NAVY BEAN COOKABILITY EVALUATION
BY
MODIFIED MATTSON BEAN COOKER
AND BY
SENSORY PANELS

by

JAMES ROY PROCTOR

A thesis
presented to the University of Manitoba
in partial fulfillment of the
requirements for the degree of
MASTER OF SCIENCE
in
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GENERAL ABSTRACT

Mattson bean cooker procedures described in the literature were modified to reproduce the sensory evaluation of the cooking time of navy beans. Neither the plunger types nor the 50% cooked point comparison method described in the literature measured cooking time in a manner consistent with sensory evaluation. Plungers modified to 48 g in weight and to a 5 mm flat-faced penetrating end provided cookability curves that corresponded with cookability curves provided by a 9 member trained sensory panel. Preference testing by the 9 member panel indicated that the preferred cooked percentage was 93.7% SD 8.68%. Therefore it was decided that the 92% cooked point provided a better comparison point than the usual 50% cooked point. Averaging the time required to attain the 92% cooked point for four replications of 25 beans each, provided a method of comparing the cooking times of bean samples that reflected the within-sample variability.

When cookabilities of Seafarer, Fleetwood and Exrico navy beans grown at Brandon, Morden and Winnipeg were compared, effect of growing location

was greater than the effect of cultivar. Cooking times for all three cultivars were significantly longer ($P<0.05$) when grown at the Winnipeg location. Exrico beans grown at Winnipeg location took significantly longer to cook ($P<0.05$) than Fleetwood or Seafarer, but at other locations cultivars had similar cooking times. Post-harvest drying was not found to affect cooking time of the Seafarer-Winnipeg samples. Cooking times of the artificially dried and field dried samples were not found to be significantly different ($P<0.05$). There was no incidence of hardshell in any of the freshly harvested navy bean samples. There was no evident relationship found between moisture content, fat, protein, ash or phytic acid and cooking time.

The cookabilities of Seafarer and Fleetwood cultivars grown at Winnipeg, Brandon and Morden locations and stored for 9 months under freezer, prairie outdoor ambient (POA) and simulated semi-tropical (SST) conditions were measured at three month intervals. The Fleetwood samples had much longer cooking times (a minimum of 40 minutes longer) after freezer storage while the Seafarer samples were not significantly affected. The Fleetwood samples showed a high incidence of hardshell (12% to 32%) while the Seafarer had 0% hardshell under freezer storage. Under POA storage conditions, the Fleetwood samples had 16% to 20% hardshell and prolonged cooking time under frozen outdoor (February-3 month) conditions but were unaffected at 6 and 9 months (May, August). Seafarer samples were unaffected by POA storage conditions. Under SST conditions, Fleetwood samples were unaffected, while the Seafarer showed a slight rise in cooking times of 12 to 15 minutes over the 9 month period. Neither cultivar showed any incidence of hardshell under SST conditions. The samples grown at the Winnipeg location had consistently longer cooking times than the samples grown at the other locations.

Samples of Fleetwood navy beans grown at three locations were stored under freezer conditions for a period of nine months. The cookabilities of the hardshell and non-hardshell fractions in blanched and unblanched samples were assessed and compared. Blanching reduced incidence of hardshell from as high as 32% to 0%, and reduced the cooking time of the hardshell fraction in all three samples. The cooking time of the non-hardshell fraction was prolonged between 5 to 25 minutes.

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CHAPTER 1

GENERAL INTRODUCTION

Pulses, also referred to as grain legumes, play a major role in human nutrition. Total world production is estimated to be at least 50 million metric tons per year (FAO-CFTRI, 1977). Some authorities consider this estimate to be low by 20-50% because in much of the developing world the crop is grown and consumed locally, and thus is not officially reported (Kay, 1979). The *Phaseolus vulgaris* L. varieties account for 30% of the total pulse crop. Pulses are also an important export crop amounting to 2,770,000 metric tons in 1980 (FAO, 1982).

