a little burnt flavour was considered to be necessary by the panelists (Figures 41 - 52).

According to the consensus of the sensory panel, the flavour of an acceptable wild rice should have a mild grainy and tea-like flavour. The rice should be free of any swampy and putrid odour and taste. A faint mouldy-like, earthy and burnt flavour were also considered to be acceptable. For example, the rice cured at 10°C produced a more acceptable rice than rice cured at higher temperatures (21.1°C and 31.1°C). The main reason was that rice cured at the higher temperatures had a fairly strong swamp odour and mouldy taste (Figures 41, 43, 45 and Appendices 2, 4, 6).

The development of the unacceptable swampy odour, and the mouldy and earthy flavour was more pronounced during high temperature curing (21.1°C and 31.1°C) than with low temperature curing (10°C), (Appendices 2 - 25). Apparently wild rice respires more rapidly and produced more heat during high temperature curing (21.1°C and 31.1°C), (Figures 9 - 12), thereby causing more flavour deterioration in the finished product (Appendices 2 - 25) than did low temperature curing (Figures 7 - 8).

Colour and kernel breakage were the main factors used to judge the acceptability of the appearance of wild rice. However, the results of the acceptability scales (Figures 41 - 52), and ΔE values (Figures 13-18),

Figure 41. Acceptability scale for 1973 lake wild rice cured at 10°C

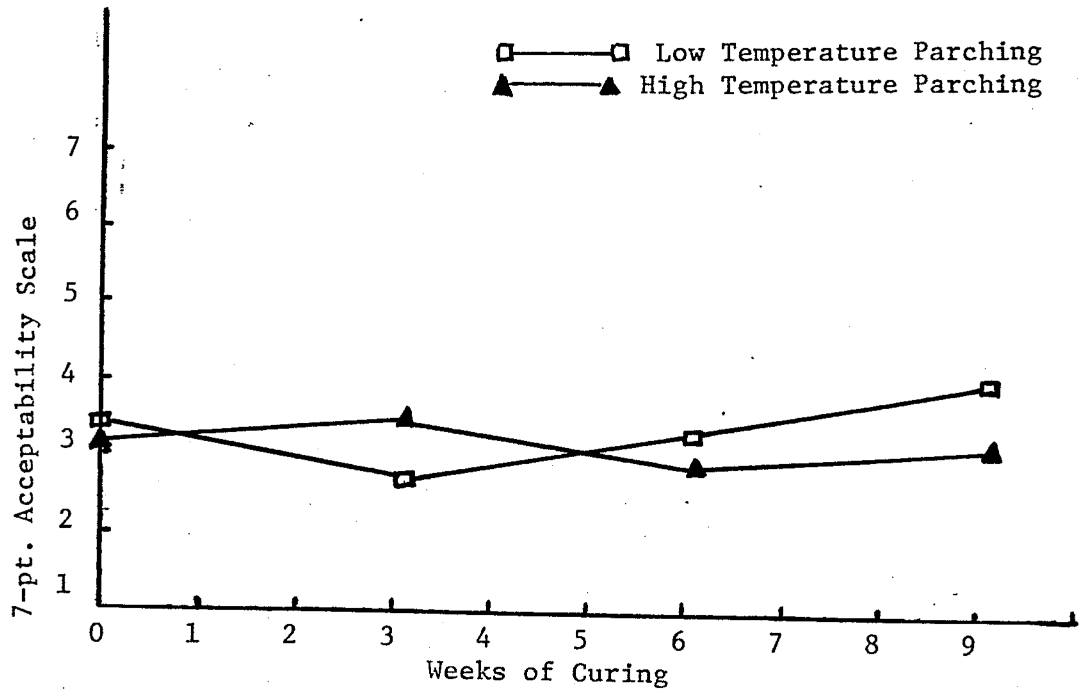
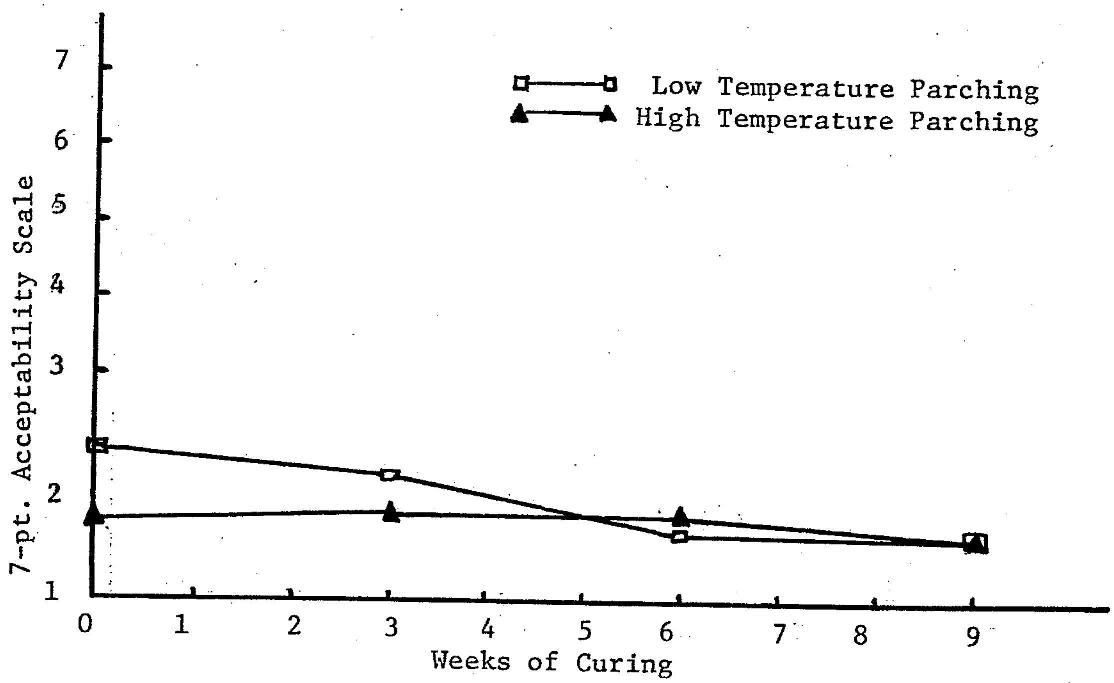


Figure 42. Acceptability Scales for 1974 lake wild rice cured at 10°C



1 indicates extremely acceptable
7 indicates extremely unacceptable

Figure 43. Acceptability Scale for 1973 Lake Wild Rice Cured at 21.1°C

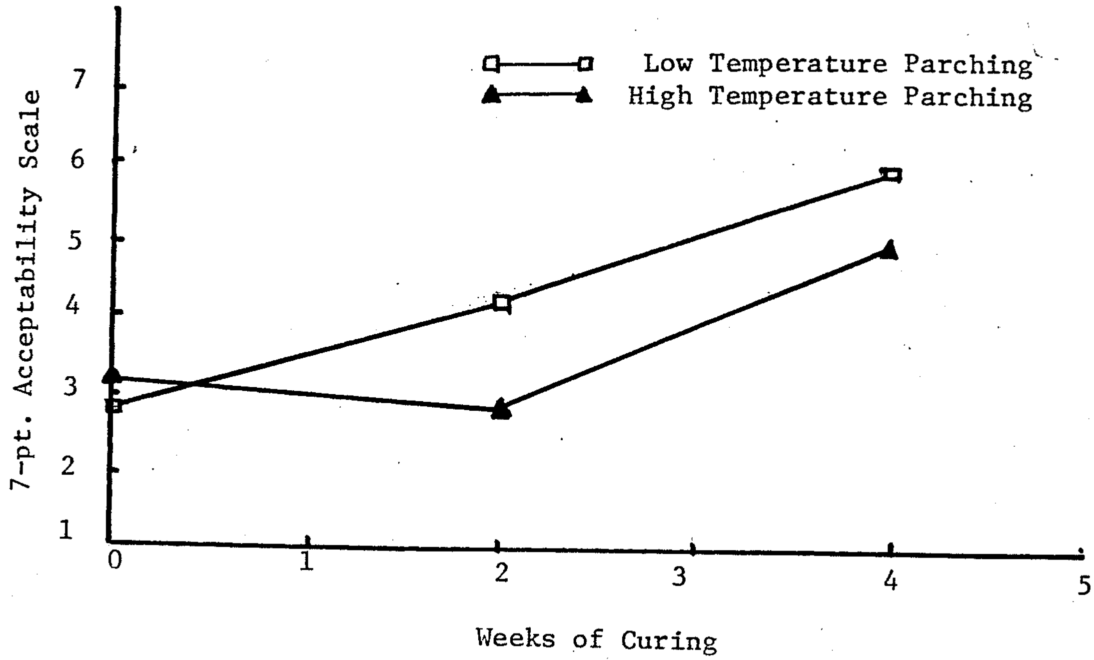
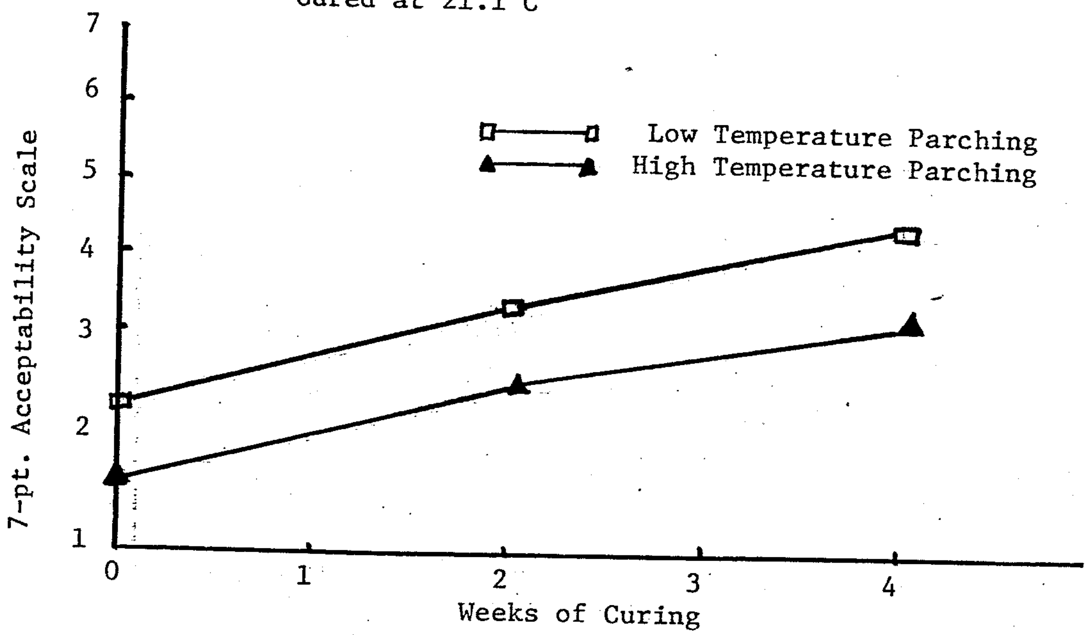


Figure 44. Acceptability Scale for 1974 Lake Wild Rice Cured at 21.1°C



1 indicates extremely acceptable
7 indicates extremely unacceptable

Figure 45. Acceptability Scales for 1973 Lake Wild Rice Cured at 31.1°C

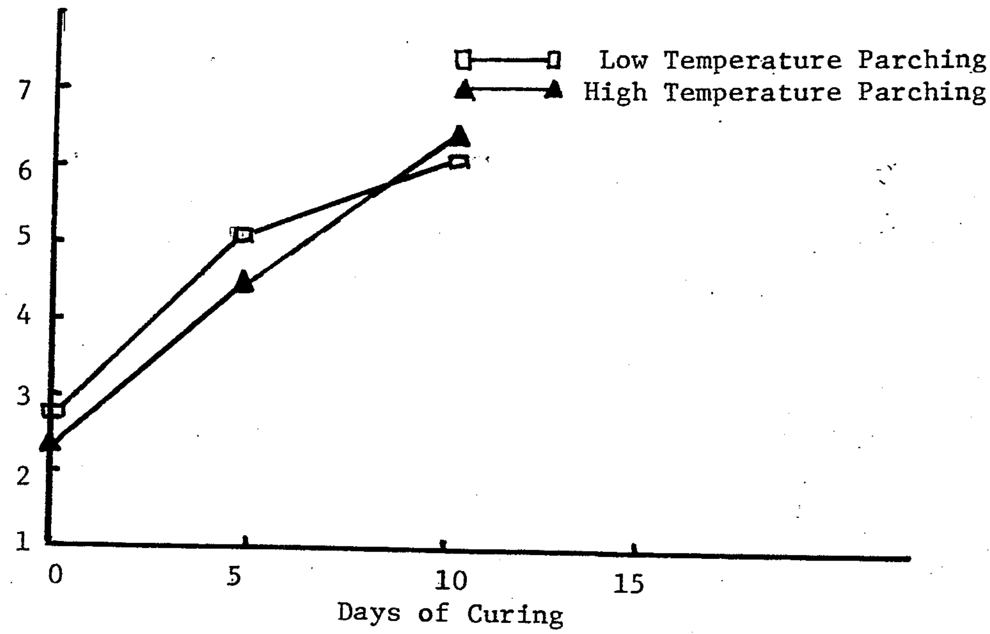
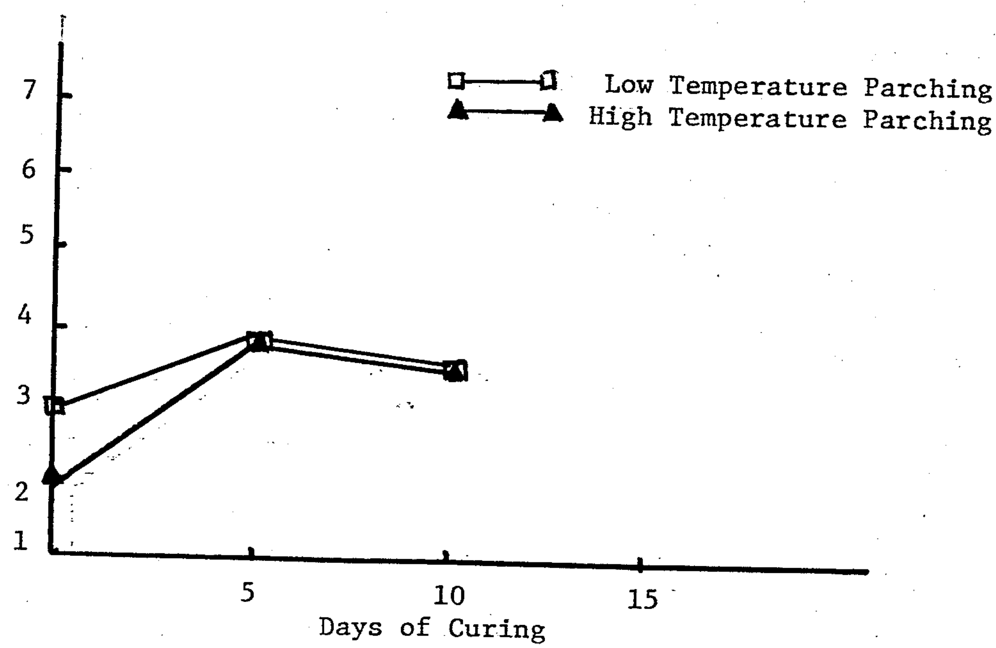


Figure 46. Acceptability Scale for 1974 Lake Wild Rice Cured at 31.1°C



1 indicates extremely acceptable
7 indicates extremely unacceptable

Figure 47. Acceptability Scale for 1973 Paddy Wild Rice Cured at 10°C

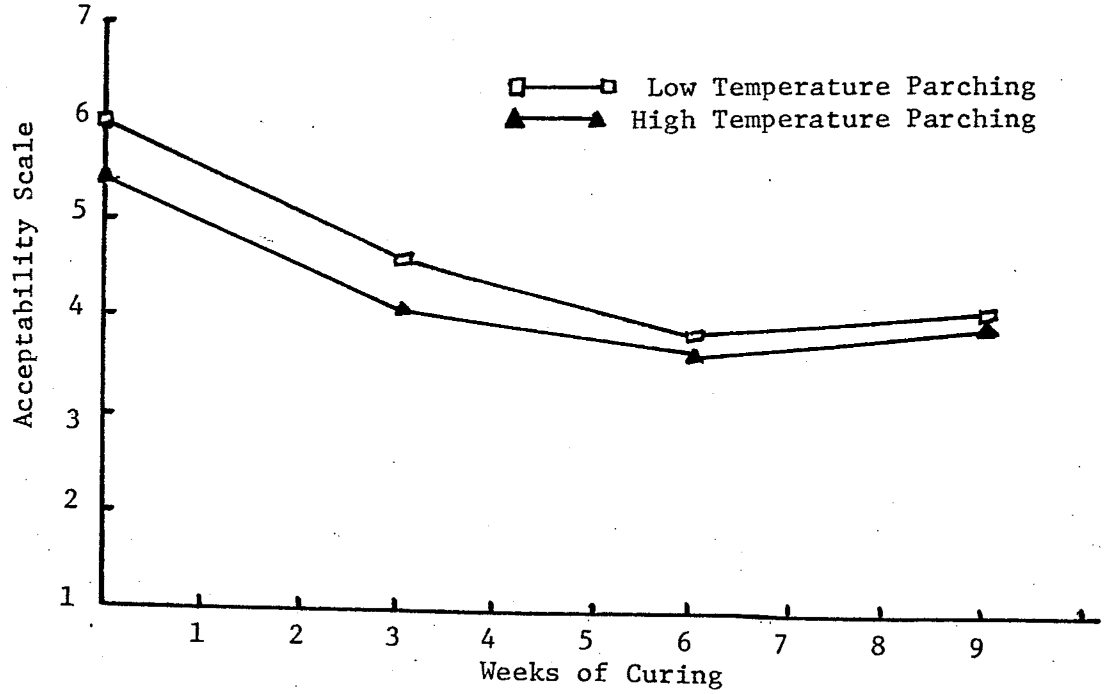
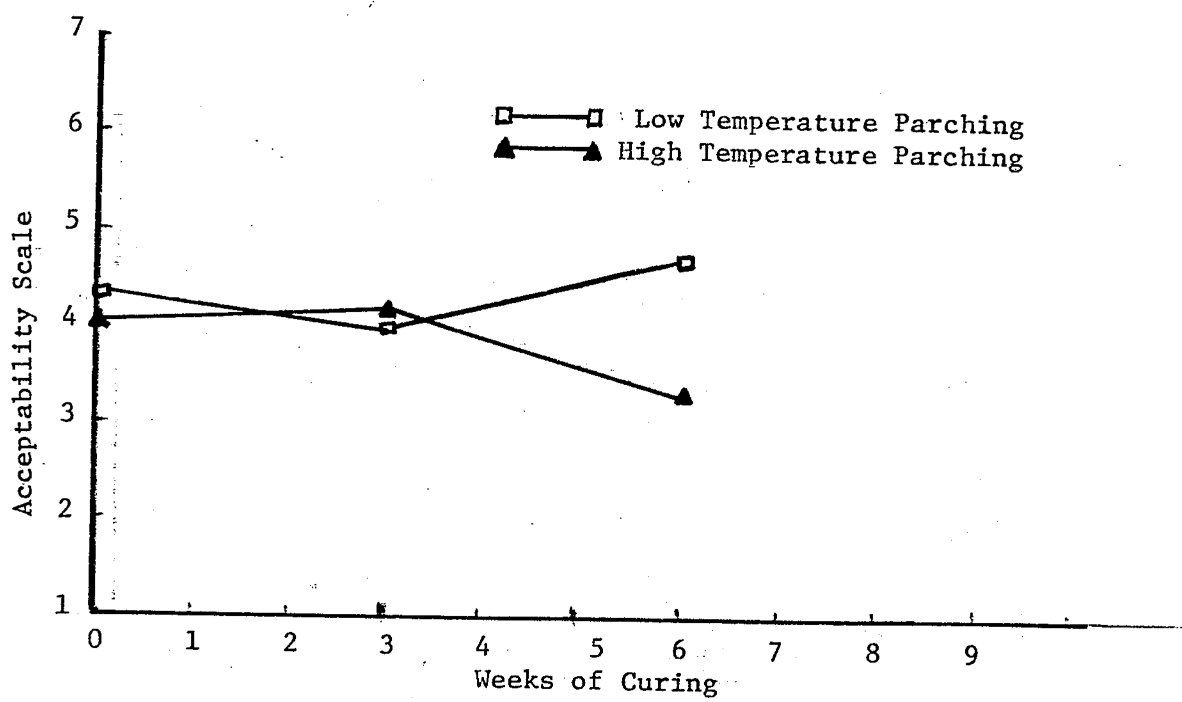


Figure 48. Acceptability Scale for 1974 Paddy Wild Rice Cured at 10°C



1 indicates extremely acceptable
7 indicates extremely unacceptable

Figure 49. Acceptability Scales for 1973 Paddy Wild Rice Cured at 21.1°C

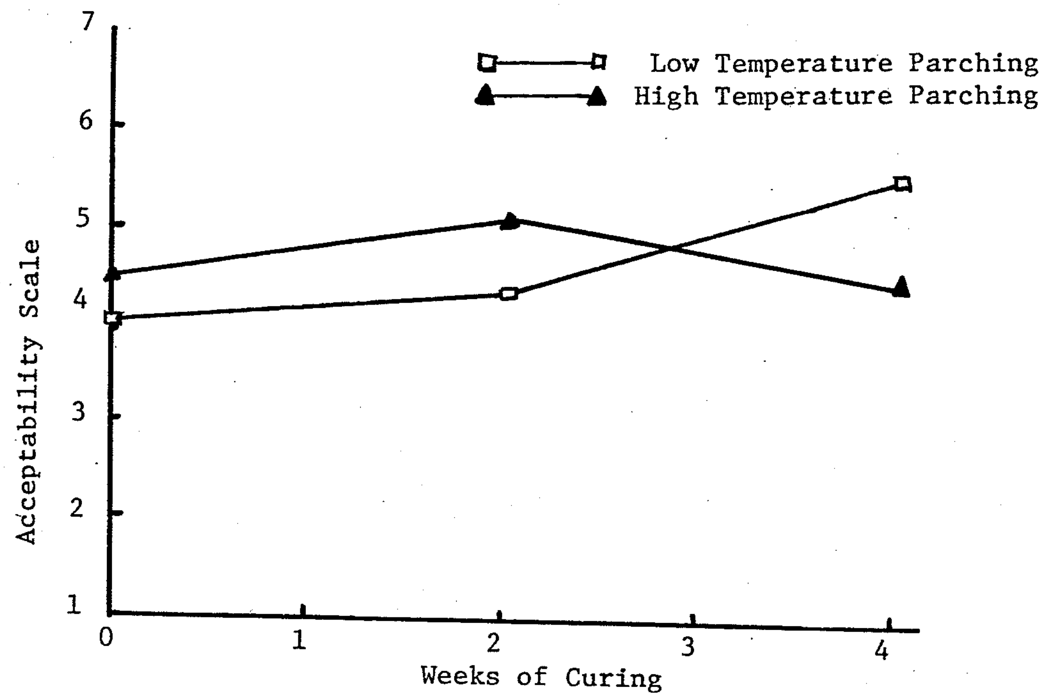
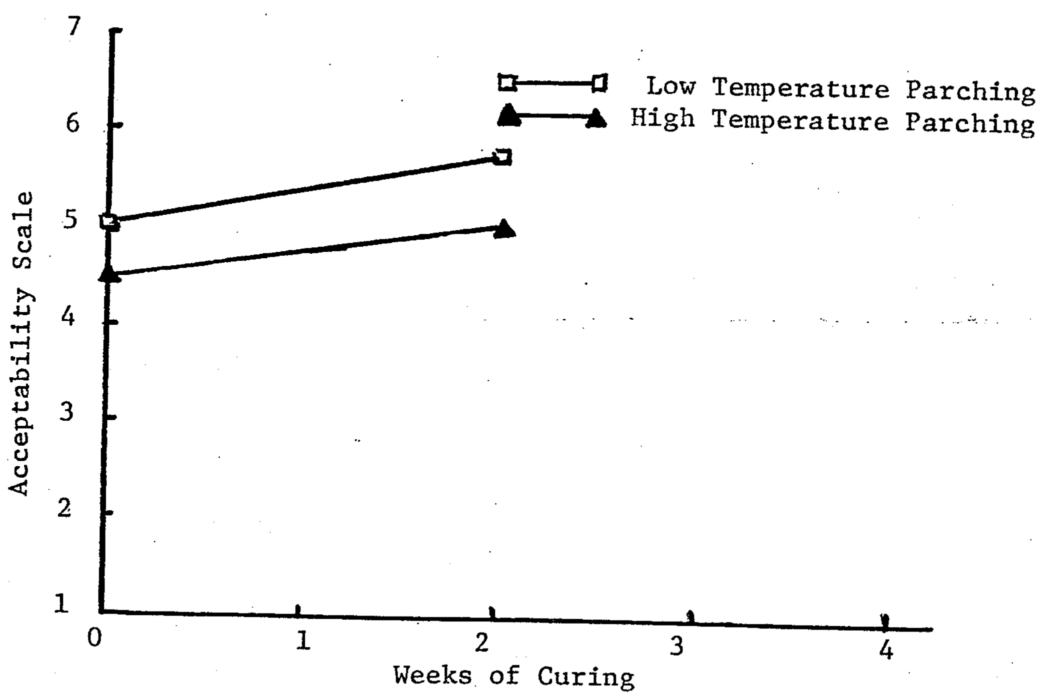