Research into methods of improving both the production and quality of pulses is presently being conducted by researchers in Canada and the United States as well as in many international centers such as CIAT (Centro International de Agricultura Tropical), INCAP (Instituto de Nutricion de Centro America y Panama) and ICARDA (International Center for Agricultural Reasearch in the Dry Areas). Because navy beans are grown commercially in western Canada, consumed by Canadian consumers and have a potential export market, plant breeders and legume marketers have expressed interest in improving the quality of navy beans grown in western Canada.

Prolonged cooking time is a major problem with the quality of dry edible legumes. Because prolonged cooking causes loss of nutrients, increased use of energy for cooking and inconvenience, consumers often reject beans with this problem.

Prolonged cooking time can occur because of two separate but related phenomena. These are identified by the stage at which they occur during the overall cooking process. "Hardshell" is a condition in which the seed fails to imbibe a sufficient quantity of water during germination or soaking. The "hard-to-cook phenomenon" or "hard cooking" is a condition in which the seed fails to become sufficiently tender within a reasonable time during the cooking period proper. Individual hardshell beans are usually but not always hard cookers. Because hardshell beans must be discarded by the consumer, the number of hardshell beans is important to the overall acceptability of the sample. Beans which exhibit the hard-to-cook phenomenon do not always have hardshell. Many hard cooking beans imbibe normally. It is very important to note that while the two conditions are related, the terms are not synomymous.

New cultivars of edible dry beans being developed in western Canada are evaluated for agronomic qualities but are not regularily assessed for tendency to develop hardshell or the hard-to-cook defect. Plant breeders developing new lines of beans and those responsible for marketing beans have expressed the need for a rapid, dependable instrumental method of measuring cooking time employing portable, easy-to-operate equipment.

The major objective of this study was to develop an instrumental method of measuring cooking time of beans. Since beans are considered "cooked" when they reach a degree of tenderness which is acceptable to consumers, the main criterion for the suitability of the instrumental method would be the ability of the method to be predictive of sensory panelists assessment of cooking time. Therefore sensory panels were used in this study to develop an instrumental method.

Two additional experiments were conducted with the twin objectives of assessing the practicality of the instrumental method and providing basic information on some of the factors which affect the cooking time of beans. In the first of these experiments the effects of cultivar, growing location and chemical composition on cooking time were studied. In the second experiment, the effects of storage conditions and duration of storage on cooking time were investigated.

The problem of hardshell can be eliminated by blanching (briefly immersing the beans in boiling water) prior to soaking. While this allows the seeds to imbibe, thus eliminating the hardshell problem, it has been reported (Dawson *et al*., 1952) that blanching can prolong the cooking time of the non-hardshell fraction of the sample. A third additional experiment was conducted to assess the effect of blanching on both the hardshell and non-hardshell fractions in samples of beans that exhibit hardshell.

The navy bean (*Phaseolus vulgaris* L.) was chosen for these studies because it is grown commercially in Manitoba and because the sensory panelists who participated in this study were familiar with this particular type of bean.

The thesis is organized in the form of four separate papers which present the materials, methods and results of the four separate experiments conducted. A general review of literature, general discussion of results and general recommendations for further research are also included to enable the reader to understand the project as a whole.

CHAPTER 2

GENERAL REVIEW OF LITERATURE

The three navy bean (*Phaseolus vulgaris* L.) cultivars studied in this thesis were Seafarer, Fleetwood and Exrico. The Seafarer is an early maturing bush-bean cultivar that is the most common commercial cultivar grown in Manitoba. Fleetwood and Exrico are late maturing bush-bean cultivars that are commonly grown in southern Ontario but are not commercially grown in Manitoba (Robertson and Frazier, 1982; McVetty, 1985). This review will discuss the measurement of cooking quality of navy and other *Phaseolus* varieties in general and the factors which affect the cooking quality of these cultivars in particular. Because of the small numbers of reports in the literature regarding these cultivars, this review will refer to reports discussing other cultivars of navy beans and reports dealing with research conducted on other varieties of *Phaseolus* beans when necessary.