Figure 50. Acceptability Scale for 1974 Paddy Wild Rice Cured at 21.1°C



1 indicates extremely acceptable
7 indicates extremely unacceptable

Figure 51. Acceptability Scale for 1973 Paddy Wild Rice Cured at 31.1°C

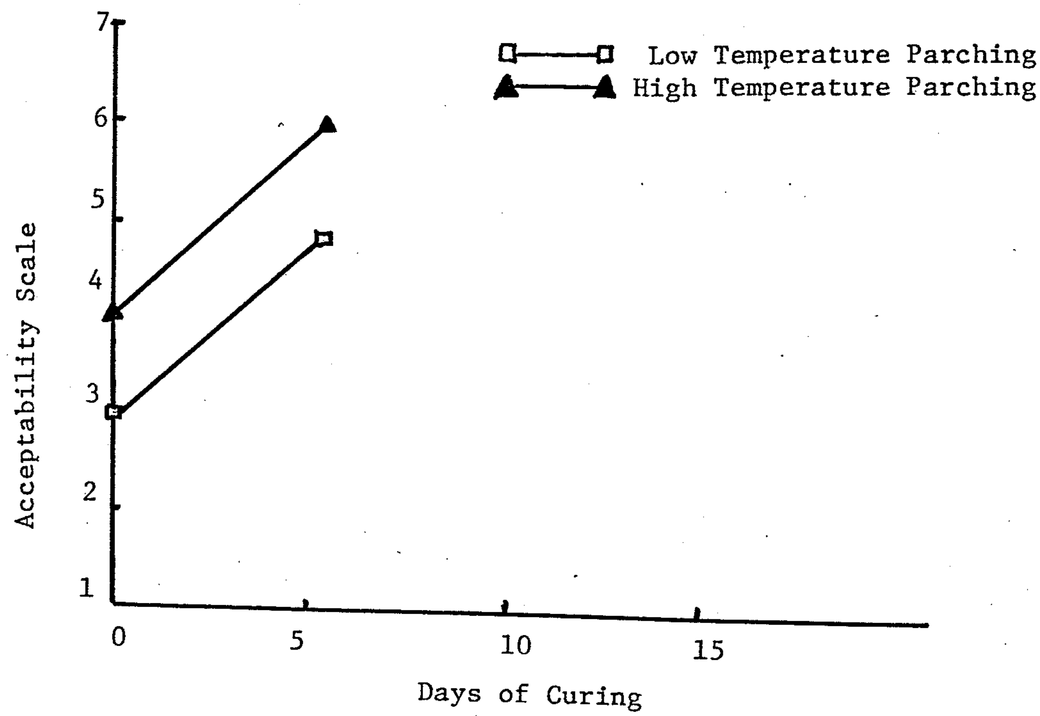
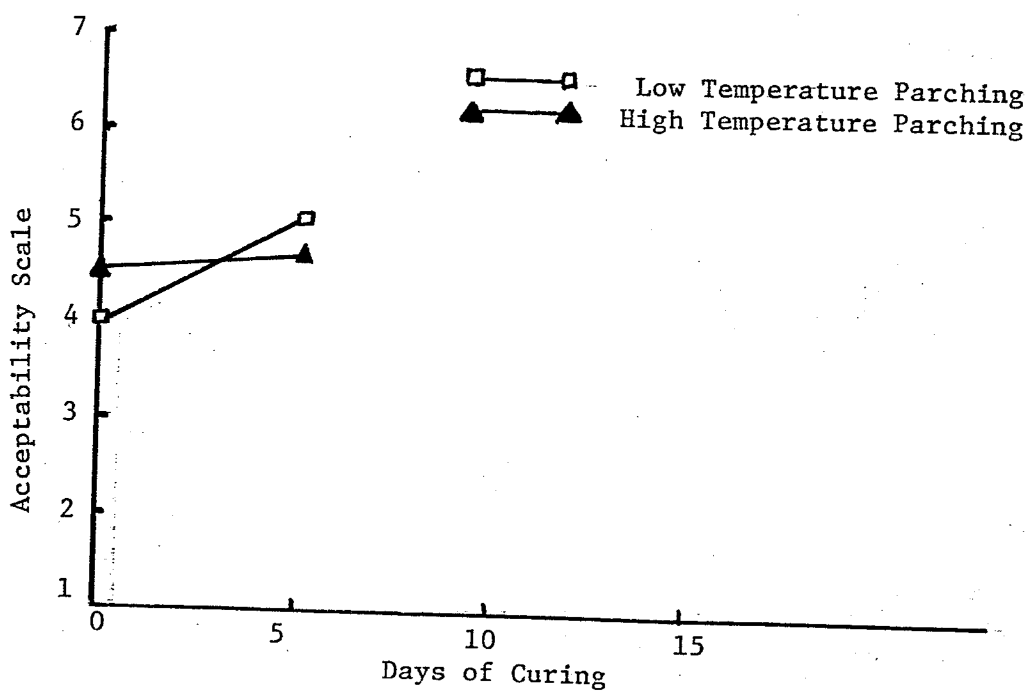


Figure 52. Acceptability Scale for 1974 Paddy Wild Rice Cured at 21.1°C



1 indicates extremely acceptable
7 indicates extremely unacceptable

colour was not considered to be the main criterion for judging the acceptability of wild rice. The 1974 lake wild rice had a lighter colour than the 1973 lake wild rice (Figures 13 - 15), but the 1974 rice was more acceptable (Figures 41 - 46). This indicated that the development of a darker colour in the rice did not coincide with the development of well accepted flavour.

Sensory panel data indicated that green paddy wild rice and paddy and lake wild rice from the later stages of curing had a higher percentage of broken kernels after cooking (Appendices 3 - 26). The reason was due to the "immaturity" of the green paddy wild rice and the physical breakdown of rice after prolonged curing.

According to the sensory panel results, a sample of cooked wild rice that was not mushy, neither too hard nor too soft, with some cohesiveness and chewiness was considered to have an acceptable texture (Figures 41 - 52), Appendices 2 - 25). The results also indicated that paddy wild rice was less acceptable than lake rice and this was partly due to its poor texture. Paddy wild rice was softer and more cohesive than lake rice (Figures 41 - 52, Appendices 2 - 25).

Curing had an effect on the texture of wild rice. As the curing time progressed the texture changed from soft to firm, then to soft. Parching also had an effect on the texture of wild rice. High temperature parching seemed to produce wild rice with a mushier texture after cooking (Appendices 2 - 25).

Statistical analysis of variance and Duncan's Multiple Range Test showed that lake and paddy wild rice cured at different periods of time produced rice which were significantly different in flavour, appearance and texture (Appendices 26 - 37). A comparison of results obtained from the Duncan's Multiple Range Test is presented in Table 7.

For each scale in Table 7, the number of comparisons are the total numbers of sample comparisons (which are AB, AC, BC and so on as used in Appendices 26 - 37) tested in the sensory panel and the number of differences are the number of significant differences between samples at the 5% level. Comparisons within this table suggest that swampiness (significant differences number 69) is a more sensitive characteristic for rating flavour change in wild rice than is the burnt characteristic (significant differences number 36) or sweetness (significant differences number 32).

Results from the analysis of the Duncan's Multiple Range Test of the sensory panel data (Table 7), indicated that swampy odour, mouldy taste and colour of the rice have the largest number of differences between the samples. In another word, these were the main sensory characteristics affected by the different processing systems. Besides these characteristics, rice kernel, straightness and breakage, grainy odour and taste, earthy bitter and tea-like taste, mushiness and hardness texture of the rice are also greatly affected by the different processing systems (Table 7). The differences in intensity of each of these sensory characteristics were easily detected by the panelists and they were the main factors used by the panelists for judging the acceptability of the finished wild rice.

4.3. Hulling Studies on Lake Wild Rice

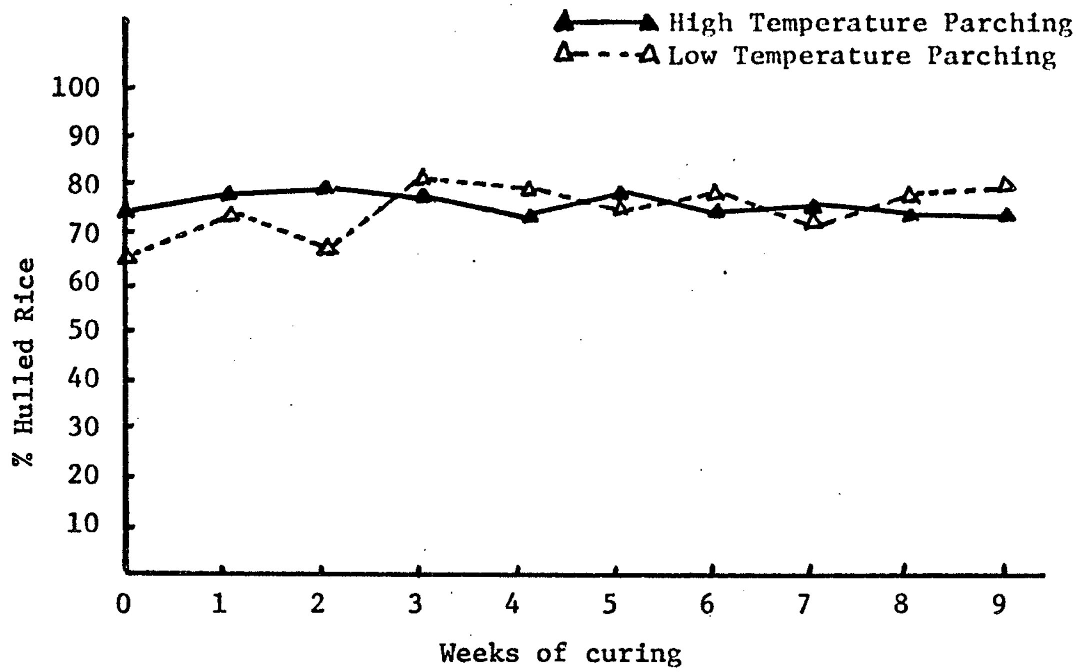
4.3.1. Effect of Curing

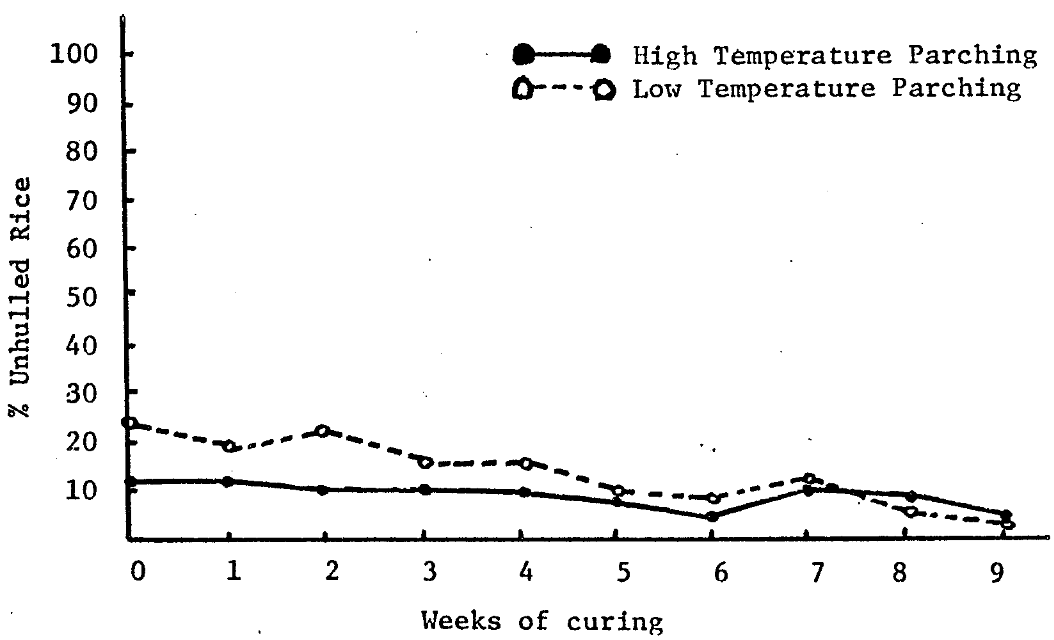
The data presented in Figures 53 - 58 represented the case of hulling of lake wild rice. The length of time wild rice was held in

Table 7. Evaluation of the Duncan Multiple Range Test comparing the mean scores obtained by the sensory tests.

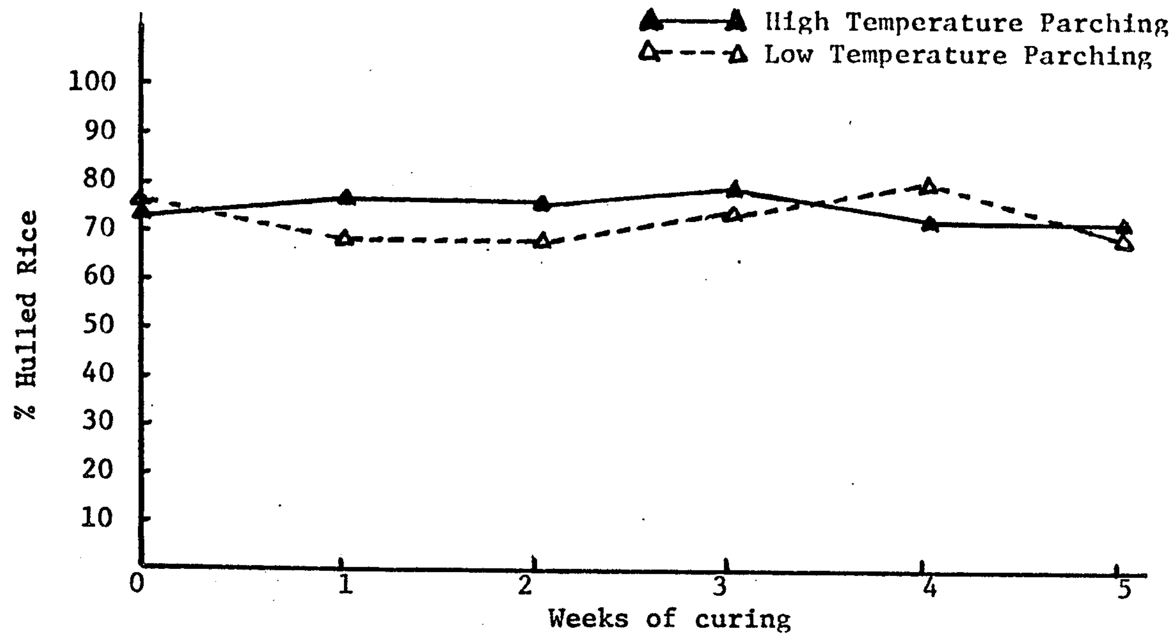
Scales	No. of Comparisons	No. of Differences
Straightness	78	51
Colour	78	58
Dryness	78	45
Splitness	78	47
Breakage	78	52
Graininess	78	50
Swampiness	78	69
Toast	78	37
Starchy	78	44
Burnt	78	36
Moldiness	78	58
Graininess	78	54
Tea-Like	78	52
Watery	78	44
Earthiness	78	55
Bitter	78	50
Sweet	78	42
Mushiness	78	52
Hardness	78	55
Cohesiveness	78	48
Chewiness	78	46
Sweet	78	32
Bitter	78	43
Aftertaste	78	40

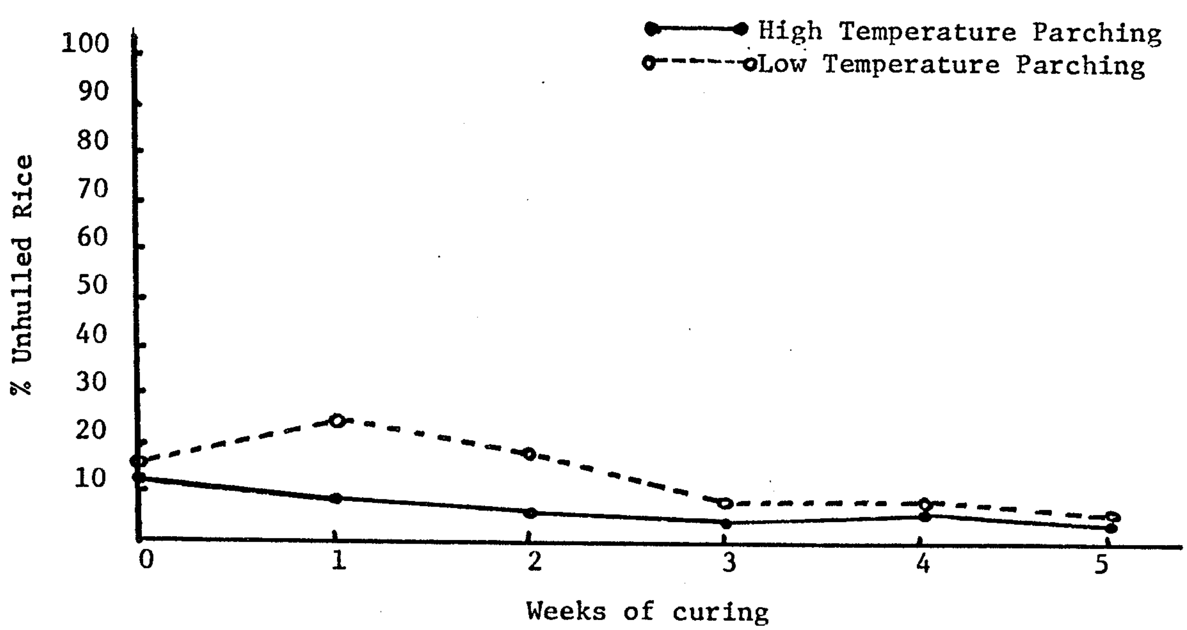
Figures 53, 54. Effect of 10°C Temperature Curing on the Ease of Hulling of 1974 Lake Wild Rice



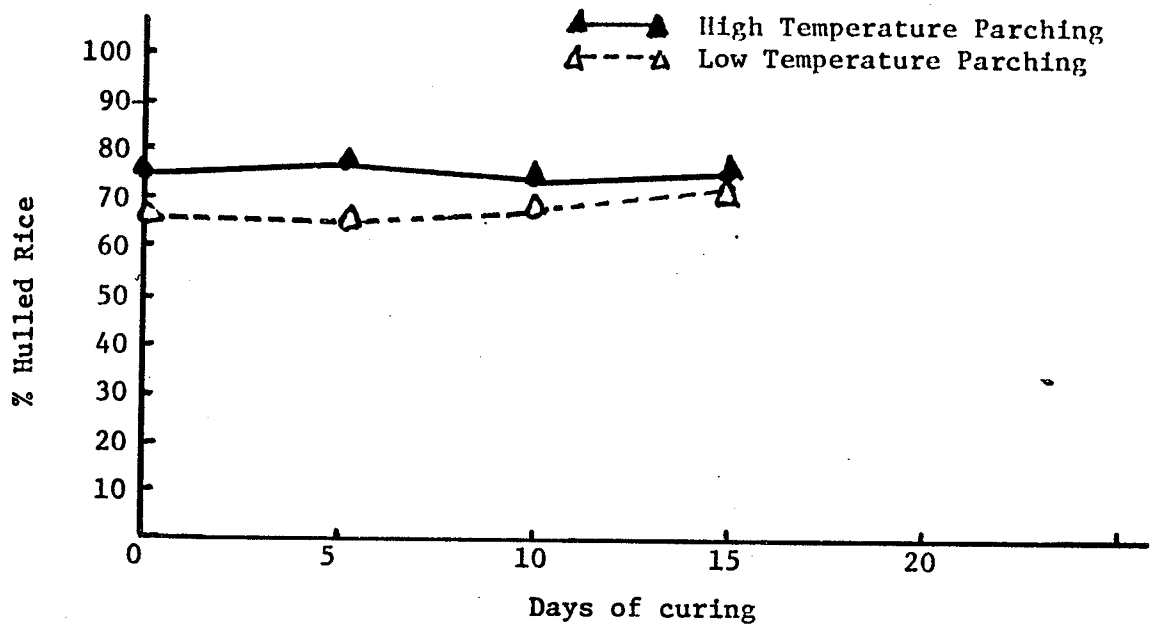


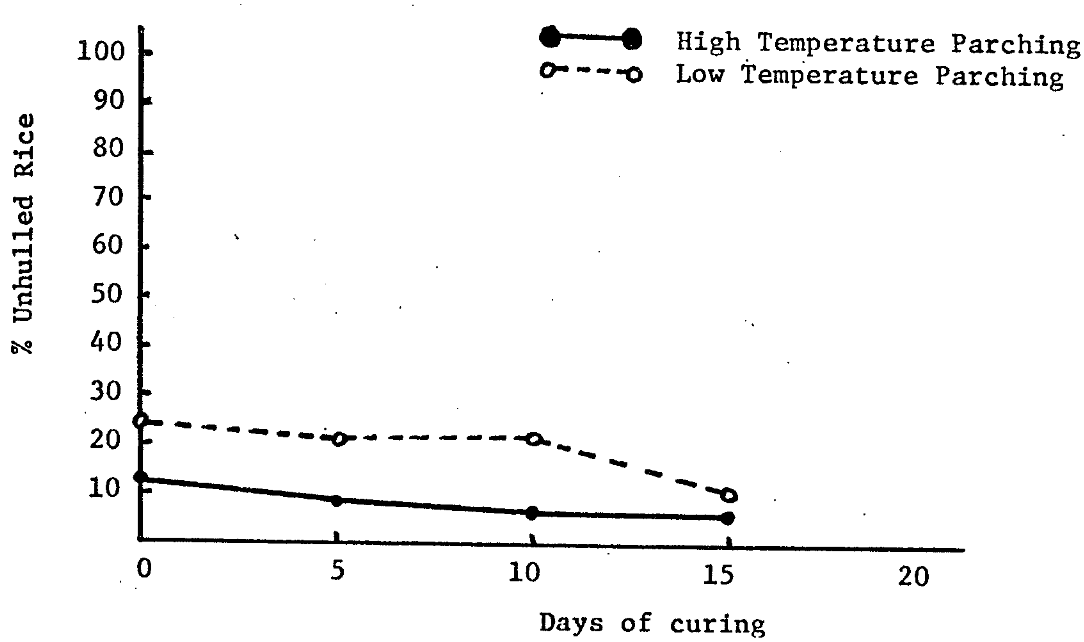
Figures 55, 56. Effect of 21.1°C Temperature Curing on the Ease of Hulling of 1974 Lake Wild Rice





Figures 57, 58. Effect of 31.1°C Temperature Curing on the Ease of Hulling of 1974 Lake Wild Rice

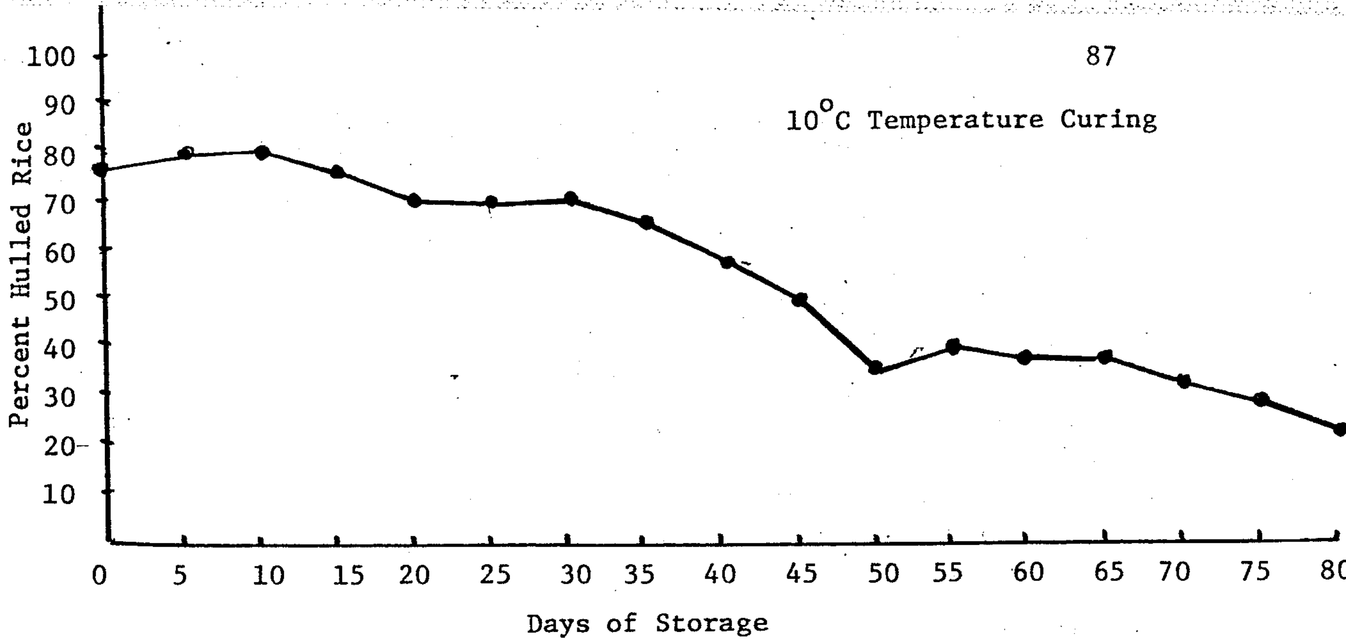


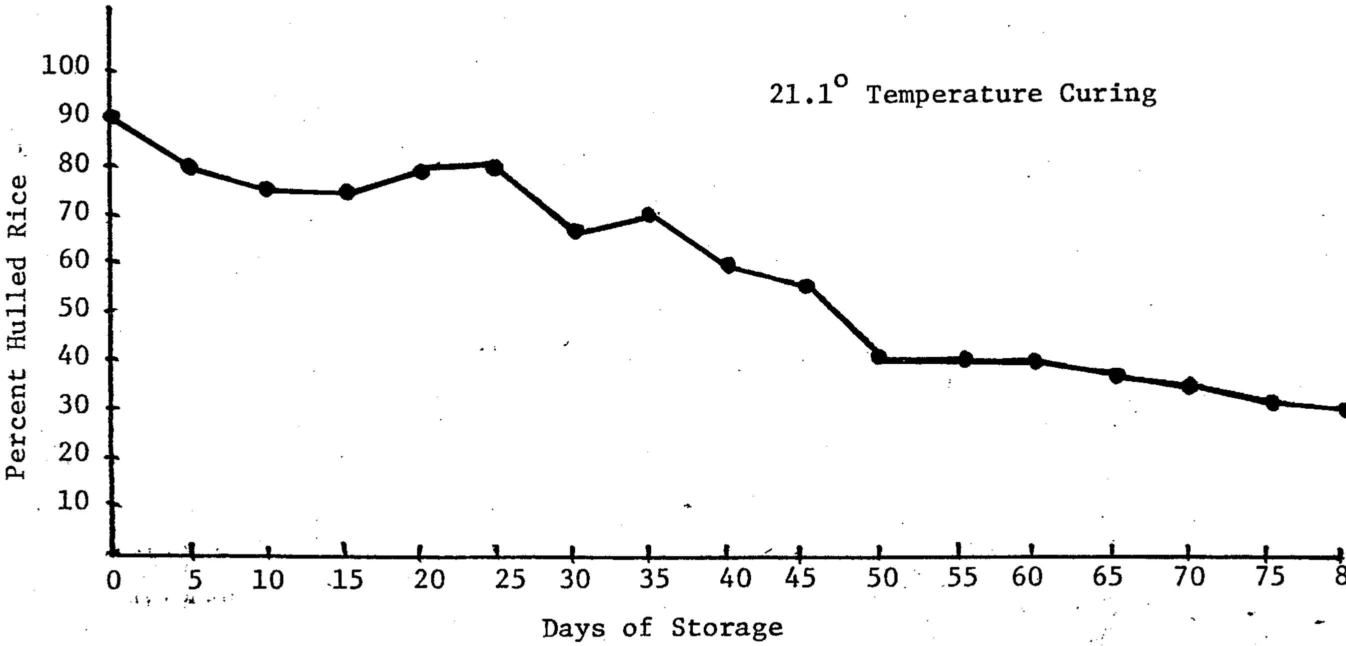


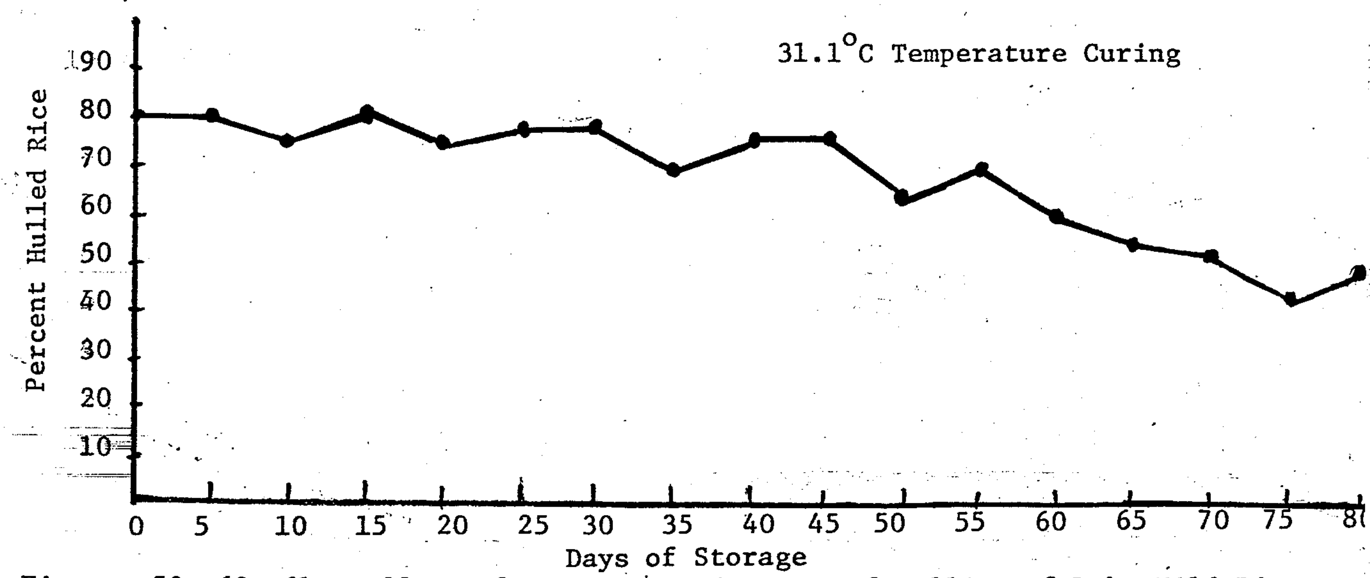
the curing pile had no effect in this factor since 74% was hulled after zero week and after 9 weeks of curing at 10°C. The curing temperature also had no effect on ease of hulling with the amount hulled ranging from 66% to 78% for all temperatures. There also was very little difference on the ease of hulling as effected by high and low parching. However, this study indicated that curing might have an effect on the weight of wild rice. The weight of wild rice appeared to decrease as curing time was prolonged. This was estimated by measuring the percentage of unhulled rice (Figures 53 - 58). The percentage of unhulled rice decreased while the percentage hulled rice remained almost constant throughout the entire curing. This indicated that there was a loss in weight by the rice kernels during curing and required further study.

4.3.2. Effect of Storage of Parched Rice

The purpose of this study was to determine if storage of parched wild rice caused any problem in hulling. The results showed that storage had an effect on the hulling of wild rice (Figures 59 - 61). The percentage of hulled rice decreased as storage time was prolonged. The possible reason was that during storage, the husk absorbed water vapour from the surrounding atmosphere and therefore made hulling more difficult. Rice cured at 10, 21.1 and 31.1°C maintained hulling percentages above 70% when stored for 25 - 30 days after being parched. After this period of time rice cured at 10°C and 21.1°C became increasingly harder to hull and percentage dropped to a low of 20 - 30% after 80 days of storage. On the other hand, rice cured at 31.1°C was easy to hull until 50 - 55 days of storage (around 70% hulled, Figure 61) and







Figures 59, 60, 61. Effect of Storage on the Ease of Hulling of Lake Wild Rice then hulling percentage dropped to a low of about 50% after 75 to 80 days. This study appeared to indicate that moisture content played a role in the ease of hulling.

Post-parching storage of rice before hulling would lower the yield of the finished product because it became more difficult to hull and would increase the danger of breaking the kernels in the hulling process.

V. SUMMARY, CONCLUSION AND RECOMMENDATION

5.1. Summary & Conclusion

The Food Science Department purchased 1973 and 1974 lake and paddy wild rice for these studies. This rice was thoroughly washed when it arrived at the Department, then the 1973 rice was placed in frozen storage. The 1974 rice was not frozen. All the rice was then cured, parched, hulled, cleaned and quality-evaluated. The quality tests used were percent broken kernels, colour, and sensory analyses.

All curing environments produced finished wild rice with highly acceptable colour and flavour, but the low temperature (10^{o}C) environment was judged to be the superior system. It produced consistently higher yields, more acceptable flavour, and the curing storage could be extended to 7 or 8 weeks. Rice curing at temperatures of 21.1^{o}C had to be parched within 2 - 3 weeks and that cured at 32.2^{o}C had to be parched within 5 - 10 days.

The yield for wild rice cured at low temperatures was 50% - 58% while the yield for rice cured at higher temperatures ranged from 40% to 50%. Besides the difference in yield and flavour of the rice, the rate of colour development was also different between the three curing environments. Wild rice cured at a higher temperature developed colour more quickly than rice cured in a cooler environment (5 days at 32.2^{o}C versus 4 weeks at 10^{o}C).

On comparison of the two different parching systems advantages and disadvantages showed in each. Low temperature parching produced rice with more fragile kernels, but it had a higher yield than high temperature parching. However, high temperature parching produced relatively more acceptable rice provided that the process was properly operated.

Hollow centres develop when wild rice is parched at too high temperatures, i.e. above 135^{o}C. This rice absorbs water very rapidly and produces a mushy texture.

Taste panel results showed that wild rice with a darker colour did not indicate well-developed flavour. Colour and flavour of wild rice did not develop at the same rate. Freezing before processing, and genotype of the rice are two factors which apparently govern the development of colour. Aeration during curing and curing temperature appear to be major factors governing the flavour development of rice. A good quality wild rice, according to the taste panel, was rice that had an acceptable colour and no broken kernels. The twenty-four sensory characteristics identified in this study were also used by the panelists for judging acceptability of wild rice. Specific sensory characteristics, such as swampy odour, mouldy and earthy taste, and mushy texture were those indicating unacceptable finished wild rice.

Most problems associated with the quality of finished wild rice were reviewed in this study. Problems of swampy odour, broken kernels, and mushy texture appear to be controllable.

The problem of colour development is still the major problem in the processing of wild rice. No correlation seems apparent between colour development of wild rice during curing and the flavour development of the finished wild rice. More research and work is required in this area. For paddy wild rice production in Manitoba the main problem seems to be "rice maturity".

Due to limited time and the variety of aspects of research involved in this project, some of the results are not positively confirmed. However, some reliable information concerning the processing of wild rice has become available for commercial use or as a guideline for future research.

5.2. Recommendations

The commercial processor handles lots of wild rice with mixed maturity. Immature rice is believed to produce finished rice which gives a lower yield and is of poor quality. Maturity must be more specifically defined for this crop, thus enabling one to select the proper time to harvest the crop. At the same time new rice varieties should be developed by the plant breeders, which would have the potential of giving uniform maturation thus overcoming the problem of mixed maturity lots.

The transporting of wild rice from the harvest location to the processing plant is not well controlled at this time. Large lots of rice apparently are moved fairly efficiently to the plant while small lots may be held under various conditions until a sufficient quantity has been collected for shipment to the processor. In order for the processor to guarantee quality in the finished product the transportation system must be improved, and holding stations require improved management i.e. ensuring that wild rice lots are adequately moistened and not allowed to overheat.

This processing research suggests that the harvested wild rice should be washed in cold water prior to curing in order to decrease spoilage problems during curing, remove sand and plant debris and eliminate the rice worm from the curing pile. This operation has not as yet been adapted to the industry. Technological research is required to develop a washing procedure which is economical and adaptable to the industry.

The height of the curing pile, watering the pile and turning of the pile are all used by the industry to maintain some temperature control during the curing process. No recommendations can be made from this research re these control measures other than they are all effective if used properly. The most important factor to monitor is the temperature of the pile. When this rises 10°C to 15°C above ambient conditions then one of the above control measures must be applied to keep this in check. The moisture content of the pile is extremely important and must never be allowed to go below forty percent in order to prevent aflotoxin development and white centers in the finished wild rice. A controlled atmosphere curing environment is the best system to use for this phase of wild rice processing, but unfortunately wild rice processors may not feel this to be an economical system at this time.

Parching can be carried out in any type of hot air dryer system. Wild rice processors wish to maintain the batch, gas fired, closed parcher which keeps some steam inside the chamber with the rice. This study has demonstrated that different parching systems will produce different flavoured final products. Further research is required to determine what the consuming public wants.

The parching system is used to dry the wild rice down to a final moisture content of 7 to 11 percent. The moisture content of the rice going into the parcher is extremely variable thereby causing the drying time required to produce a desirable final product extremely difficult to predict. This phase of the operation has been an art.

Further research is required to produce parching times and temperatures that are applicable to industry as this research program has pointed out.

The hulling operation is very critical as it removes the hull and polishes the final product. Great care must be taken to prevent breakage of the rice kernel. Further research is required to devise more efficient hullers for this purpose. Also further research is required to study the heat effect on kernel fragility in the parching process. The the present time it is recommended that a series of Japanese Kyowa hullers be used for this process and that the rice be size graded prior to hulling. The huller could be adjusted for specific kernel sizes. This system would ensure that oversize kernels would not pass through an inadequately set huller thereby reducing kernel breakage. It would also eliminate under size kernels from passing through this same huller, thereby increasing its efficiency.

The flavour of wild rice was described under 24 different characteristics. Several specific characteristics and processing systems were identified as contributing to poor flavoured wild rice, such as mouldiness, swampiness, high temperature curing and prolonged storage in curing. These systems must be avoided by the commercial processor. Further flavour research must be conducted to a) more extensively evaluate the affects of flavour, and b) to obtain knowledge as to what the consuming public consider to be excellent flavoured wild rice.

BIBLIOGRAPHY

1. Amerine, M.A., Pangborn, R.M., Roessler, E.B. Principles of Sensory Evaluation of Food, Academic Press 1965.

2. Anderson, J.E., Some Facts Concerning Vacuum-oven Moisture Determination, Cereal Chemistry, 13: 437 - 452, 1936.

3. Association of Official Analytical Chemists' Official Methods of Analysis. Edited by William Hornitz. 11th Edition 1970.

4. Ban, Toshizo, Rice Cracking in High Rate Drying, Japan Agricultural Research Quarterly, 6: 113 - 116, 1971.

5. Brook, Erwin, Economic Feasibility of Wild Rice Production, 1973.

6. Capen, R.G., Lemlerc, J.A., Wild Rice and its Chemical Composition, Journal of Agriculture Research, 77: 65 - 79, 1948.

7. Calderwood, D.L., Rice Drying and Storage Studies, Rice Journal, 76:67, 1973.

8. Calderwood, D.L., Webb, B.D., Effect of the Method of Dryer Operation on Performance and on Milling and Cooking Characteristic of Rice, Transaction of the Asae, P. 142 - 145, 1971.

9. Carr, L., The Food of Certain American Indians and Their Methods of Preparing It., Proc. Amer. Antiquarian Soc. 10: 155 - 190, 1895.

10. Chan, W.W., Fluidized Bed Dehydration of Manitoba Onion, Master Thesis, University of Manitoba, 1974, Unpublished.

11. Chen, C.Y., Skarsaune, S.K., Watson, C.A., Relation of Kernel Colour to Wheat Class and Grade, Cereal Science Today, 17: 340 - 343, 1972.

12. "Composition of Food", Agricultural Handbook, No. 8, U.S. Department of Agriculture.

13. Development Technique for Processing Paddy and Natural Stand Wild Rice. Departments of Food Science and Agronomy, Co-operative Extension Programs, University of Wisconsin - Madison, 1973.

14. Dore, William, G., Wild Rice, Ottawa, Department of Agriculture, Research Branch, 1969.

15. Fact Sheet, Agricultural Extension, University of Minnesota, 1971.

16. Gerbasi, G.I., A Study of Hot Water Blanch Systems and the Stimulation of Model Blanch Systems and their Effect on the Quality of Potato Chips, Master Thesis, University of Manitoba, Unpublished.

17. Hustrulid, A., Comparative Drying Rates of Naturally Moisture, Remoistened and Frozen Wheat, Transaction of the Asae, P. 304 - 308, 1963.

18. Jenks, H.J., The Wild Rice Gatherings of the Upper Lakes, Bur. Amer. Etherol, Ann. Rpt. (1897-98), 19: 1013 - 1137, Illus.

19. Jones, M.A., Research on Rice at the Southern Regional Research Laboratory, Cereal Science Today, 4: 293 - 295 and 308, 1959

20. Kennedy, C., The Nutritive Properties of Wild Rice (Zizania Aquatica), Jour. Agr. Res. 27: 219 - 224, Illus. 1924.

21. Klugh, H.E., Statistic, The Essential for Research, Copyright, c 1970 by John Wiley and Sons Inc., Printed in U.S.A.

22. Louvier, Jr., F.J., Calderwood, D.L., Breakage of Processed Rice Due to Falling Impact, Cereal Science Today, 17: 98 - 101, 1972.

23. Lund, D.B., Lindsay, R.C., Stuiber, D.A., Johnson, C.E., Marth, E.H., University of Wisconsin - Madison, Drying and Hulling Characteristics of Wild Rice.

24. Martin, J.H., Leonard, Win., Principals of Field Crop Production, 1968.

25. Matthews, J., Hogan, J.I., Mottern, H.H., Deobald, H.J., Southern Laboratory is Study Rice Milling, Rice Journal, 74: 28 - 30 and 34, 1971.

26. Matthews, J., Veal, D.M., Deobald, H.J., Comparating Head Rice yields from Commercial and Laboratory Milling Equipment Rice Journal, 74: 5 - 9, 1971.

27. Nellist, M.E., Hughes, M. Physical and Biological Processing in the drying of seed. Seed Science and Technology 1: 613 - 643, 1973.

28. Nelson, J.W., Palmer, L.S., The Thiamin, Riboflavin, Nicotinic Acid and Pantothenic Acid Contents of Wild Rice (Zizanic Aquatica), Cereal Chemistry, 19: 539 - 540, 1942.

29. Peters, E., Mittheilungen Aus Dem Laboratorium Der VerSuchsstation Kerschen Bei Schmiegel (Provinz Posen) Ann. Der Landn, in Preussen Jahrg. 2: 459 - 461, 1862.

30. Progress Report of 1973 Wild Rice Research, Dept. of Food Science, Co-operative Extension, University of Wisconsin-Madison.

31. Rice, Chemistry and Technology, Edited by D.F. Houston, Monograph Series Volume 4, 1972.

32. Statistical Package, Computer Centre, University of Manitoba, 1974.

33. Taylor, A.S., Wild Rice - Indian Food and a Modern Delicacy, Economic Botany 62: 107 - 142, 1952.

34. U.S. Department of Agriculture, Tech. Bull. 634.

35. Wild Rice Processing Handbook, Dept. of Food Science and Agronomy, University of Wisconsin - Extension and Upper Great Lake Regional Commission, 1971.

36. Wild Rice Processing in the upper Great Lake Region. Co-operative Extension Programs, University of Wisconsin Extension, 1972.

37. Woll, F.W., Miscellaneous Chemical Work, Wisconsin Agriculture Experimental Station, Ann. Rpt. 16: 267 - 274, 1879.

Please evaluate the rice sample by circling a point on each of the scales.