2.1 TAXONOMY OF NAVY BEANS

The navy bean is a variety belonging to the species *Phaseolus vulgaris* L. or "common" bean. It belongs to the Genus *Phaseolus*, Tribe *Phaseoleae* and family *Leguminosae*. Other varieties of *Phaseolus* vulgaris L. include the black, pinto, red kidney and white kidney. Seafarer, Fleetwood and Exrico are self-pollinating cultivars with a single genotype per cultivar. They are therefore pure lines and as a result each cultivar displays considerable uniformity of characteristics.

Other pulses such as the lima (Phaseolus lunatus L.), pigeon pea (Cajanus cajan L.) and the field pea (Pisum sativum L.) belong to different Species, Genera and Tribes respectively and as such can be expected to differ widely in cooking time and other characteristics (Adams and Pipoly, 1980).

Figure 2-1 shows the external and internal parts of the Phaseolus vulgaris L. seed. The distictive shape of the Phaseolus vulgaris varieties is illustrated. The hilum and micropylar area, through which water enters the seed during imbibition is shown as is the cotyledon, the portion of the seed that stores the starch granules which must be gelatinized during the cooking process.

2.2 DEFINITIONS OF COOKING TIME, HARDSHELL AND THE HARD-TO-COOK PHENOMENON

Each variety of edible dry bean has a particular cooked texture which is considered acceptable or "cooked" to consumers and the term "cookability" refers to the cooking time required to reach that

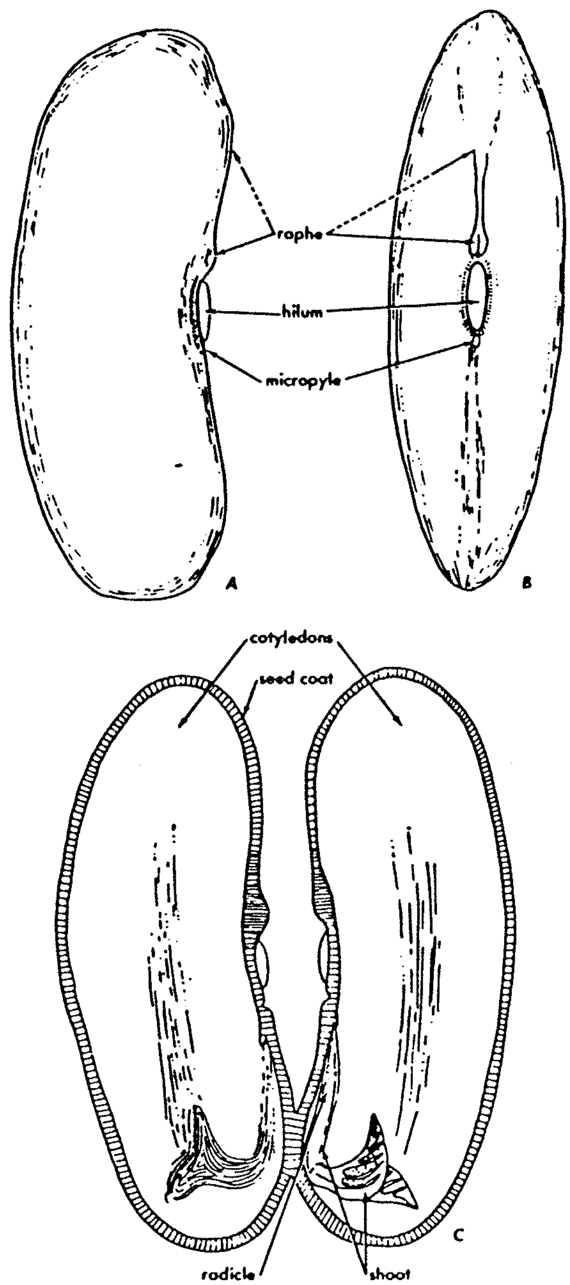

Figure 2-1. Bean (<u>Phaseolus</u> <u>vulgaris</u> L.) seed. A, external side view; B, external face or edge view; C, embryo opened (Weier <u>et</u> <u>al</u>., 1974).

texture (Moscoso, 1981). Cookability will be influenced by the range of cooking times of individual beans within a sample. Poor cookability, the result either of long cooking time required to soften the majority of beans within a sample, or of extended cooking time required because of a small but significant proportion of hard-to-cook beans in an otherwise good cooking sample, is a major problem with edible dry beans because it can cause loss of nutrients, increased consumption of energy and consumer rejection (Bressani et al., 1963).