NAME:
SAMPLE:
DATE:

APPEARANCE:

Scale I

All Straight — All Curled

Scale II

Green — Dark Brown

Scale III

Dry — Moist

Scale IV

All Split — All Intact

Scale V

All Whole — All Broken

AROMA:

Scale I

Bland — Grainy

Scale II

Bland — Swampy

Scale III

Bland — Toast

TASTE:

Scale I

Bland — Ext. Starchy

Scale II

Bland — Ext. Burnt

Scale III

Bland — Ext. Moldy Like

Bland — Ext. Grainy Like

Scale V

Bland — Ext. Tea Like

Scale VI

Bland — Watery

Scale VII

Bland — Earthness

Scale VIII

Bland — Bitter

Scale IX

Bland — Sweet

TEXTURE:

Scale I

Not Mushy — Ext. Mushy

Scale II

Very Soft — Very Hard

Scale III

No Cohesiveness — Ext. Cohesive

Scale IV

No Chewiness — Ext. Chewy

AFTER TASTE:

Scale I

Not Sweet — Ext. Sweet

Scale II

Not Bitter — Ext. Bitter

Scale III

None — Ext. Strong

This rice sample is:

(a) Extremely Acceptable — (b) Extremely Unacceptable

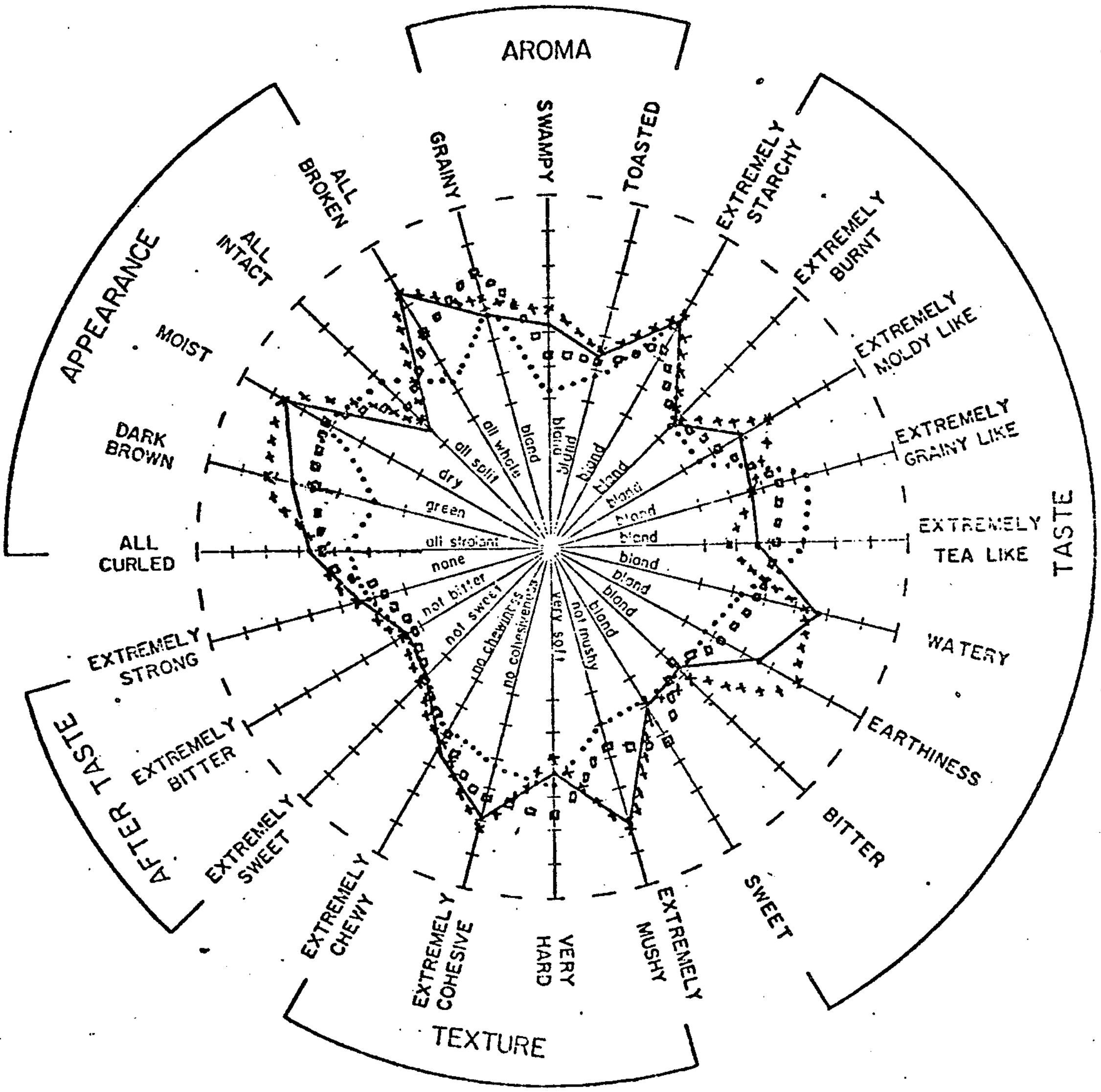
COMMENT:

APPENDIX 1

Appendices 2 - 25

Flavour Profiles of Finished Lake and Paddy Wild Rice

FLAVOUR PROFILE OF WILD RICE

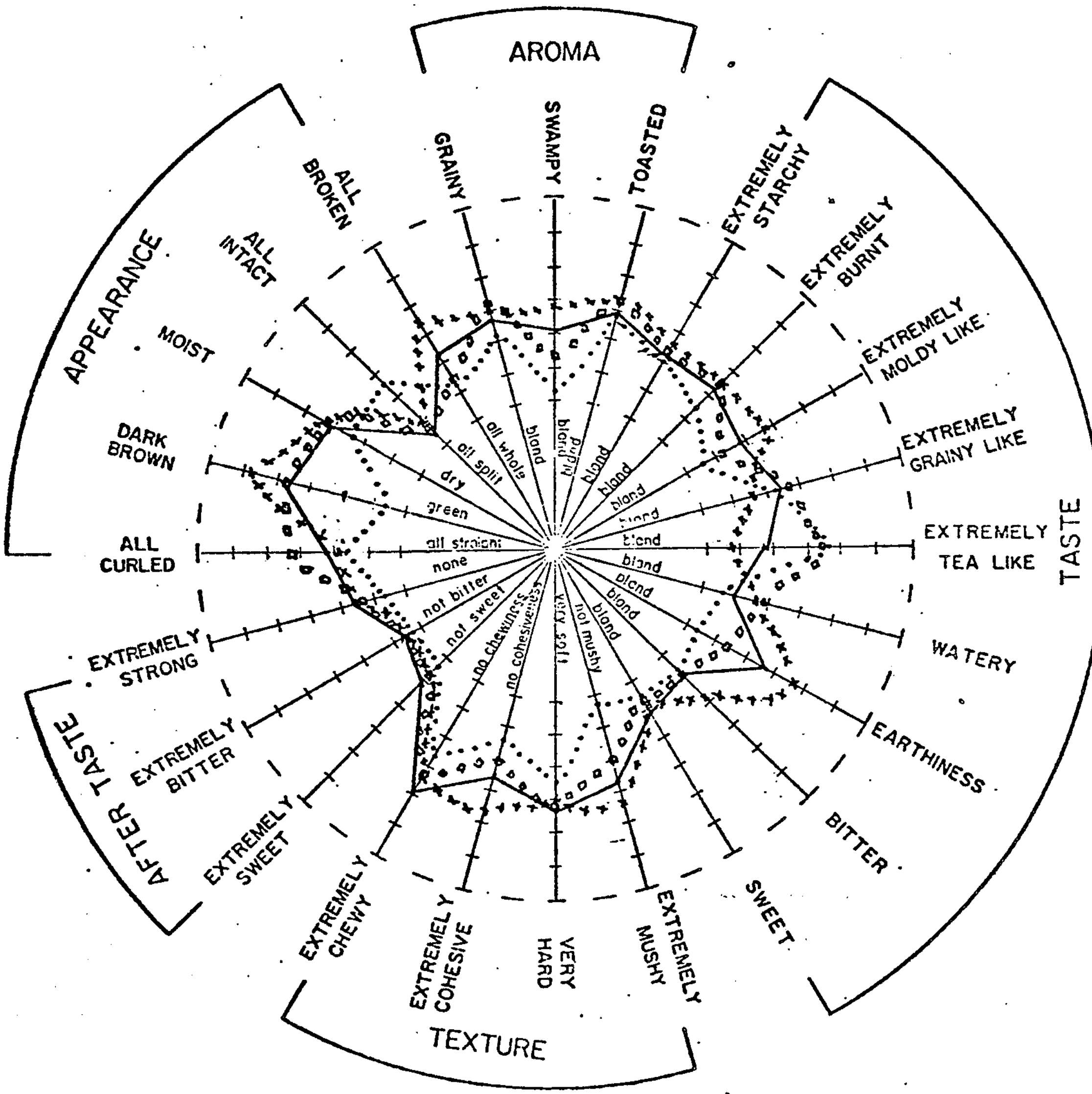


1973 Lake Wild Rice
10^{o}C Temperature Curing
Low Temperature Parching

.... no curing
oooo 3 weeks curing
---- 6 weeks curing
xxxx 9 weeks curing

APPENDIX 2

FLAVOUR PROFILE OF WILD RICE

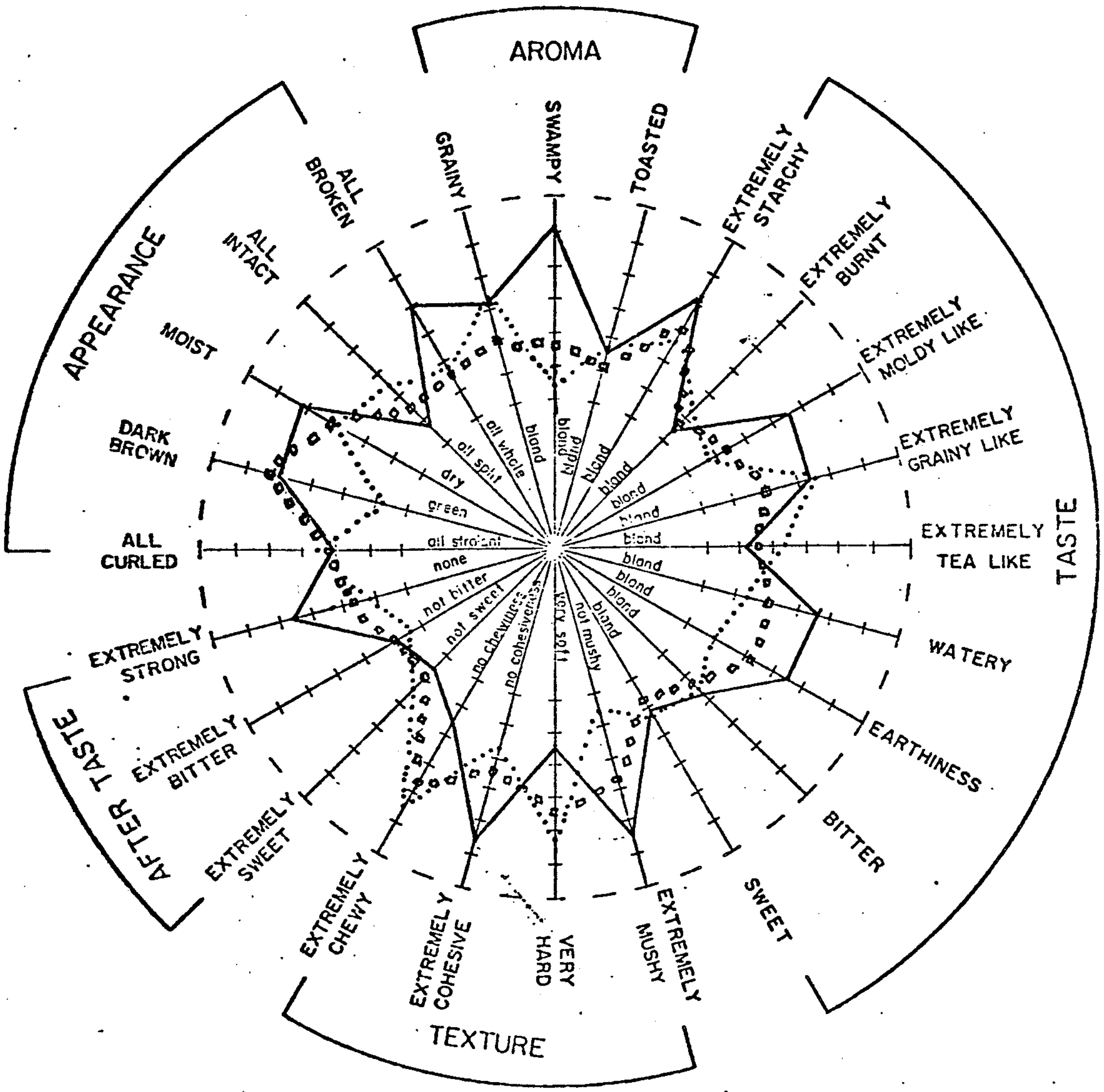


1973 Lake Wild Rice
10^{o}C Temperature Curing
High Temperature Parching

.... no curing
oooo 3 weeks curing
—— 6 weeks curing
xxxx 9 weeks curing

APPENDIX 3

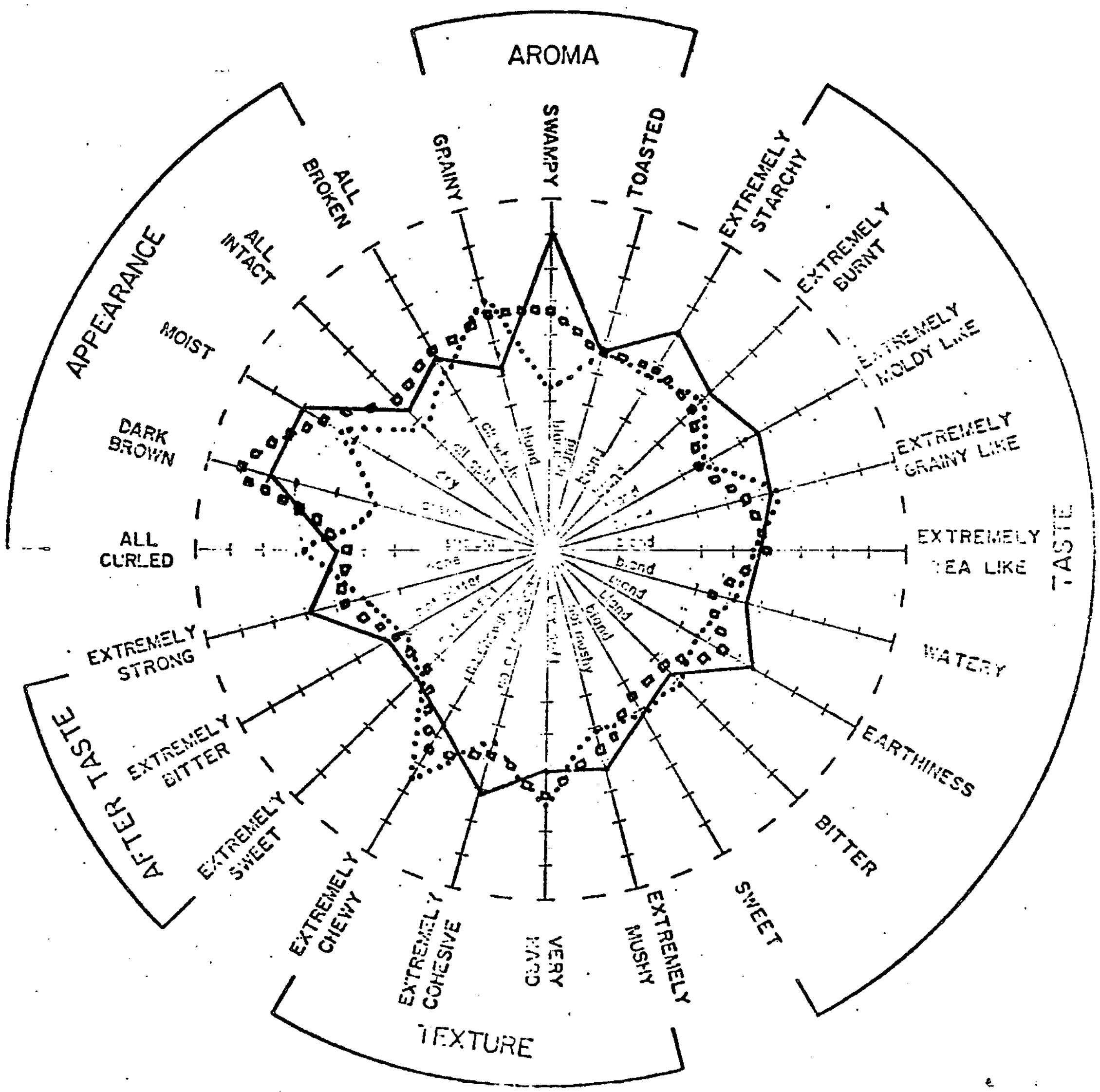
FLAVOUR PROFILE OF WILD RICE



1973 Lake Wild Rice ···· no curing
21.1°C Temperature Curing oooo 2 weeks curing
Low Temperature Parching —— 4 weeks curing

APPENDIX 4

FLAVOUR PROFILE OF WILD RICE

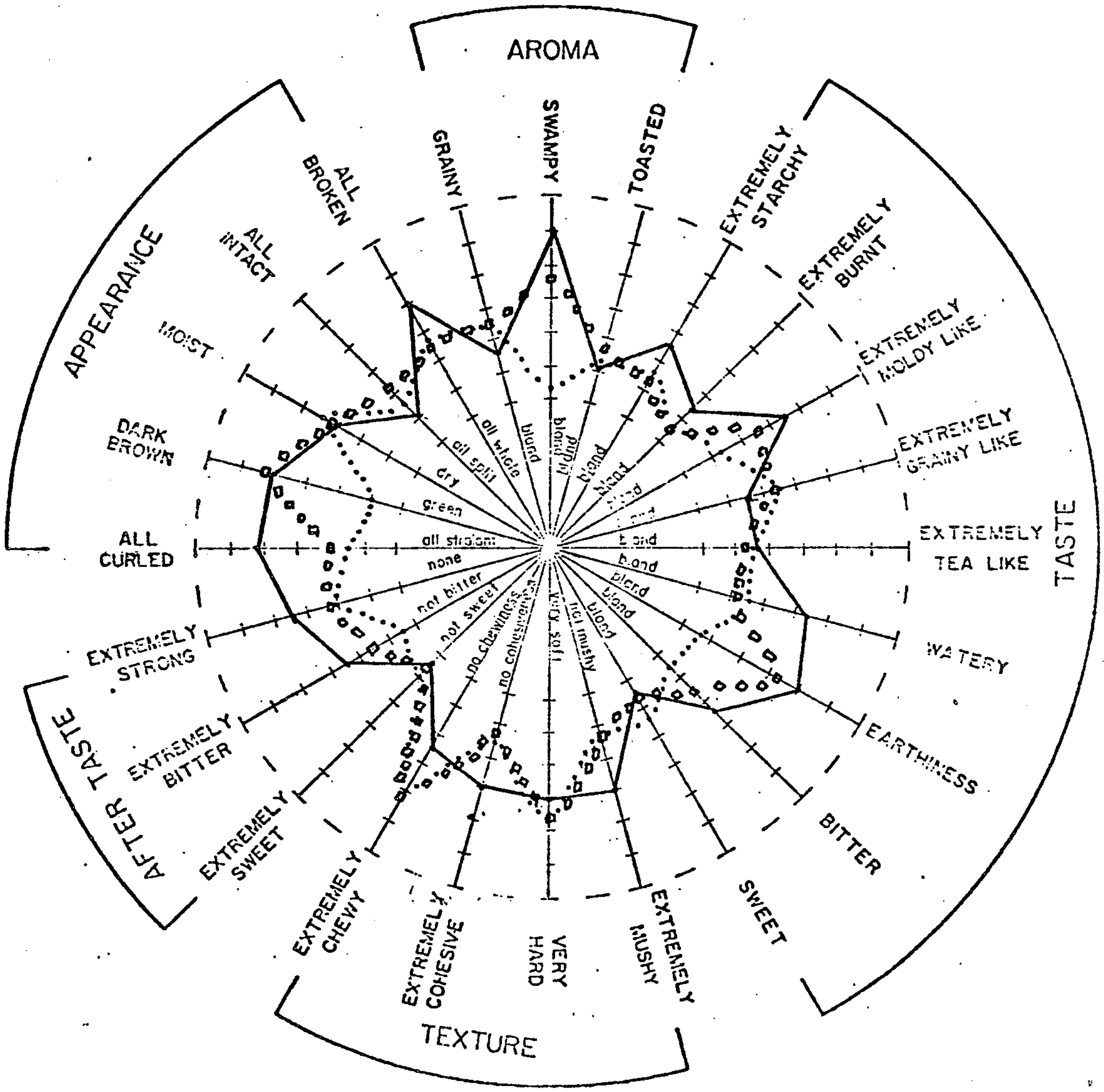


1973 Lake Wild Rice
21.1°C Temperature Curing
High Temperature Parching

.... no curing
oooo 2 weeks curing
—— 4 weeks curing

APPENDIX 5

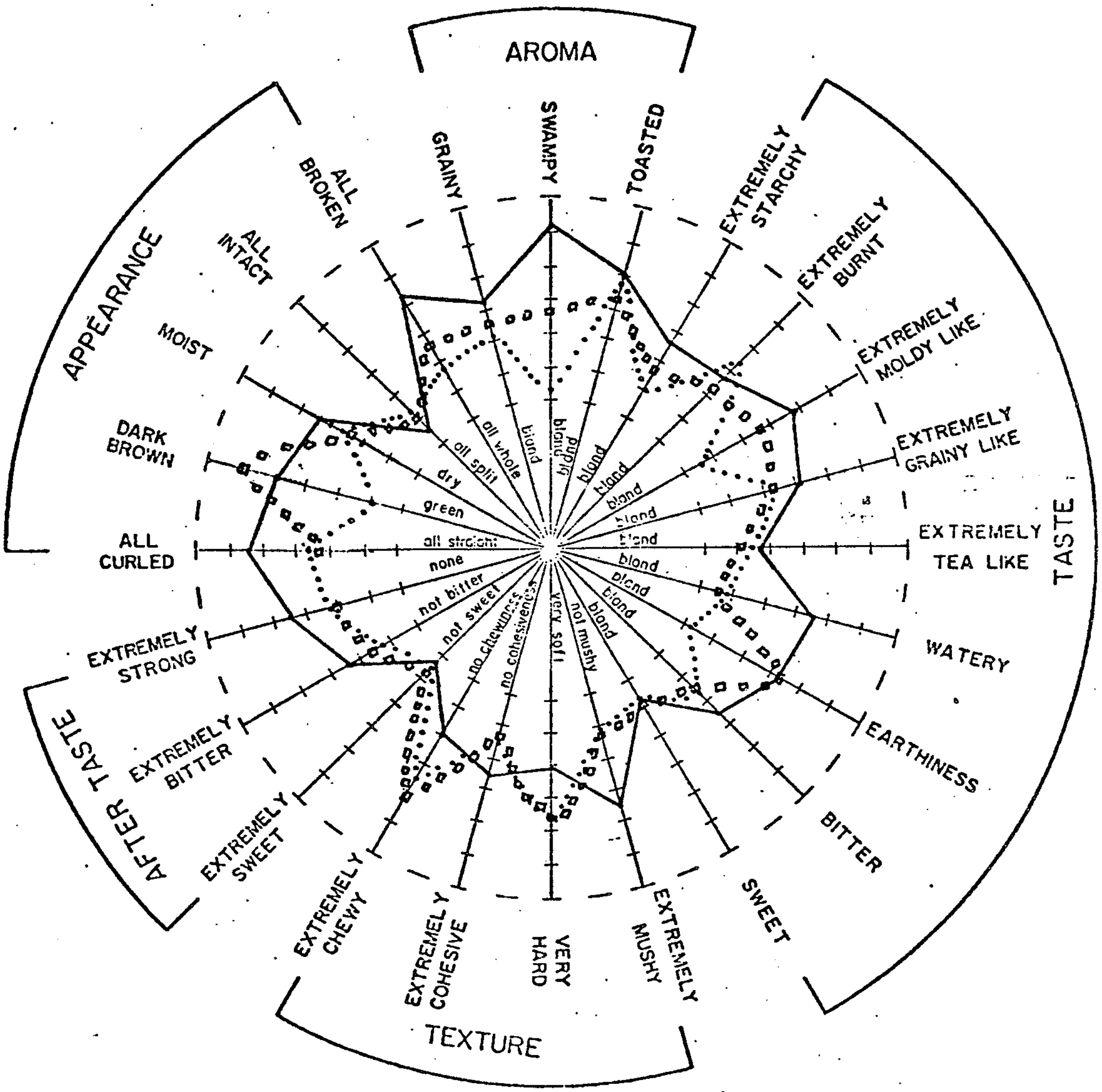
FLAVOUR PROFILE OF WILD RICE



1973 Lake Wild Rice .... no curing
31.1°C Temperature Curing oooo 5 days curing
Low Temperature Parching —— 10 days curing

APPENDIX 6

FLAVOUR PROFILE OF WILD RICE

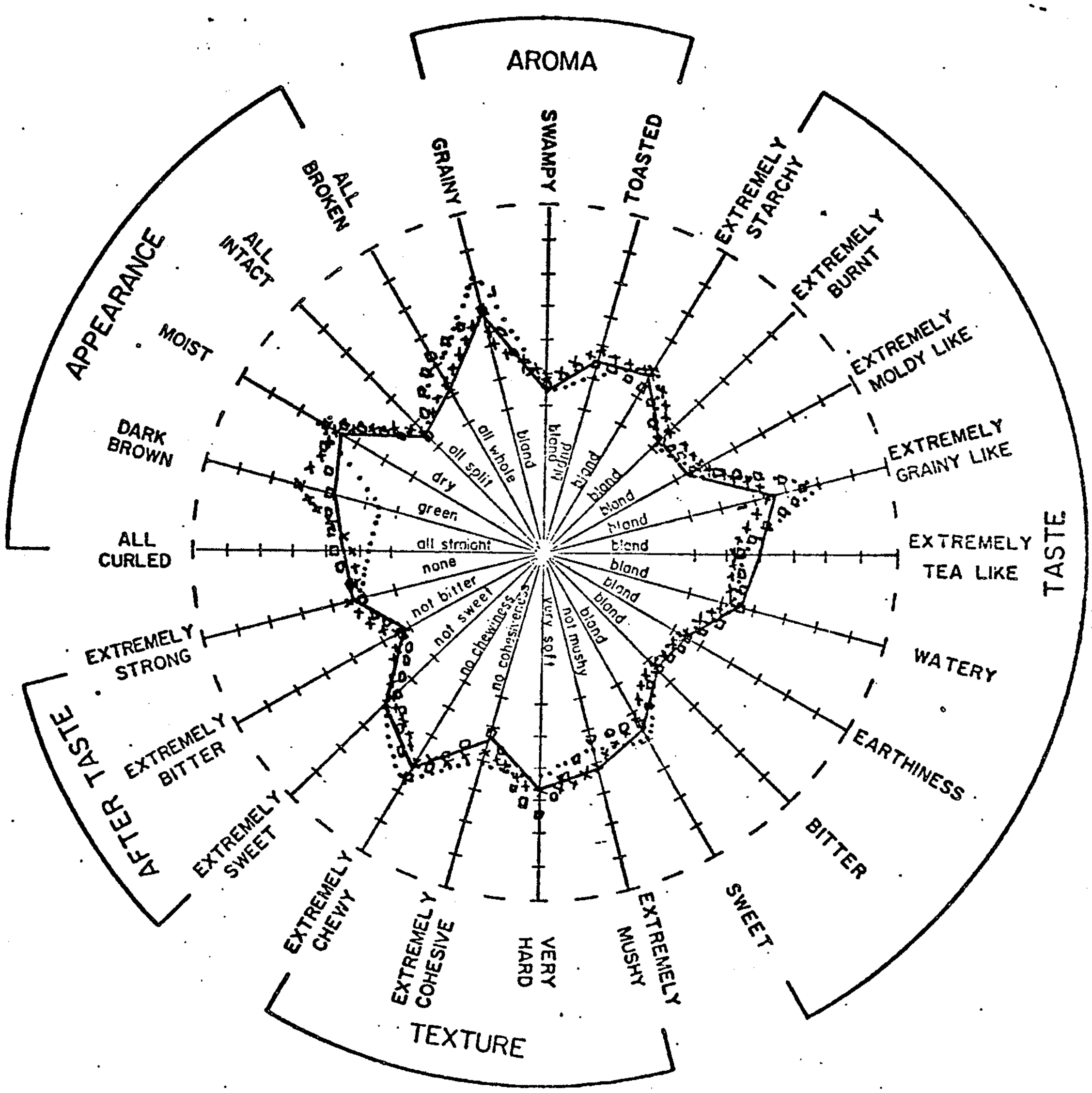


1973 Lake Wild Rice
31.1°C Temperature Curing
High Temperature Parching

.... no curing
oooo 5 days curing
—— 10 days curing

APPENDIX 7

FLAVOUR PROFILE OF WILD RICE

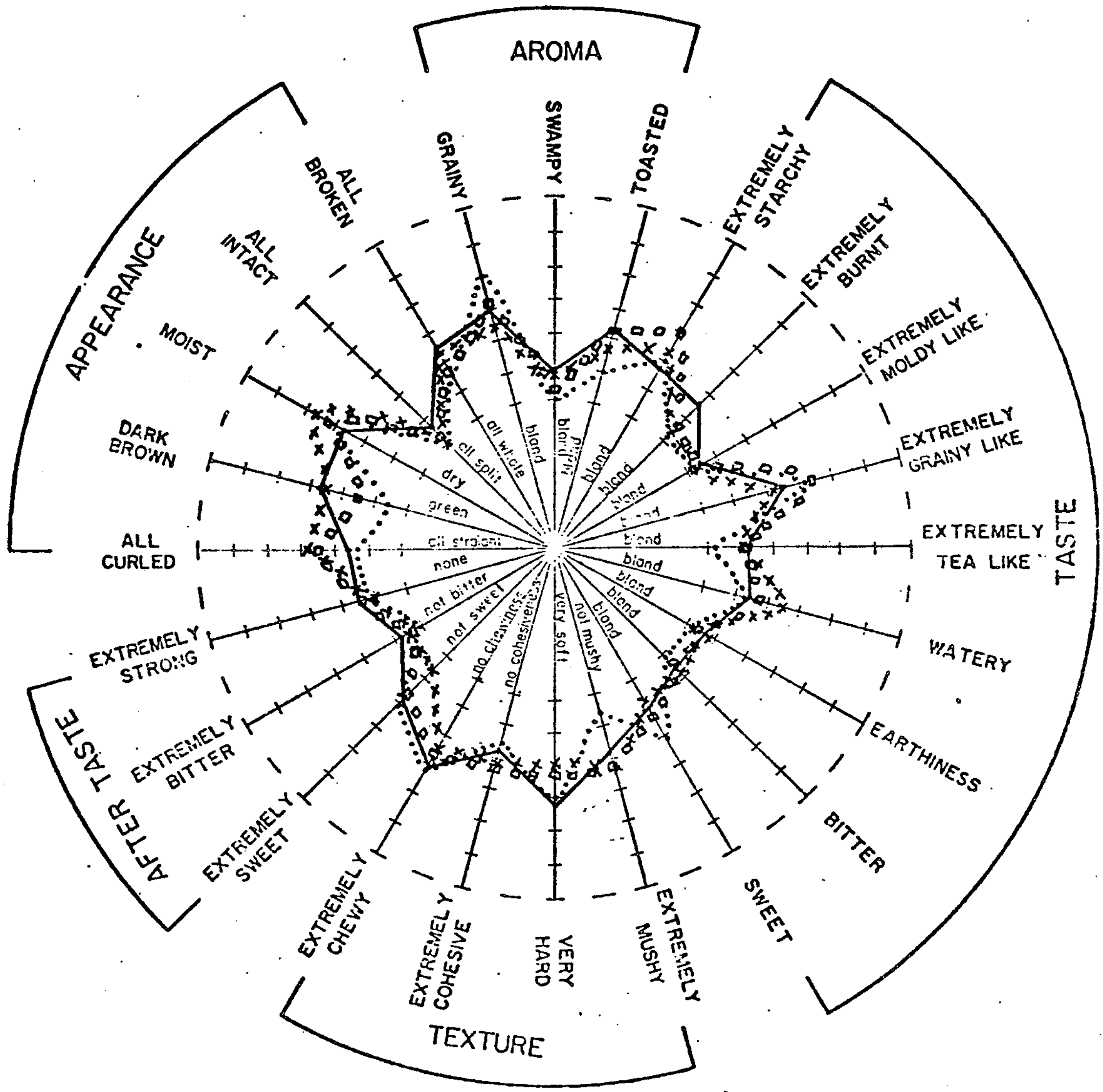


1974 Lake Rice
10^{o}C Curing Temperature
Low Parching Temperature

.... no curing
oooo 3 weeks curing
——— 6 weeks curing
xxxx 9 weeks curing

APPENDIX 8

FLAVOUR PROFILE OF WILD RICE

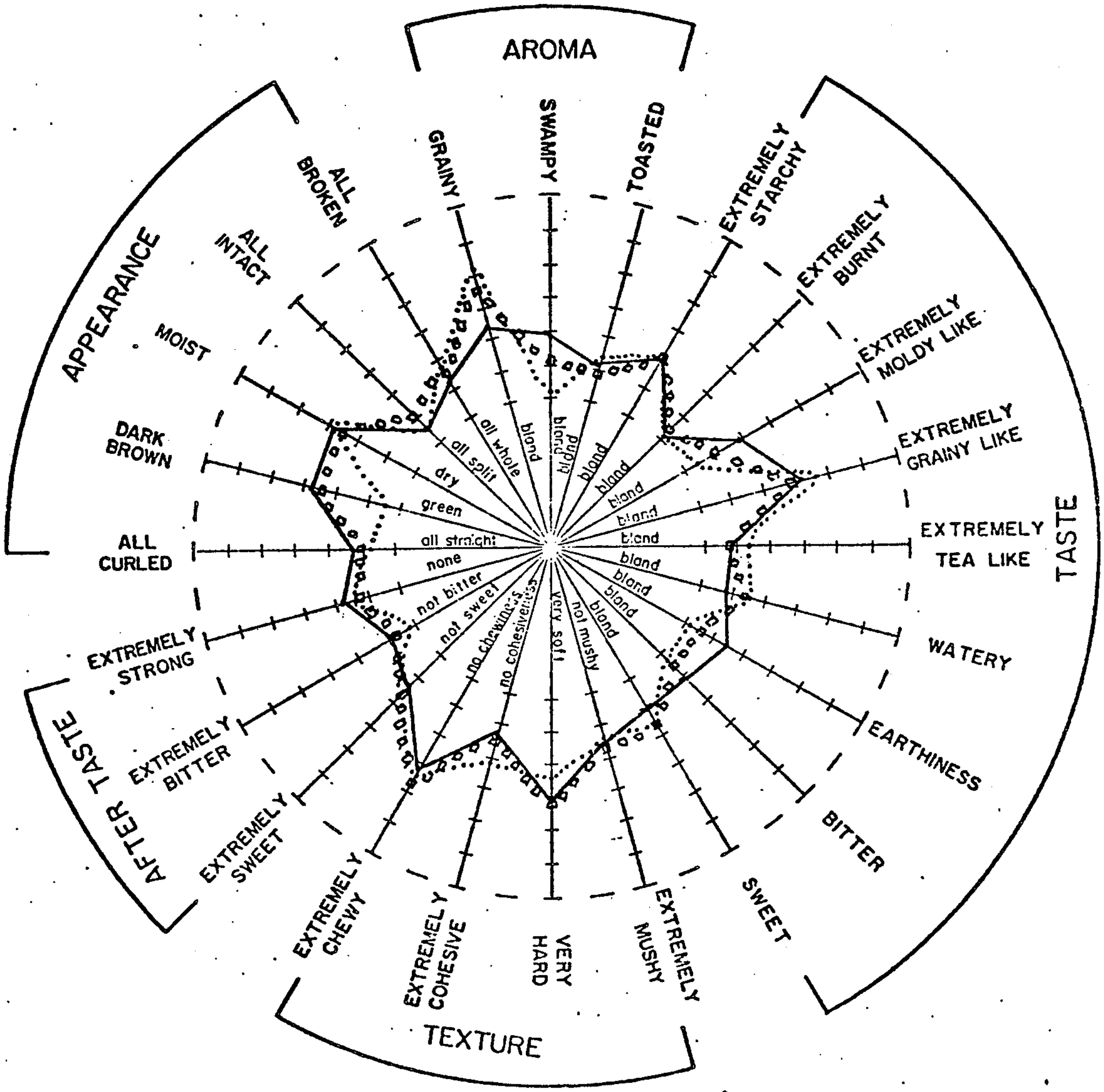


1974 Lake Wild Rice
10^{o}C Temperature Curing
High Temperature Parching

.... no curing
oooo 3 weeks curing
—— 6 weeks curing
xxxx 9 weeks curing

APPENDIX 9

FLAVOUR PROFILE OF WILD RICE

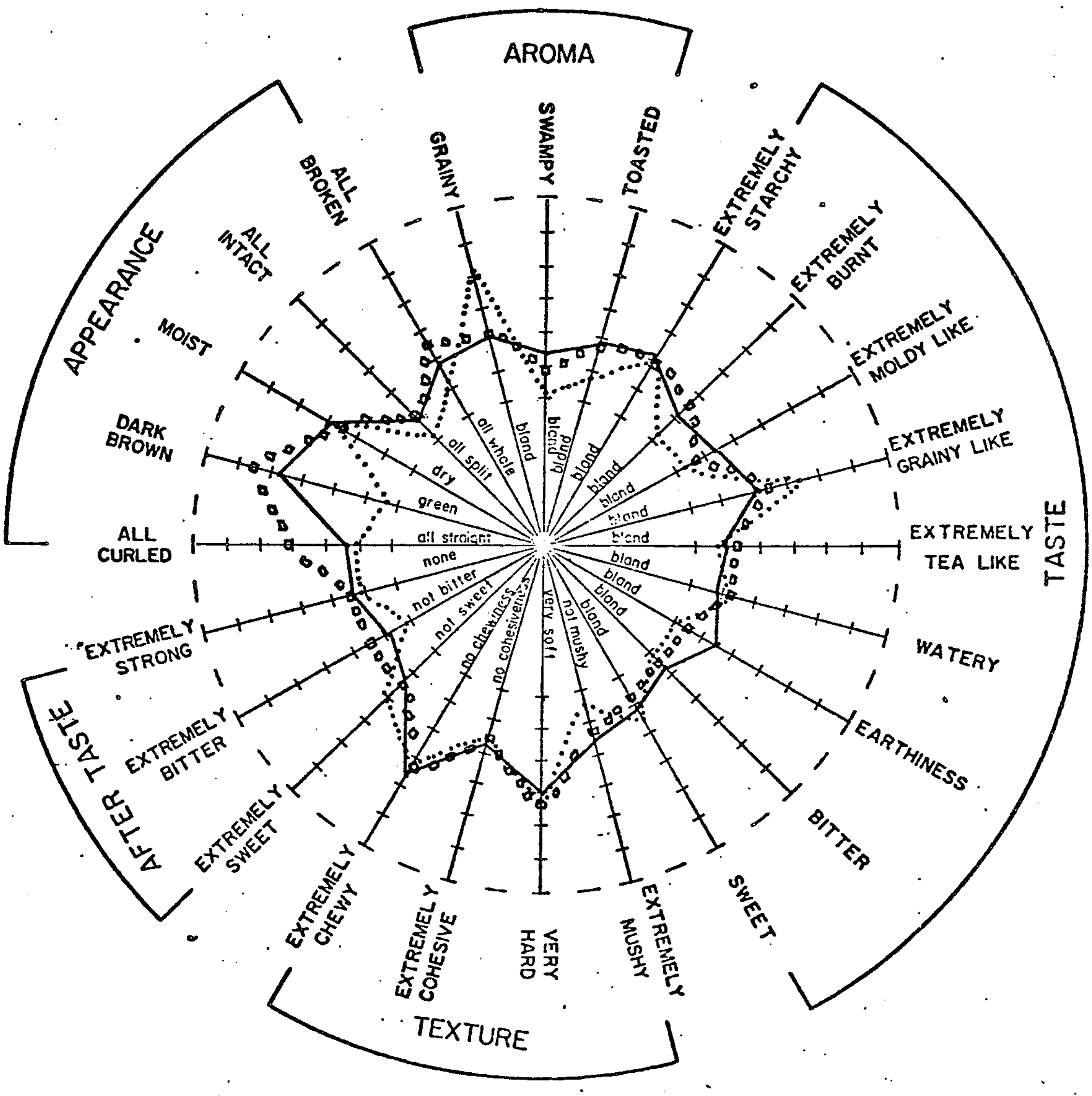


1974 Lake Wild Rice
21.1°C Temperature Curing
Low Temperature Parching

.... no curing
oooo 2 weeks curing
—— 4 weeks curing

APPENDIX 10

FLAVOUR PROFILE OF WILD RICE



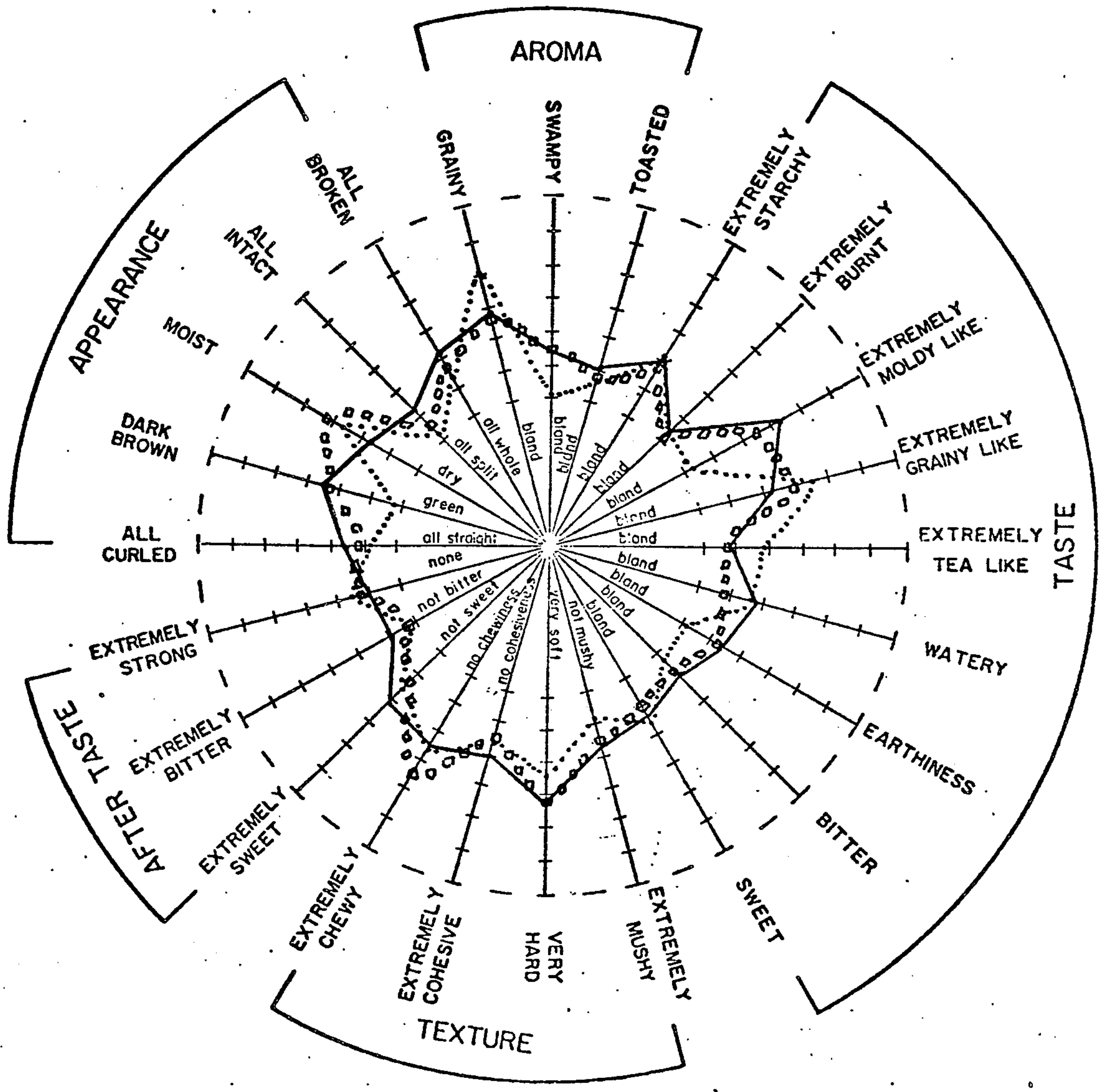
1974 Lake Wild Rice
21.1°C Temperature Curing
High Temperature Parching