Prolonged cooking or poor cookability can occur because of two separate but sometimes related phenomena, "hardshell" and the "hard-to-cook condition". These are identified by the stage at which they occur during preparation, whether at the hydration stage when the soaking seed physically imbibes water or at the cooking stage, when heat and moisture cause the seed to soften. These stages can occur simultaneously if the bean is not hydrated prior to cooking. Cooking time is usually decreased as the extent of hydration prior to cooking is increased (Kon, 1979; Rockland and Metzler, 1967). "Hardshell" is a condition in which the seed fails to imbibe within a reasonable length of time during the soaking stage (Bourne, 1967); while the hard-to-cook phenomenon is a condition in which the bean has prolonged cooking time during the cooking stage itself often after having imbibed normally (Molina _et al_., 1976; Burr _et al_., 1968). The terms are not synonymous and much confusion has resulted in the literature because of the ambiguous use of these terms (Stanley and Aguilera, 1985). Hardshell beans usually have prolonged cooking times, although this is not always the case, while hard-to-cook beans will often exhibit hardshell but not always (Jackson and Varriano-Marston, 1981).

"Hydration", the physical imbibition by the seed of water, usually takes from 8-24 hours at room temperature. A study by Jackson and Varriano-Marston (1980) used autoradiograms to identify the hydration stages of black beans which had been cut at the hilum, perpendicular to the intercotyledon face (Figure 2-2). The areas into which the water had penetrated are indicated in black, while the white areas indicate the unhydrated regions. After one hour, (a), water had entered the hilum region and had passed along the seed coat and to a slight degree into the cotyledon. After 8 hours, (b), water had penetrated into all but the interior portion of the cotyledon. Water had completely penetrated the cotyledon after 14 hours