..:.. no curing
oooo 2 weeks curing
—— 4 weeks curing

APPENDIX 11

105

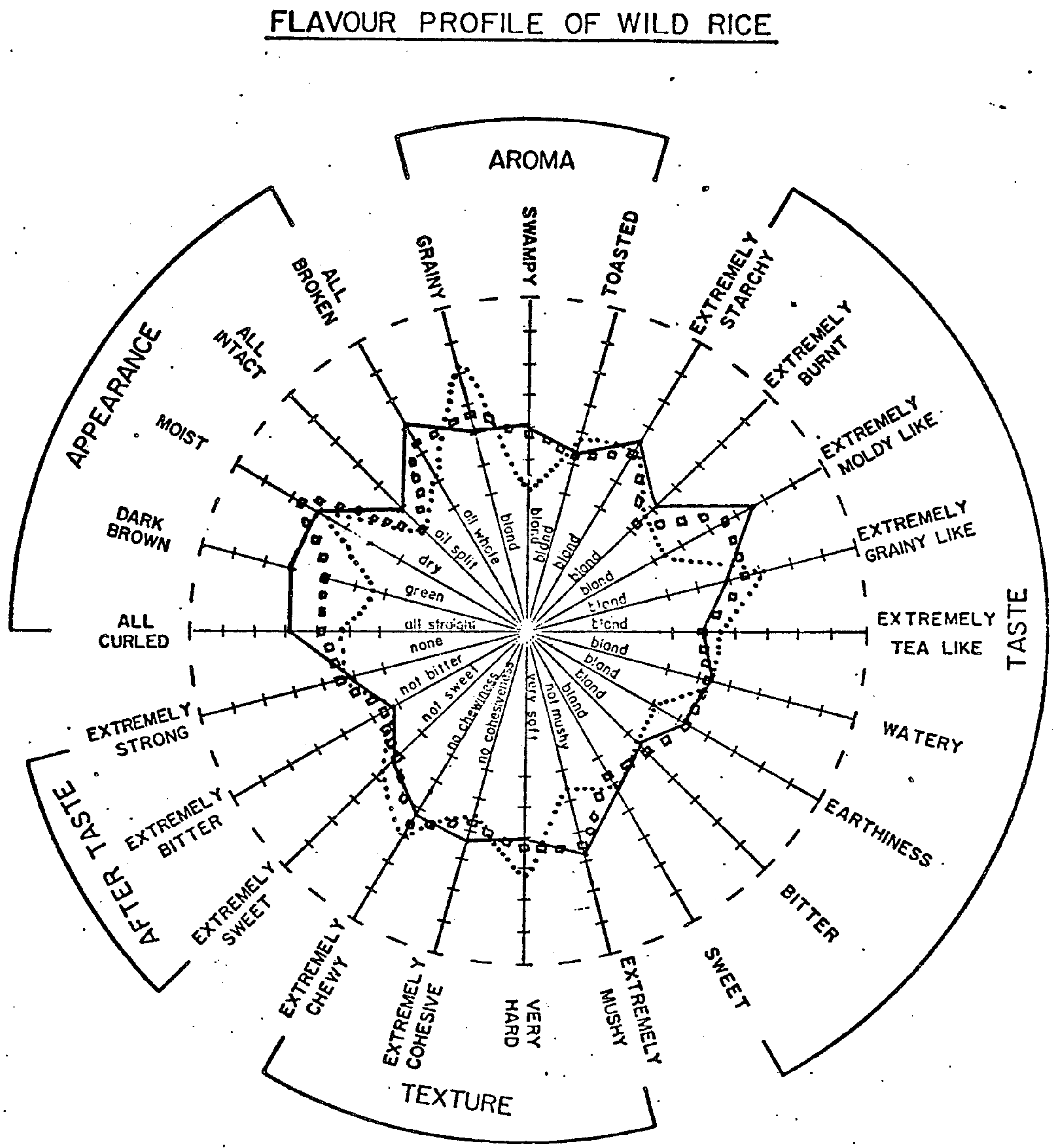
FLAVOUR PROFILE OF WILD RICE



1974 Lake Wild Rice
31.1°C Temperature Curing
Low Temperature Curing

.... no curing
oooo 5 days curing
—— 10 days curing

APPENDIX 12

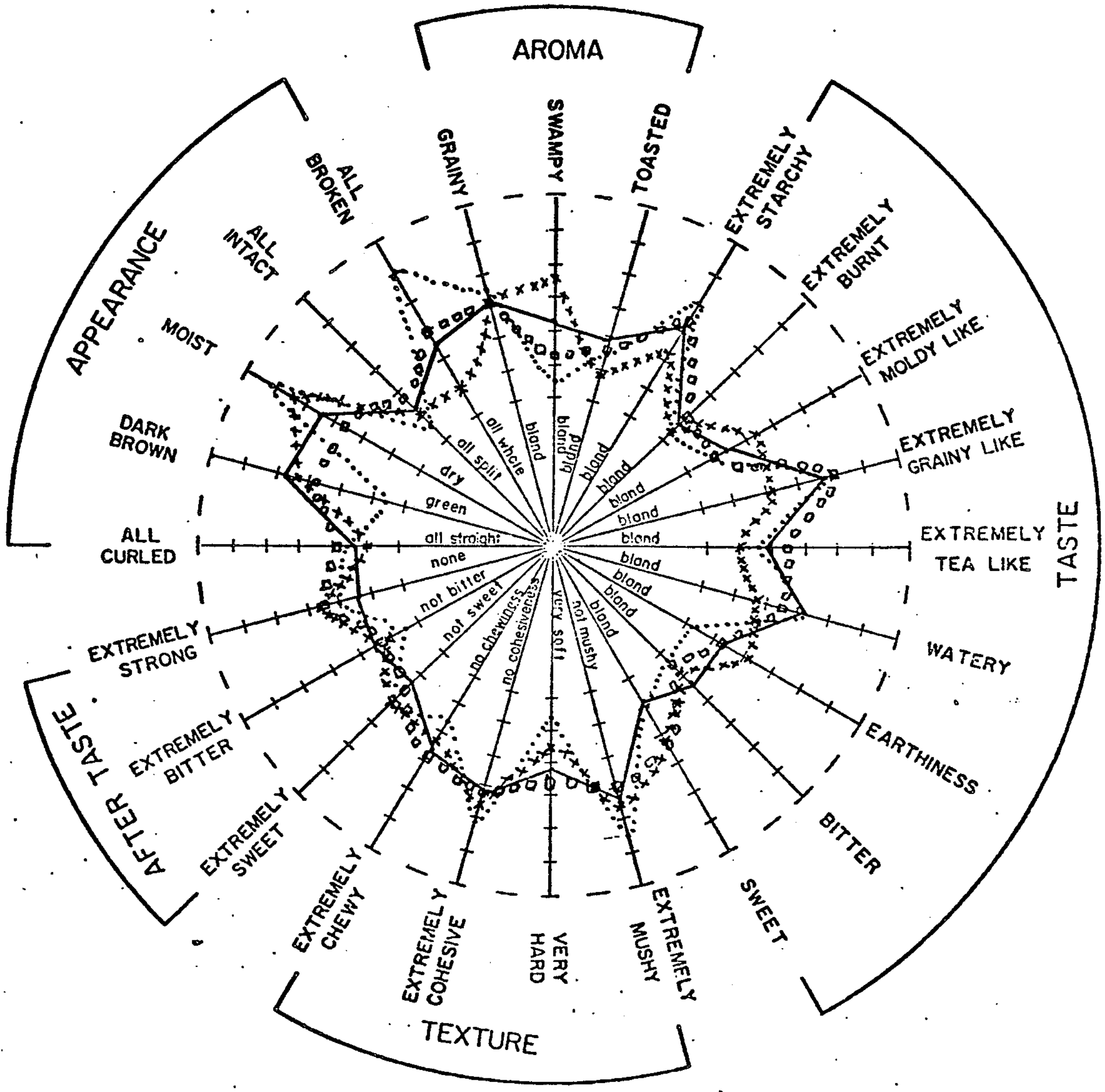


1974 Lake Wild Rice
31.1°C Temperature Curing
High Temperature Parching

.... no curing
oooo 5 days curing
—— 10 days curing

APPENDIX 13

FLAVOUR PROFILE OF WILD RICE

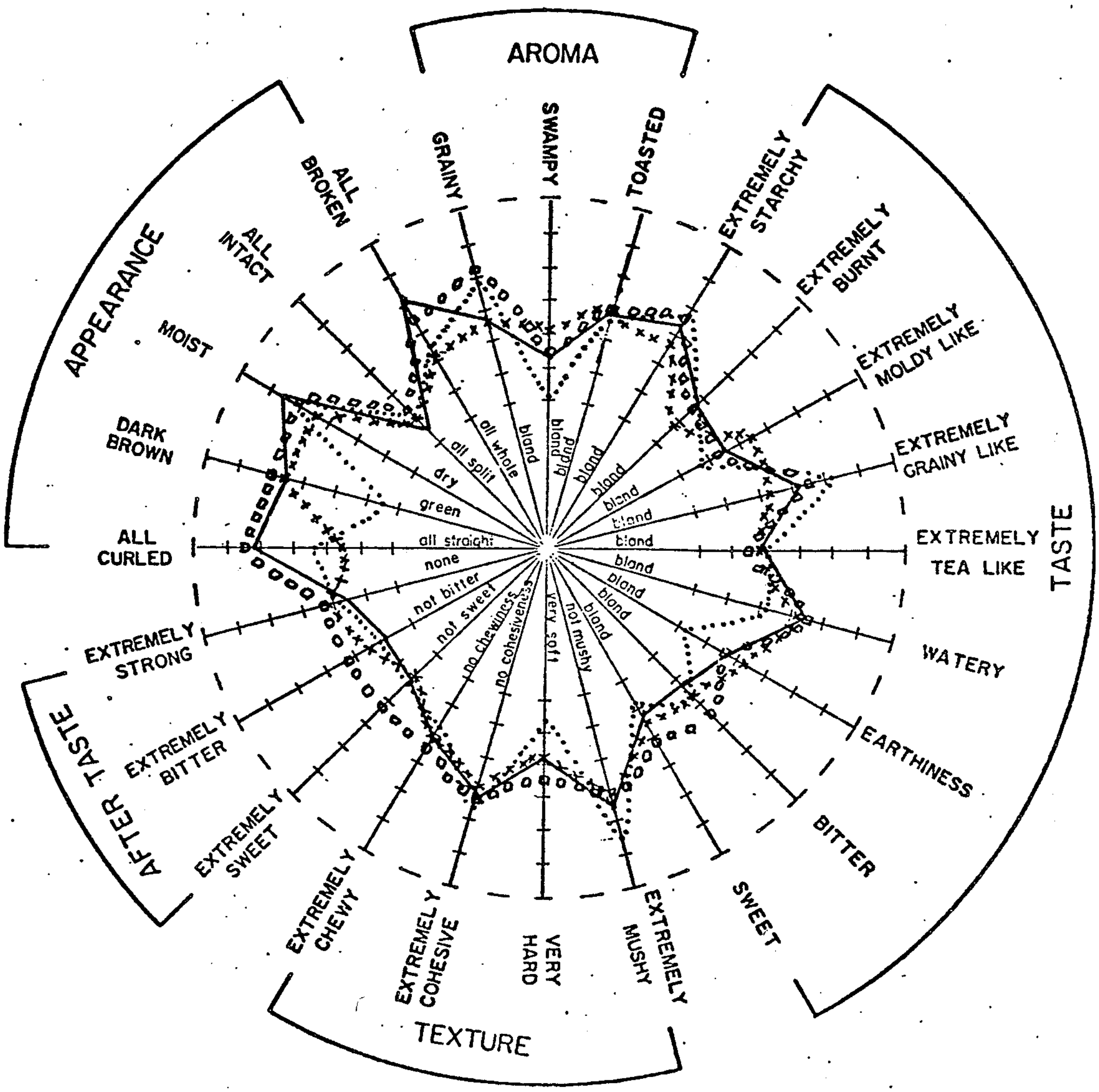


1973 Paddy Wild Rice
10°C Temperature Curing
Low Temperature Curing

.... no curing
oooo 3 weeks curing
—— 6 weeks curing
xxxx 9 weeks curing

APPENDIX 14

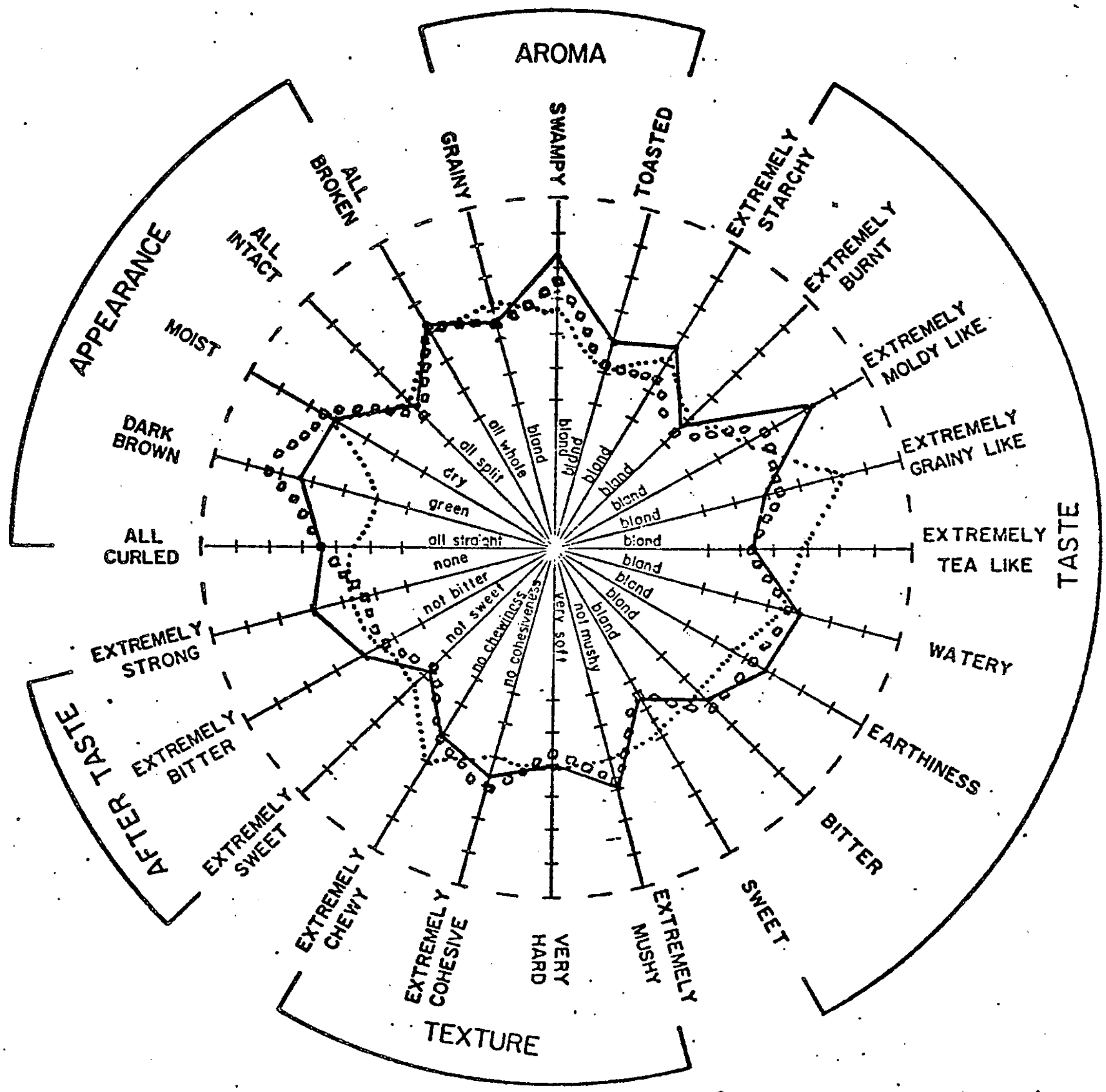
FLAVOUR PROFILE OF WILD RICE



1973 Paddy Wild Rice
10^{o}C Temperature Curing
High Temperature Parching

.... no curing
oooo 3 weeks curing
—— 6 weeks curing
xxxx 9 weeks curing

FLAVOUR PROFILE OF WILD RICE

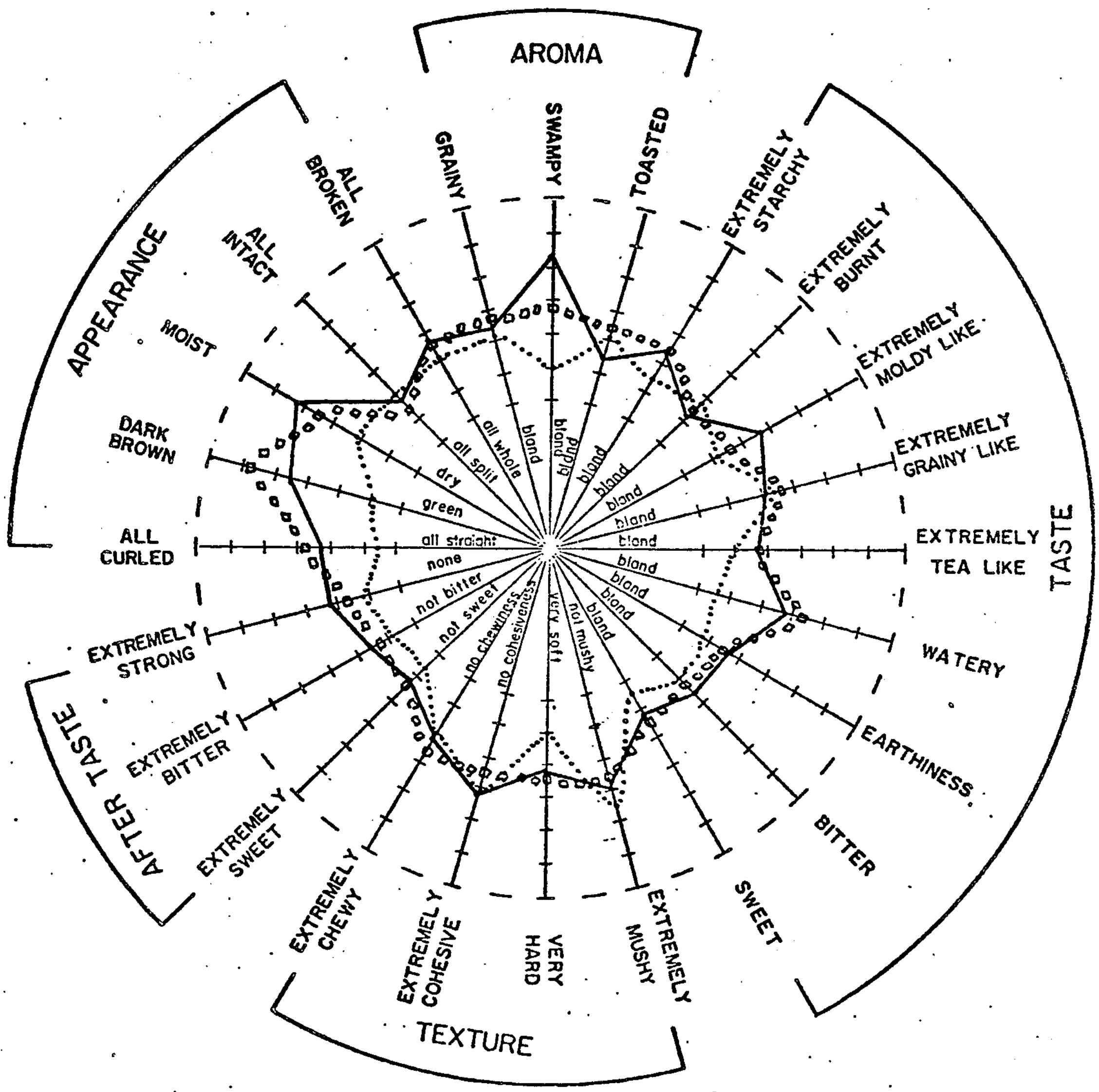


1973 Paddy Wild Rice
21.1°C Temperature Curing
Low Temperature Parching

.... no curing
oooo 2 weeks curing
—— 4 weeks curing

APPENDIX 16

FLAVOUR PROFILE OF WILD RICE

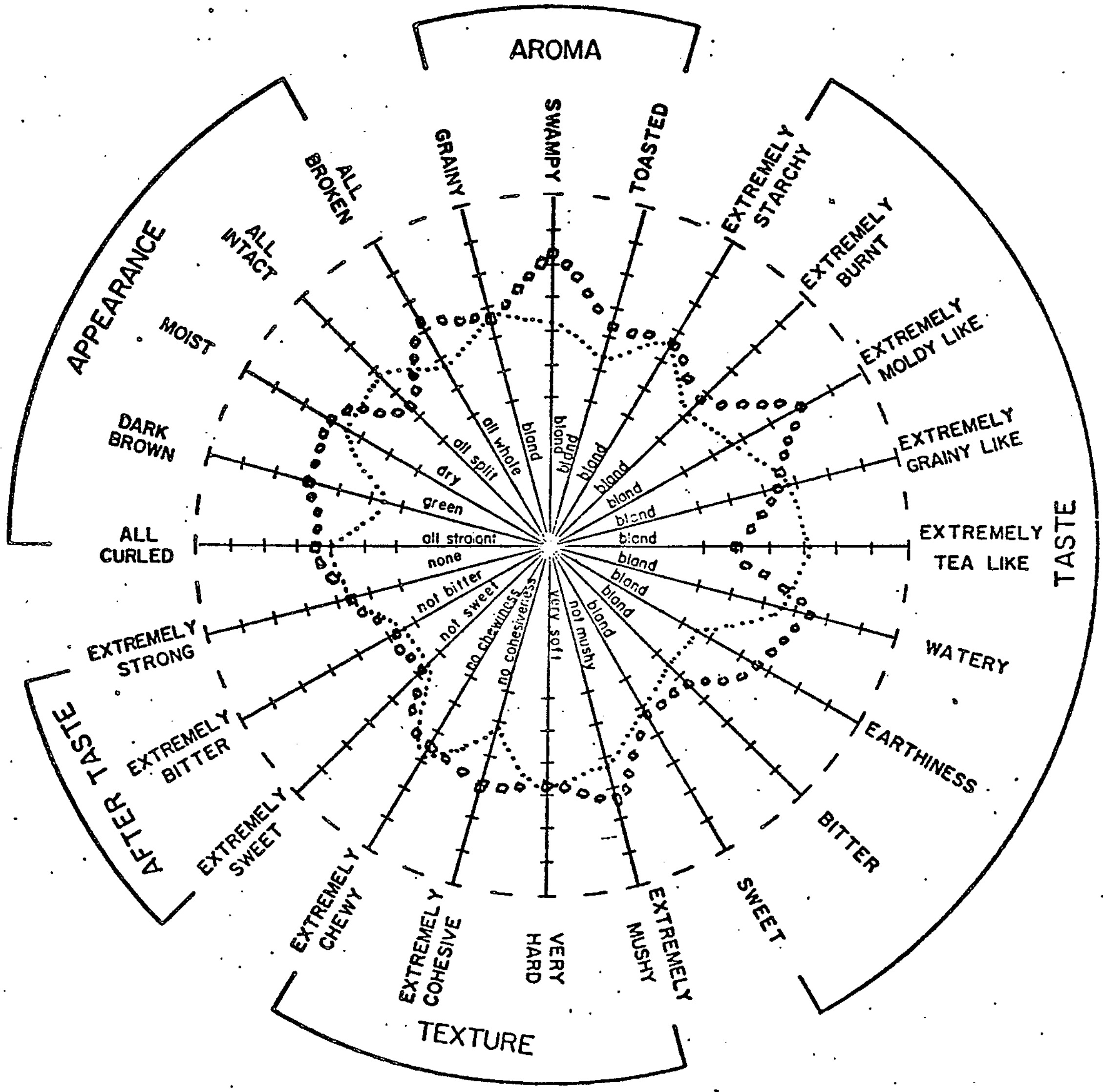


1973 Paddy Wild Rice
21.1^{o}C Temperature Curing
High Temperature Parching

.... no curing
oooo 2 weeks curing
—— 4 week curing

APPENDIX 17

FLAVOUR PROFILE OF WILD RICE

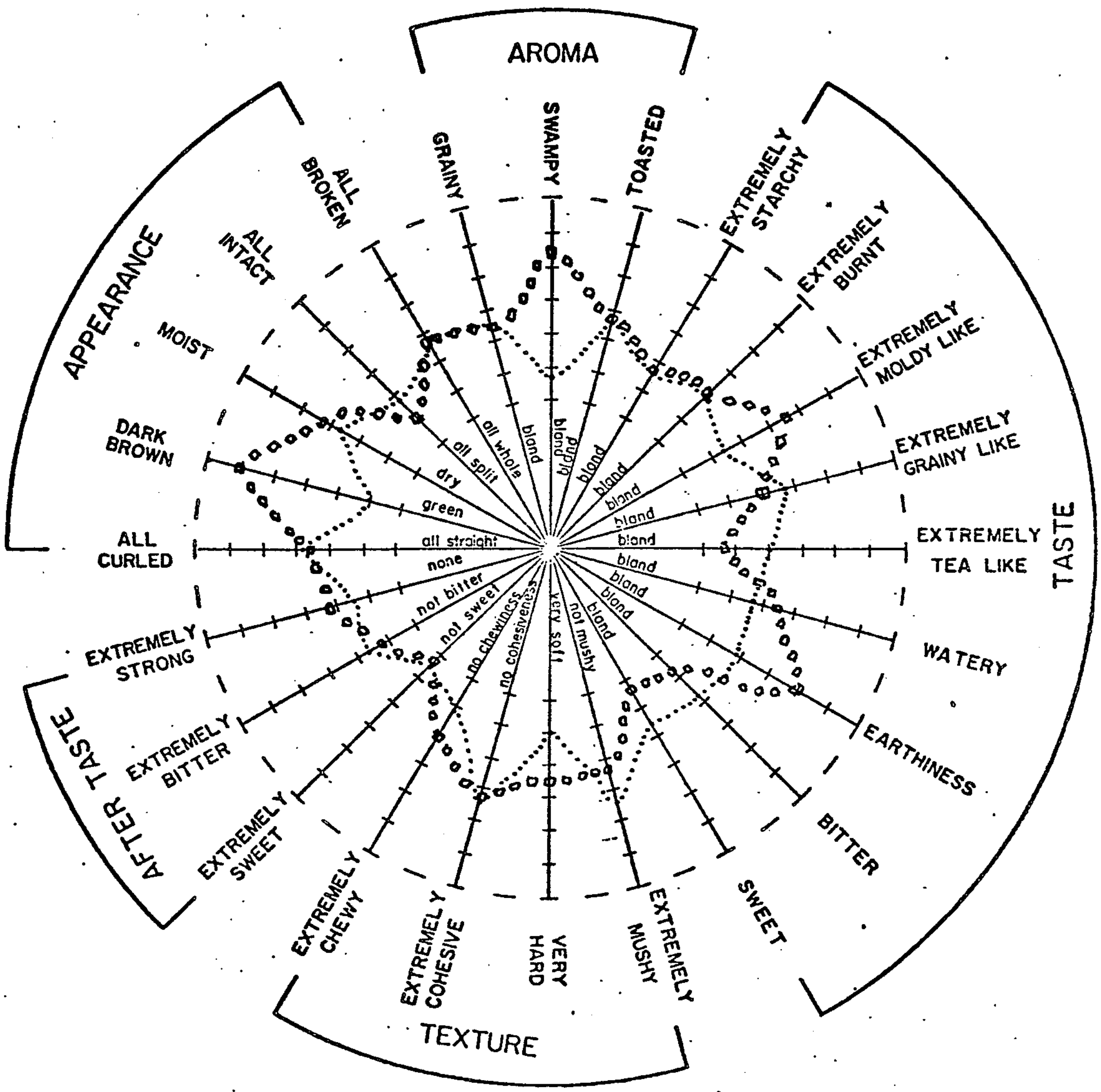


1973 Paddy Wild Rice
31.1 ^{o}C Temperature Curing
Low Temperature Parching

.... no curing
oooo 5 days curing

APPENDIX 18

FLAVOUR PROFILE OF WILD RICE

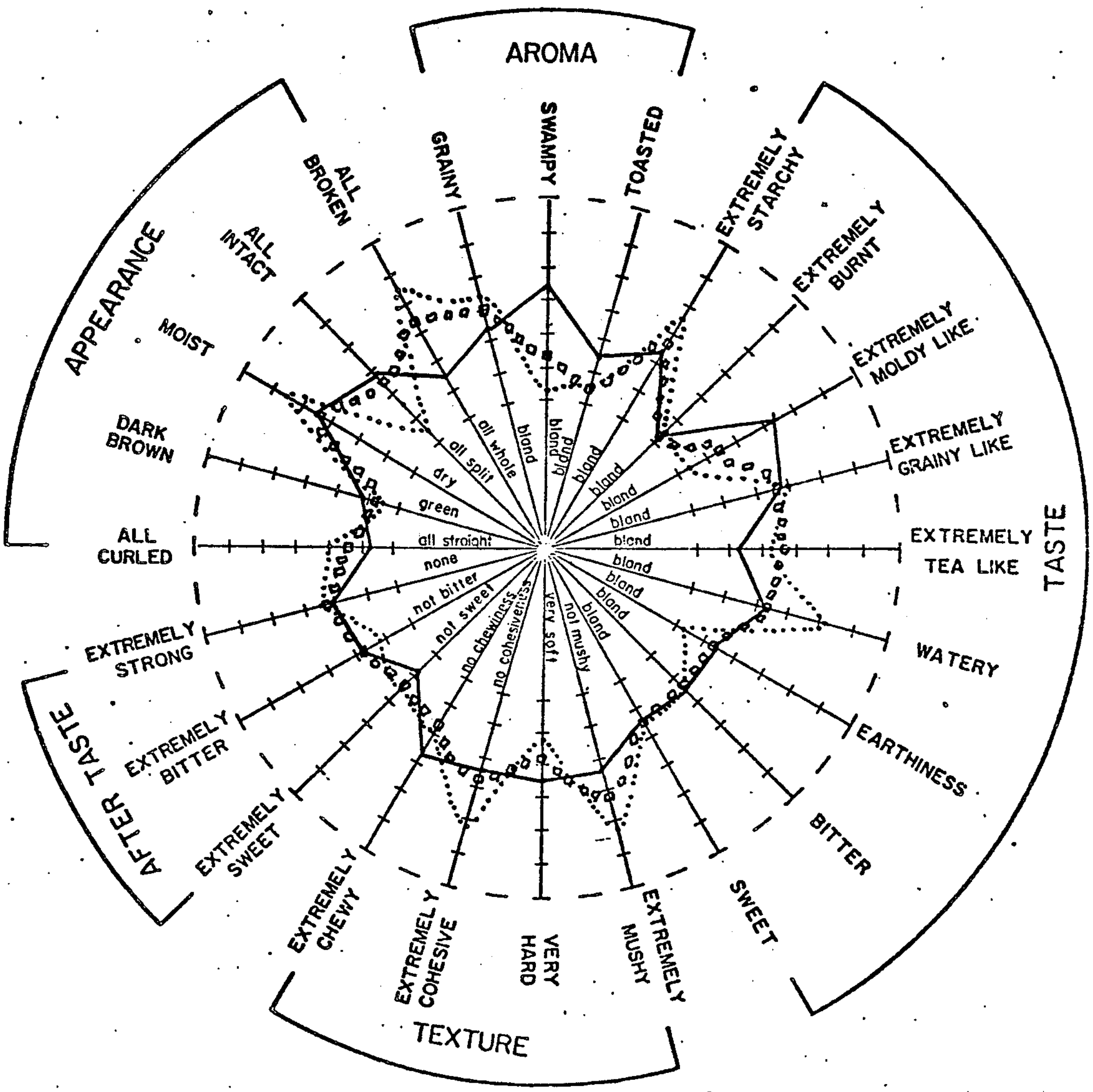


1973 Paddy Wild Rice
31.1°C Temperature Curing
High Temperature Parching

.... no curing
oooo 5 days curing

APPENDIX 19

FLAVOUR PROFILE OF WILD RICE

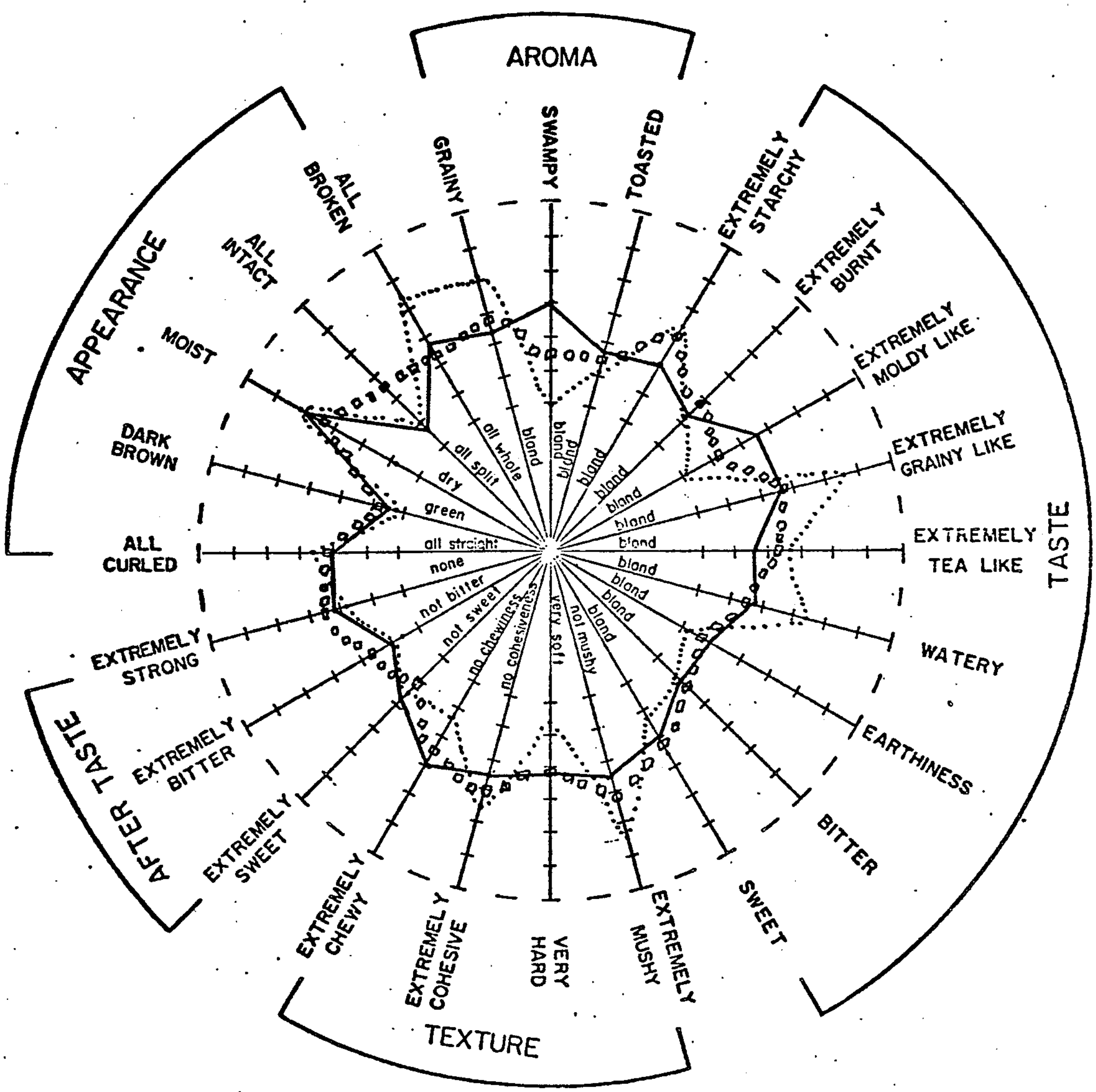


1974 Paddy Wild Rice
10^{o}C Temperature Curing
Low Temperature Parching

.... no curing
oooo 3 weeks curing
—— 6 weeks curing

APPENDIX 20

FLAVOUR PROFILE OF WILD RICE



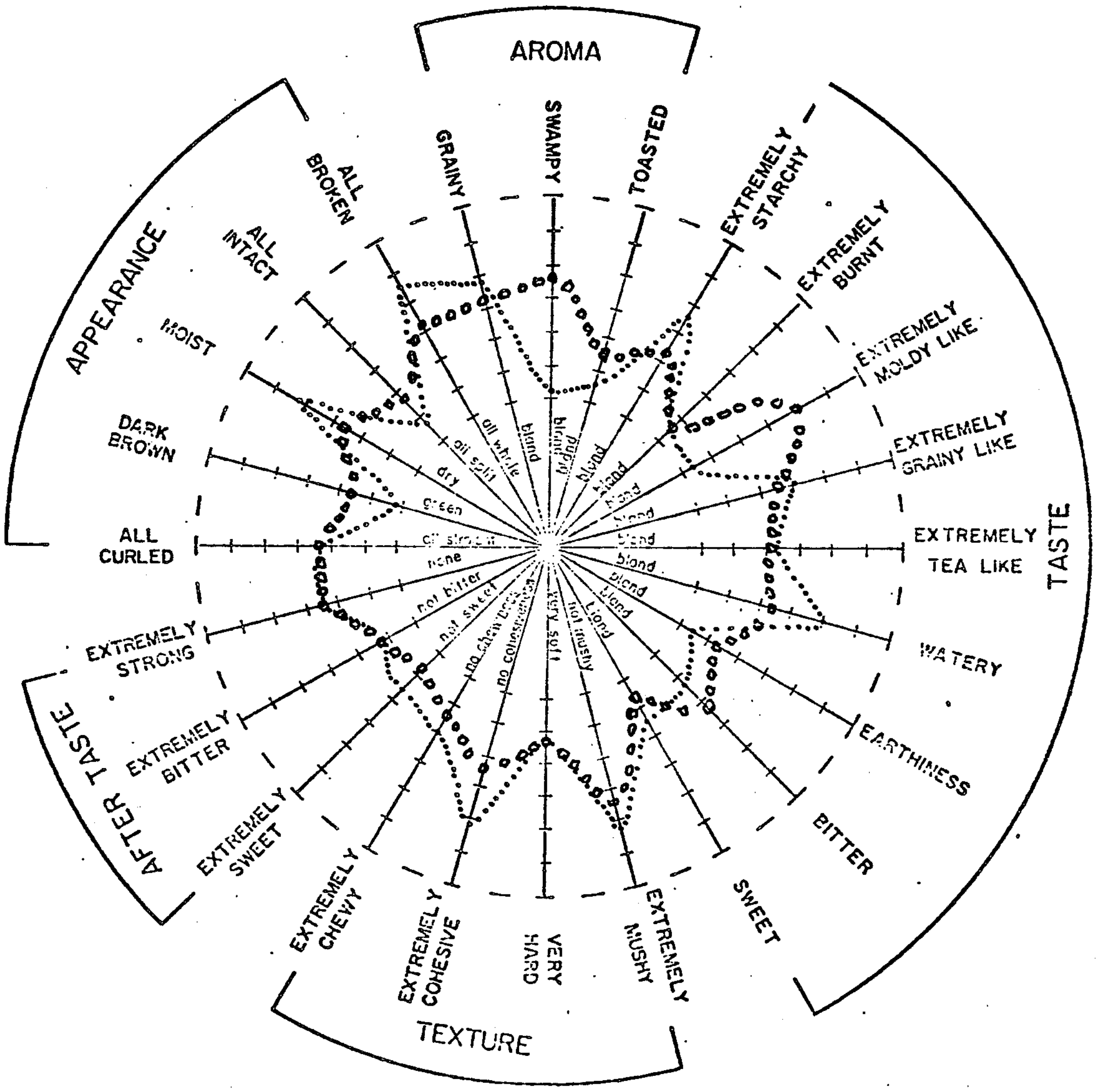
1974 Paddy Wild Rice
10°C Temperature Curing
High Temperature Parching

.... no curing
oooo 3 weeks curing
—— 6 weeks curing

APPENDIX 21

(15)

FLAVOUR PROFILE OF WILD RICE

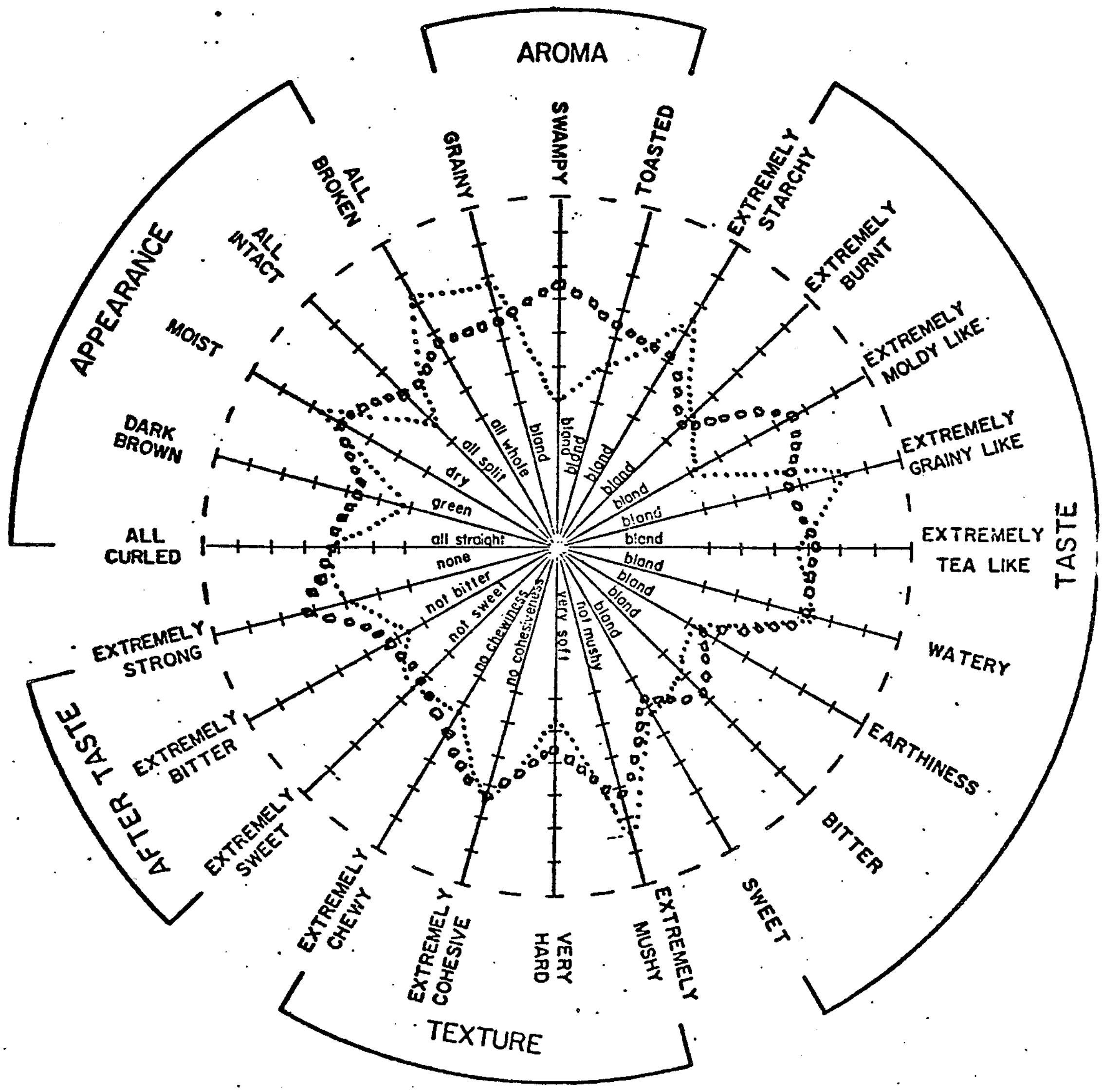


1974 Paddy Wild Rice
21.1^{o}C Temperature Curing
Low Temperature Parching

.... no curing
oooo 2 weeks curing

APPENDIX 22

FLAVOUR PROFILE OF WILD RICE

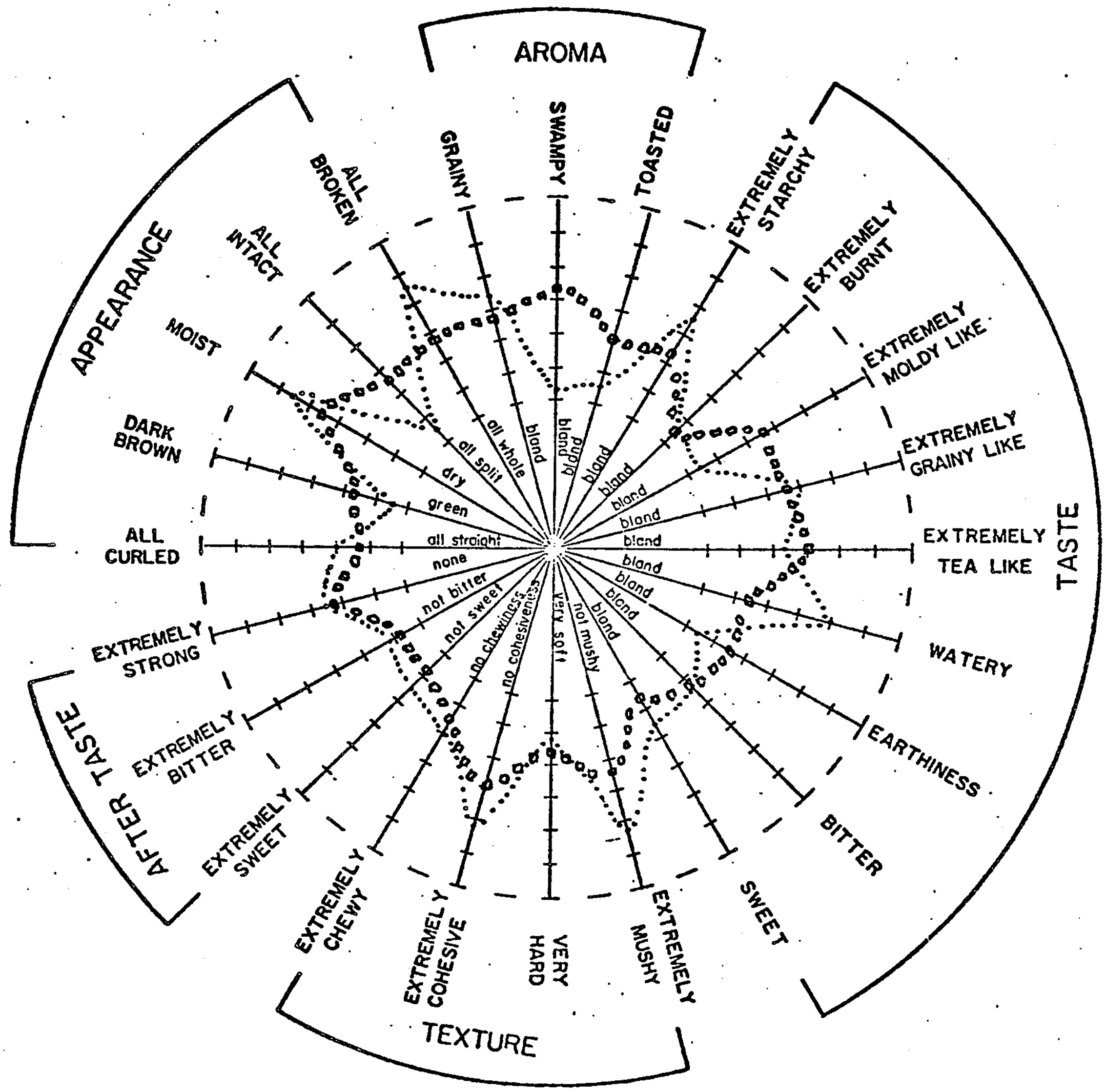


1974 Paddy Wild Rice
21.1^{o}C Temperature Curing
High Temperature Parching

.... no curing
oooo 2 weeks curing

APPENDIX 23

FLAVOUR PROFILE OF WILD RICE

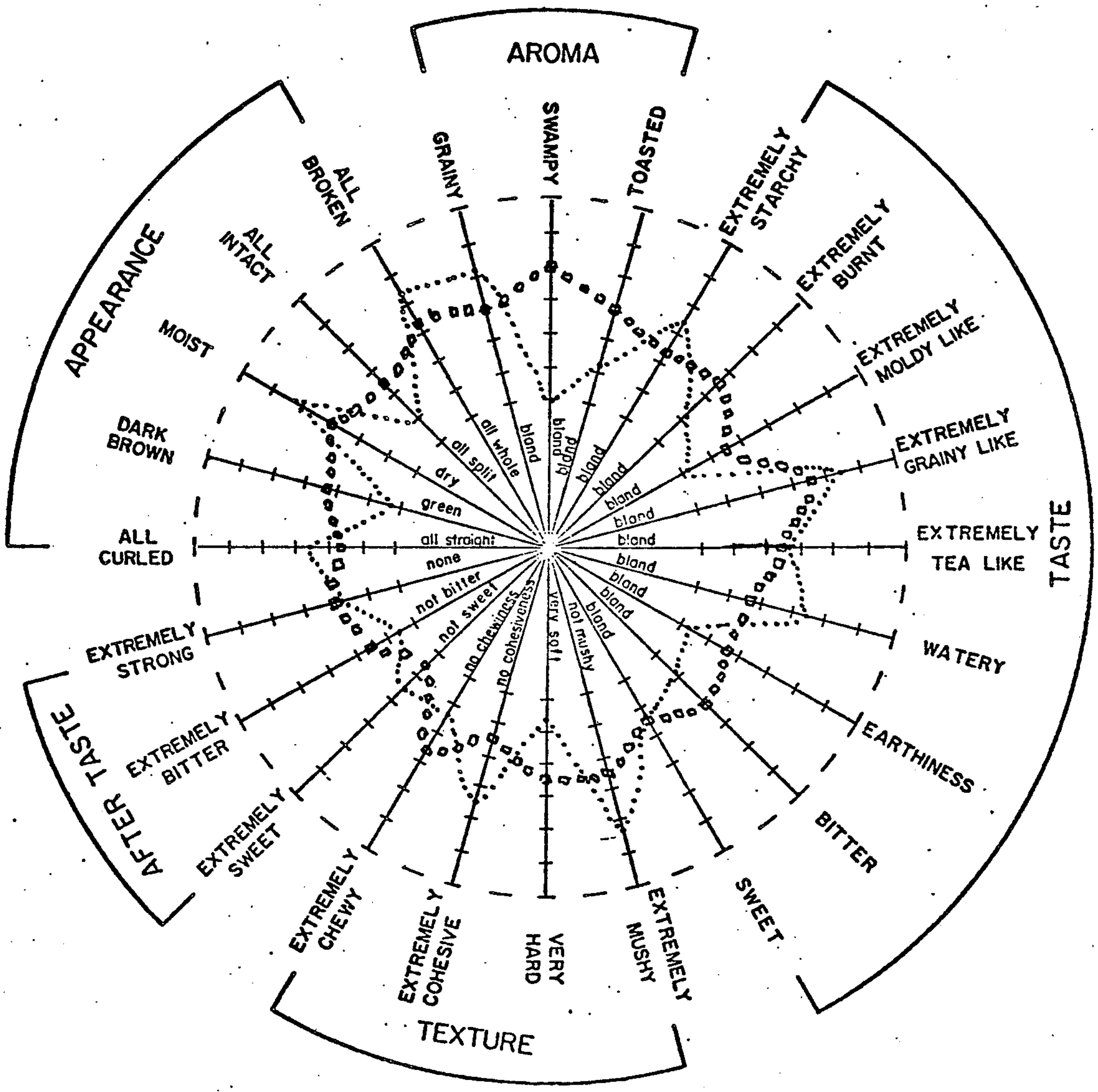


1974 Paddy Wild Rice
31.1^{o} Temperature Curing
Low Temperature Parching

.... no curing
oooo 5 days curing

APPENDIX 24

FLAVOUR PROFILE OF WILD RICE



1974 Paddy Wild Rice
31.1°C Temperature Curing
High Temperature Parching

.... no curing
oooo 5 days curing

APPENDIX 25

Appendices 26 - 37. Analysis of Variance and Duncan's Multiple Range Test Summaries for the Rice Samples Tested by the Sensory Panel. The Following Indications are Used in These Appendices.

10°C Temperature Curing

A: no curing
B: 3 weeks curing
C: 6 weeks curing
D: 9 weeks curing

21.1°C Temperature Curing

A: no curing
B: 2 weeks curing
C: 4 weeks curing

31.1°C Temperature Curing

A: no curing
B: 5 days curing
C: 10 days curing

Appendix 26: 1973 Lake Wild Rice 10^{o}C Temperature Curing

Scales	Factors	F Value	Duncan's Multiple Range Test: High Temp. Parching	Duncan's Multiple Range Test: Low Temp. Parching
Straightness	Time Temp.	16.78* 2.46	A B C D	A B C D
Colour	Time Temp.	6.0 * 0.05	A B C D	A B C D
Dryness	Time Temp.	6.91 18.67*	A B C D	A B C D
Splitness	Time Temp.	82.33* 4.28	B A C D	A B D C
Breakage	Time Temp.	111.64* 114.8	A B C D	A B C D
Graininess (Odour)	Time Temp.	5.84* 1.63	B A C D	B A C D
Swampiness	Time Temp.	101.7 * 0.02	A B C D	A B C D
Toast	Time Temp.	2.88 223.1 *	A B C D	A B C D
Starchy	Time Temp.	1.29 9.88*	A B C D	A B C D
Burnt	Time Temp.	6.23* 167.7 *	A B C D	A B C D
Moldiness	Time Temp.	64.69* 0.28	A B C D	A B C D
Graininess (Taste)	Time Temp.	10.91* 0.01	B C A D	A B C D
Tea-Like	Time Temp.	59.83* 14.1 *	A B C D	A B C D
Watery	Time Temp.	31.1* 72.76*	B D C A	A B C D
Earthiness	Time Temp.	148.8 * 0.013	A B C D	A B C D

Scales	Factors	F Value	Duncan's Multiple Range Test High Temp. Parching	Duncan's Multiple Range Test Low Temp. Parching
Bitter	Time Temp.	11.72* 2.34	A B C D	D A C B
Sweet	Time Temp.	7.11* 14.37*	A B D C	B A C D
Mushiness	Time Temp.	150.63* 29.84*	A B C D	A B C D
Hardness	Time Temp.	8.39* 6.77*	A D B C	B A C D
Cohesiveness	Time Temp.	60.57* 90.88*	A B D C	A B C D
Chewiness	Time Temp.	9.28* 113.1 *	A B D C	A B C D
Sweet (Aftertaste)	Time Temp.	1.59 2.94	A B C D	A B C D
Bitter (Aftertaste)	Time Temp.	3.9 0.23	A B C D	B A C D
Strongliness (Aftertaste)	Time Temp.	6.23* 0.507	C A B D	A B C D

* Significant at both 1% and 5% level.

Appendix 27. 1973 Lake Wild Rice 21.1°C Temperature Curing

Scales	Factors	F Value	Duncun'a Multiple Range Test High Temp. Parching	Low Temp. Parching
Straightness	Time Temp.	110.1 * 29.43*	A B C	A B C
Colour	Time Temp.	9.93* 0.05	A B C	A B C
Dryness	Time Temp.	27.28* 0.281	A B C	A B C
Splitness	Time Temp.	11.82* 5.414	A B C	A B D
Breakage	Time Temp.	28.37* 29.04*	A B C	A B C
Graininess (Odour)	Time Temp.	10.63* 5.01	A B C	B A C
Swampiness	Time Temp.	561.61* 9.103*	A B C	A B C
Toast	Time Temp.	3.79 92.47*	A B C	B A C
Starchy	Time Temp.	80.1 * 49.9 *	A B C	A B C
Burnt	Time Temp.	3.37 44.8 *	A B C	A B C
Moldiness	Time Temp.	120.1 * 22.8 *	A B C	A B C
Graininess (Taste)	Time Temp.	44.06* 70.17*	B A C	B A C
Tea-Like	Time Temp.	13.76* 0.0	B A C	A B C
Watery	Time Temp.	66.47* 135.1 *	B A C	A B C
Earthiness	Time Temp.	146.6 * 72.99*	A B C	A B C

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Duncun's Multiple Range Test Low Temp. Parching
Bitter	Time Temp.	5.06* 65.34*	A B C	B A C
Sweet	Time Temp.	0.65 1.24	A B C	A B C
Mushiness	Time Temp.	182.9 * 56.8 *	A B C	A B C
Hardness	Time Temp.	166.4 * 0.91	A B C	A B C
Cohesiveness	Time Temp.	169.8 * 51.25*	A B C	A B C
Chewiness	Time Temp.	168.1 * 32.62*	A B C	A B C
Sweet (Aftertaste)	Time Temp.	5.89* 3.24	B A C	A B C
Bitter (Aftertaste)	Time Temp.	2.96 14.34*	A B C	A B C
Strongliness	Time Temp.	178.6 * 3.17	A B C	A B C

* Significant at both 1% and 5% level

Appendix 28. 1973 Lake Wild Rice 31.1°C Temperature Curing

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Low Temp. Parching
Straightness	Time Temp.	126.89* 36.34*	A B C	A B C
Colour	Time Temp.	6.88* 14.21*	A B C	A B C
Dryness	Time Temp.	2.65 4.29	A B C	A B C
Splitness	Time Temp.	17.97* 27.30*	A B C	A B C
Breakage	Time Temp.	89.19* 6.15	A B C	A B C
Graininess (Odour)	Time Temp.	0.84 9.59*	A B C	A B C
Swampiness	Time Temp.	589.9 * 7.03*	A B C	A B C
Toast	Time Temp.	2.23 295.9 *	A B C	A B C
Starchy	Time Temp.	44.84* 1.17	A B C	A B C
Burnt	Time Temp.	11.45* 224.1 *	A C B	C A B
Moldiness	Time Temp.	175.13* 0.79	A B C	A B C
Graininess (Taste)	Time Temp.	0.59 10.24*	A B C	A B C
Tea-Like	Time Temp.	14.71* 1.93	B A C	B A C
Watery	Time Temp.	245.96* 9.64*	A B C	A B C
Earthiness	Time Temp.	424.57* 29.98*	A B C	A B C

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Duncun's Multiple Range Test Low Temp. Parching
Bitter	Time Temp.	55.29* 12.54*	A B C	A B C
Sweet	Time Temp.	3.76 1.01	A B C	A B C
Mushiness	Time Temp.	163.44* 0.27	A B C	A B C
Hardness	Time Temp.	51.28* 23.99*	A B C	A B C
Cohesiveness	Time Temp.	32.10* 3.16*	A B C	A B C
Chewiness	Time Temp.	100.69* 13.77*	A B C	A B C
Sweet (Aftertaste)	Time Temp.	4.66 3.66	B A C	A B C
Bitter (Aftertaste)	Time Temp.	80.94* 2.20	A B C	A B C
Strongliness	Time Temp.	58.99* 0.10	A B C	A B C

* Significant at both 1% and 5% level.

Appendix 29. 1974 Lake Wild Rice 10°C Temperature Curing

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Duncun's Multiple Range Test Low Temp. Parching
Straightness	Time Temp.	22.80* 41.39*	A C D B	B C D A
Colour	Time Temp.	77.73* 0.38	A B C D	A B C D
Dryness	Time Temp.	3.29 5.51	C A B D	A B D C
Splitness	Time Temp.	1.96 13.73*	C B A D	A B C D
Breakage	Time Temp.	0.56 10.01*	A B C D	A B C D
Graininess (Odour)	Time Temp.	23.5 * 1.19	A B C D	A B C D
Swampiness	Time Temp.	8.31* 1.18	A B C D	C A B D
Toast	Time Temp.	21.43* 15.95*	A D B C	A B C D
Starchy	Time Temp.	1.46 39.0 *	B D A C	A C D B
Burnt	Time Temp.	12.56* 13.95*	A D B C	A B C D
Moldiness	Time Temp.	0.61 6.84	A B C D	A B C D
Graininess (Taste)	Time Temp.	25.68* 14.78*	A B C D	A B C D
Tea-Like	Time Temp.	6.06* 3.01	A B C D	A B C D
Watery	Time Temp.	2.80 15.63*	A C B D	A B C D
Earthiness	Time Temp.	7.09* 22.43*	A B D C	A C B D

Scales	Factors	F Value	Duncun's Multiple Range Test: High Temp. Parching	Duncun's Multiple Range Test: Low Temp. Parching
Bitter	Time Temp	13.00* 10.29*	A B C D	A B D C
Sweet	Time Temp.	4.98* 0.27	A B C D	A C B D
Mushiness	Time Temp.	2.23 0.31	A B C D	A B C D
Hardness	Time Temp.	7.66* 25.67*	A C B D	B D C A
Cohesiveness	Time Temp.	8.12* 8.20*	A C B D	A B C D
Chewiness	Time Temp.	1.45 0.83	A C B D	A B C D
Sweet (Aftertaste)	Time Temp.	6.91* 1.32	A C B D	A C B D
Bitter (Aftertaste)	Time Temp.	16.22* 7.74*	A B C D	B A C D
Strongliness (Aftertaste)	Time Temp.	20.00* 1.53	D A B C	B A C D

* Significant at both 1% and 5% level.

Appendix 30. 1974 Lake Wild Rice 21.1°C Temperature Curing

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Duncun's Multiple Range Test Low Temp.Parching
Straightness	Time	33.16*	A B C	A B C
	Temp.	59.28*		
Colour	Time	29.9*	A B C	A B C
	Temp.	72.1*		
Dryness	Time	0.65	A B C	A B C
	Temp.	0.61		
Splitness	Time	15.58*	A B C	A C B
	Temp.	0.15		
Breakage	Time	7.26*	A C B	A B C
	Temp.	2.68		
Graininess (Odour)	Time	69.54*	A B C	A B C
	Temp.	21.24*		
Swampiness	Time	110.6 *	A B C	A B C
	Temp.	9.15*		
Toast	Time	5.49*	A B C	A C B
	Temp.	9.42		
Starchy	Time	0.11	A B C	A B C
	Temp.	0.0		
Burnt	Time	21.32*	A B C	A B C
	Temp.	52.39*		
Moldiness	Time	47.69*	A B C	A B C
	Temp.	8.04*		
Graininess (Taste)	Time	38.14*	A B C	A B C
	Temp.	10.83*		
Tea-Like	Time	2.92	B A C	A B C
	Temp.	0.51		
Watery	Time	10.1 *	A B C	A B C
	Temp.	5.42		
Earthiness	Time	99.81*	A B C	A B C
	Temp.	6.59°		

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Duncun's Multiple Range Test Low Temp. Parching
Bitter	Time Temp.	23.45* 0.0	A B C	A B C
Sweet	Time Temp.	5.56* 5.13	A B C	A B C
Mushiness	Time Temp.	11.01* 19.14*	A B C	A C B
Hardness	Time Temp.	4.36 4.88	A B C	A B C
Cohesiveness	Time Temp.	1.33 0.10	A B C	A B C
Chewiness	Time Temp.	1.25 1.51	A B C	B A C
Sweet (Aftertaste)	Time Temp.	5.42* 0.08	A B C	A B C
Bitter (Aftertaste)	Time Temp.	19.94* 3.22	A B C	A B C
Strongliness (Aftertaste)	Time Temp.	2.32 1.49	B C A	A B C

* Significant at both 1% and 5% level.

Appendix 31. 1974 Lake Wild Rice 31.1°C Temperature Curing

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Low Temp. Parching
Straightness	Time Temp.	14.08* 18.77*	A B C	A B C
Colour	Time Temp.	220.43* 0.91	A B C	A B C
Dryness	Time Temp.	18.35* 21.28*	A C B	A B C
Splitness	Time Temp.	42.38* 13.43*	A B C	A B C
Breakage	Time Temp.	15.27* 7.43*	A B C	A B C
Graininess (Odour)	Time Temp.	60.53* 3.21	A B C	A B C
Swampiness	Time Temp.	87.15* 4.98	A B C	A B C
Toast	Time Temp.	0.6 18.05*	A B C	A B C
Starchy	Time Temp.	2.44 4.25	A B C	A B C
Burnt	Time Temp.	6.74* 29.55*	A B C	A B C
Moldiness	Time Temp.	6.77* 58.08*	A B C	A B C
Graininess (Taste)	Time Temp.	29.92* 12.84*	A B C	A B C
Tea-Like	Time Temp.	21.43* 0.68	A B C	A B C
Watery	Time Temp.	4.66 0.45	A B C	B A C
Earthiness	Time Temp.	50.63* 2.07	A B C	A B C

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Duncun's Multiple Range Test Low Temp. Parching
Bitter	Time Temp.	11.16* 5.28	A C B	A B C
Sweet	Time Temp.	4.59 6.77*	A B C	B A C
Mushiness	Time Temp.	69.71* 22.86*	A B C	A B C
Hardness	Time Temp.	04.7 18.47*	A B C	A B C
Cohesiveness	Time Temp.	4.09 0.0	A B C	B A C
Chewiness	Time Temp.	9.85* 3.40	A B C	B C A
Sweet (Aftertaste)	Time Temp.	5.93* 2.88	B C A	B C A
Bitter (Aftertaste)	Time Temp.	4.81* 2.58	B C A	A B C
Strongliness (Aftertaste)	Time Temp.	2.35 0.175	A B C	A B C

* Significant at both 1% and 5% level.

Appendix 32. 1973 Paddy Wild Rice 10°C Temperature Curing

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Duncun's Multiple Range Test Low Temp. Parching
Straightness	Time Temp.	61.36* 223.81*	A B C D	A C B D
Colour	Time Temp.	188.9 * 0.034	A B C D	A B C D
Dryness	Time Temp.	12.83* 0.23	A B C D	A B C D
Splitness	Time Temp.	15.59* 5.67	A D B C	A B C D
Breakage	Time Temp.	64.15* 5.28	A B C D	A B C D
Graininess (Odour)	Time Temp.	18.54* 0.131	A B C D	A B C D
Swampiness	Time Temp.	146.97* 55.96*	A B C D	A B C D
Toast	Time Temp.	0.436 20.946*	A B C D	A B C D
Starchy	Time Temp.	32.3 * 5.49	A B C D	A B C D
Burnt	Time Temp.	6.17* 56.95*	A B C D	A D C B
Moldiness	Time Temp.	53.2 * 4.41	A B C D	A B C D
Graininess	Time Temp.	79.9 * 3.87	A B C D	A B C D
Tea-Like	Time Temp.	6.12* 0.24	A B C D	A B C D
Watery	Time Temp.	7.86* 6.74	A B C D	A C B D
Earthiness	Time Temp.	42.08* 4.14	A B C D	A B C D

Scales	Factors	F Value	Duncun's Multiple Range Test For the Different Curing Time: High Temp. Parching	Low Temp. Parching
Bitter	Time Temp.	3.61 114.8 *	A D B C	A B C D
Sweet	Time Temp.	23.39* 4.43	A B C D	A C B D
Mushiness	Time Temp.	15.26* 0.02	A B C D	A B C D
Hardness	Time Temp.	40.56* 0.03	A B C D	A B C D
Cohesiveness	Time Temp.	4.23* 1.36	A B C D	A B C D
Chewiness	Time Temp.	9.86* 6.48	A B C D	A B C D
Sweet (Aftertaste)	Time Temp.	3.46 7.94	B A C D	A D B C
Bitter (Aftertaste)	Time Temp.	8.58* 8.51*	A C B D	A C B D
Strongliness (Aftertaste)	Time Temp.	7.33* 2.63	C A B D	A C B D

* Significant at both 1% and 5% level.

Appendix 33. 1973 Paddy Wild Rice 21.1°C Temperature Curing

Scales	Factors	F Value	Duncun's Multiple Range Test for Different Curing Time High Temp. Parching	Low Temp. Parching
Straightness	Time Temp.	33.52* 1.31	A B C	A B C
Colour	Time Temp.	4.46* 5.27	A B C	B A C
Dryness	Time Temp.	09.24* 5.81	A B C	A B C
Splitness	Time Temp.	7.34* 3.35	B C A	A B C
Breakage	Time Temp.	3.230 12.76*	A B C	A B C
Graininess (Odour)	Time Temp.	0.687 1.628	A C B	B A C
Swampiness	Time Temp.	27.96* 2.73	A B C	A B C
Toast	Time Temp.	0.77 19.60*	A B C	A B C
Starchy	Time Temp.	12.86* 0.04	A B C	A B C
Burnt	Time Temp.	9.35* 47.33*	A B C	A B C
Moldiness	Time Temp.	69.91* 71.83*	A B C	A B C
Graininess (Taste)	Time Temp.	25.47* 7.55*	B A C	A B C
Tea-Like	Time Temp.	2.14 4.06	A B C	A B C
Watery	Time Temp.	23.23* 5.29	A B C	A B C
Earthiness	Time Temp.	14.63* 32.24*	A B C	A B C

Scales	Factors	F Value	Duncun's Multiple Range Test for Different Curing Time	
			High Temp. Parching	Low Temp. Parching
Bitter	Time Temp.	2.76 15.70*	A B C	A B C
Sweet	Time Temp.	0.50 0.15	A B C	A B C
Mushiness	Time Temp.	35.48* 17.53*	A B C	A B C
Hardness	Time Temp.	21.26* 46.82*	A B C	A B C
Cohesiveness	Time Temp.	16.32* 1.57	A B C	A B C
Chewiness	Time Temp.	25.03* 12.53*	A B C	A B C
Sweet (Aftertaste)	Time Temp.	0.05 2.51	A B C	A B C
Bitter (Aftertaste)	Time Temp.	11.12* 11.91*	A B C	A B C
Strongliness (Aftertaste)	Time Temp.	17.09* 15.07*	A B C	A B C

* Significant at both 1% and 5% level.

Appendix 34. 1973 Paddy Wild Rice 31.1°C Temperature Curing

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Duncun's Multiple Range Test Low Temp. Parching
Straightness	Time Temp.	1.53 18.78*	A B	A B
Colour	Time Temp.	16.57* 122.1 *	A B	A B
Dryness	Time Temp.	6.97* 0.52	A B	A B
Splitness	Time Temp.	125.2 * 40.8 *	A B	A B
Breakage	Time Temp.	20.4 * 1.43	A B	A B
Graininess (Odour)	Time Temp.	0.09 2.25	A B	A B
Swampiness	Time Temp.	350.8 * 6.23	A B	A B
Toast	Time Temp.	5.99 39.12*	A B	A B
Starchy	Time Temp.	0.21 30.95*	A B	A B
Burnt	Time Temp.	8.09* 11.66*	A B	A B
Moldiness	Time Temp.	223.7 * 8.94	A B	A B
Graininess (Taste)	Time Temp.	7.85° 3.76	A B	A B
Tea-Like	Time Temp.	162.71* 24.1 *	A B	A B
Watery	Time Temp.	28.93* 25.34*	A B	A B
Earthiness	Time Temp.	217.89* 24.21*	A B	A B

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Duncun's Multiple Range Test Low Temp. Parching
Bitter	Time Temp.	0.3 7.66	$\underline{A\ B}$	$\underline{A\ B}$
Sweet	Time Temp.	0.11 25.0 *	$\underline{A\ B}$	$\underline{A\ B}$
Mushiness	Time Temp.	38.06* 44.67*	$\underline{A}\ \underline{B}$	$\underline{A}\ \underline{B}$
Hardness	Time Temp.	15.87* 1.29	$\underline{A}\ \underline{B}$	$\underline{A}\ \underline{B}$
Cohesiveness	Time Temp	278.8 * 6.74	$\underline{A}\ \underline{B}$	$\underline{A}\ \underline{B}$
Chewiness	Time Temp.	7.41* 0.86	$\underline{A}\ \underline{B}$	$\underline{A}\ \underline{B}$
Sweet (Aftertaste)	Time Temp.	0.14 11.71*	$\underline{A\ B}$	$\underline{A\ B}$
Bitter (Aftertaste)	Time Temp.	0.324 32.39*	$\underline{A\ B}$	$\underline{A\ B}$
Strongliness (Aftertaste)	Time Temp.	7.83* 0.49	$\underline{A}\ \underline{B}$	$\underline{A}\ \underline{B}$

* Significant at both 1% and 5% level.

Appendix 35. 1974 Paddy Wild Rice 10^{o}C Temperature Curing

Scales	Factors	F Value	Duncun's Multiple Range Test: High Temp. Parching	Duncun's Multiple Range Test: Low Temp. Parching
Straightness	Time Temp.	10.54* 22.71*	A B C	A B C
Colour	Time Temp.	10.40* 0.0	B A C	A B C
Dryness	Time Temp.	14.52* 0.03	B A C	A B C
Splitness	Time Temp.	40.1 * 13.27*	B A C	A B C
Breakage	Time Temp.	66.84* 0.03	A B C	A B C
Graininess (Odour)	Time Temp.	12.21* 1.68	A B C	A B C
Swampiness	Time Temp.	115.08* 1.0	A B C	A B C
Toast	Time Temp.	6.4 0.98	A B C	A B C
Starchy	Time Temp.	19.51* 0.23	A B C	A B C
Burnt	Time Temp.	0.43 28.2 *	A B C	A B C
Moldiness	Time Temp.	116.24* 6.02	A B C	A B C
Graininess (Taste)	Time Temp.	10.6 * 5.78	A B C	A B C
Tea-Like	Time Temp.	13.10* 1.63	A B C	A B C
Watery	Time Temp.	47.34* 12.0	A B C	A B C
Earthiness	Time Temp.	17.18 4.41	A B C	A B C

Scales	Factors	F Value	Duncun's Multiple Range Test: High Temp. Parching	Duncun's Multiple Range Test: Low Temp. Parching
Bitter	Time	0.49	A B C	A B C
	Temp.	5.47		
Sweet	Time	1.57	A B C	A B C
	Temp.	1.61		
Mushiness	Time	31.85	A B C	A B C
	Temp.	0.18		
Hardness	Time	37.15*	A B C	A B C
	Temp.	2.25		
Cohesiveness	Time	9.98*	A B C	A B C
	Temp.	0.056		
Chewiness	Time	16.54*	A B C	A B C
	Temp.	0.09		
Sweet (Aftertaste)	Time	0.72	B A C	A B C
	Temp.	0.83		
Bitter (Aftertaste)	Time	14.10*	B C A	A B C
	Temp.	8.53*		
Strongliness (Aftertaste)	Time	0.87	A B C	A B C
	Temp.	0.50		

* Significant at both 1% and 5% level.

Appendix 36. 1974 Paddy Wild Rice 21.1°C Temperature Curing

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Low Temp. Parching
Straightness	Time Temp.	0.058 0.519	$\underline{A\ B}$	$\underline{A\ B}$
Colour	Time Temp	152.1 * 0.11	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$
Dryness	Time Temp.	23.32* 0.28	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$
Splitness	Time Temp.	47.76* 0.59	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$
Breakage	Time Temp.	51.13* 3.38	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$
Graininess (Odour)	Time Temp.	20.20* 1.26	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$
Swampiness	Time Temp.	460.27* 4.38	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$
Toast	Time Temp.	24.15* 17.42*	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$
Starchy	Time Temp.	34.16 0.32	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$
Burnt	Time Temp.	0.05 6.22*	$\underline{A\ B}$	$\underline{A\ B}$
Moldiness	Time Temp.	324.63* 2.81	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$
Graininess	Time Temp.	18.81* 10.58*	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$
Tea-Like	Time Temp.	0.32 12.99*	$\underline{A\ B}$	$\underline{A\ B}$
Watery	Time Temp.	13.01* 0.025	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$
Earthiness	Time Temp.	20.73 11.66	$\underline{A}$ $\underline{B}$	$\underline{A}$ $\underline{B}$

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Low Temp. Parching
Bitter	Time Temp.	13.32* 2.99	A B	A B
Sweet	Time Temp.	9.68* 0.0	A B	A B
Mushiness	Time Temp.	15.38* 0.03	A B	A B
Hardness	Time Temp.	16.00* 0.25	A B	A B
Cohesiveness	Time Temp.	8.9 * 0.42	A B	A B
Chewiness	Time Temp.	0.036 0.036	A B	A B
Sweet (Aftertaste)	Time Temp.	7.99* 0.04	A B	A B
Bitter (Aftertaste)	Time Temp.	3.92 2.0	A B	A B
Strongliness (Aftertaste)	Time Temp.	8.09* 0.04	A B	A B

* Significant at both 1% and 5% level.

Appendix 37. 1974 Paddy Wild Rice 31.1°C Temperature Curing

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Low Temp. Parching
Straightness	Time Temp.	13.86* 6.48	A B	A B
Colour	Time Temp.	146.37* 0.09	A B	A B
Dryness	Time Temp.	37.88* 6.95	A B	A B
Splitness	Time Temp.	76.84* 0.7	A B	A B
Breakage	Time Temp.	36.7 * 0.11	A B	A B
Graininess (Odour)	Time Temp.	8.44* 2.83	A B	A B
Swampiness	Time Temp.	0.45 209.49*	A B	A B
Toast	Time Temp.	135.29* 27.39*	A B	A B
Starchy	Time Temp.	23.6 * 0.12	A B	A B
Burnt	Time Temp.	16.5 * 49.79*	A B	A B
Moldiness	Time Temp.	92.59* 13.21*	A B	A B
Graininess (Taste)	Time Temp.	8.6 * 29.67*	A B	A B
Tea-Like	Time Temp.	1.32 0.0	A B	A B
Watery	Time Temp.	63.98* 0.22	A B	A B
Earthiness	Time Temp.	51.13* 0.04	A B	A B

Scales	Factors	F Value	Duncun's Multiple Range Test High Temp. Parching	Duncun's Multiple Range Test Low Temp. Parching
Bitter	Time Temp.	4.84 1.96	A B	A B
Sweet	Time Temp.	2.20 1.24	A B	A B
Mushiness	Time Temp.	49.04* 0.41	A B	A B
Hardness	Time Temp.	48.36* 1.93	A B	A B
Cohesiveness	Time Temp.	22.25* 10.19*	A B	A B
Chewiness	Time Temp.	4.0 1.0	A B	A B
Sweet (Aftertaste)	Time Temp.	11.36* 0.56	A B	A B
Bitter (Aftertaste)	Time Temp.	10.8 * 1.2	A B	A B
Strongliness (Aftertaste)	Time Temp.	0.04 3.11	A B	A B

* Significant at both 1% and 5% level.