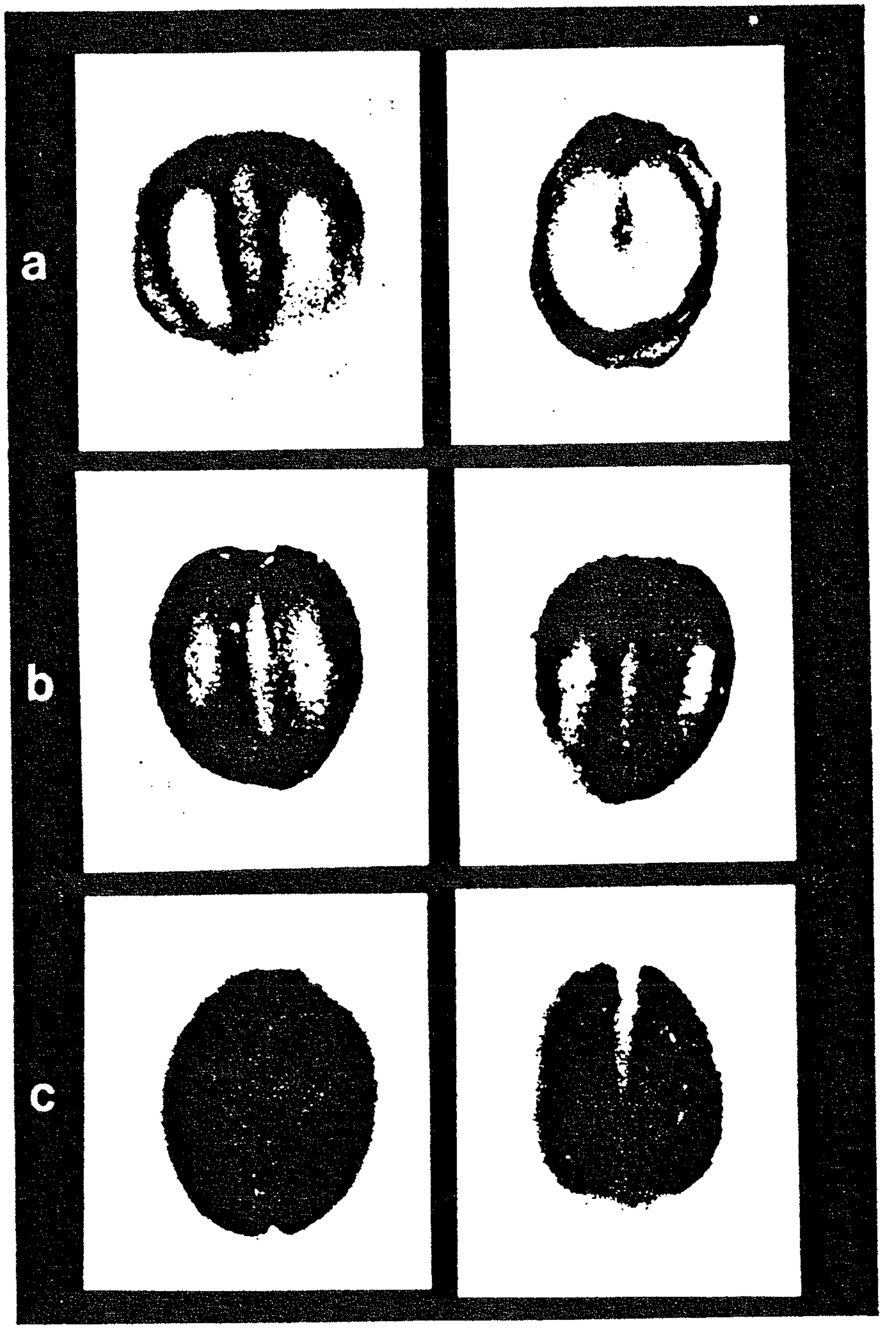

Figure 2-2. Autoradiograms of black beans soaked for 1 hour (a), 8 hour (b), and 14 hour (c) (Jackson and Varriano-Marston, 1980).

had elapsed (c).

Snyder (1936) reported that the seed coat of *Phaseolus* beans is largely impervious to water and that most water enters through the hilum-micropylar region. When beeswax was placed over this area it was noted that imbibition rates were drastically reduced. Jackson and Varriano-Marston (1980), reported that black beans with seed coats removed hydrated much more quickly than those beans with intact seed coats.

During the cooking stage, the middle lamella must dissolve before the gelatinization of starch, denaturation of protein and destruction of anti-nutritional factors can occur. The middle lamella is an intercellular layer which separates the starch cells within the bean cotyledon. Using electron microscopy studies (Sefa-Dedeh *et al*.,1979; Rockland and Jones, 1974) reported that during the cooking process, the middle lamella became soluble and disappeared. This enabled the other three events of the cooking process to proceed so that cooking could continue. If the middle lamella does not dissolve, the cooking process cannot be completed. Muller (1967), Mattson (1946) and Moscoso (1981) have all noted that in legumes with poor cooking times, the middle lamella remains largely insoluble during cooking.

Because hardshell and the hard-to-cook phenomenon usually affect beans in a sample unequally, time of hydration and cooking time can vary widely both within and between samples (Bourne, 1972; Morris, 1964; Snyder, 1936). The phenomenon of within sample variability complicates cookability measurement and the comparison of bean samples. Figure 2-3 and Table 2-1 illustrate the range in cooking time that can occur within samples of beans. In Figure 2-3 cooking times for individual beans range from 17 to 38 minutes. In Table 2-1 puncture force (a measurement of texture) shows a wide variation between individual beans that have been cooked for the same length of time. Even after extended cooking time (300 min) puncture force varies from 30 to 90 g. For this reason, the testing of large numbers of beans is required to ensure the statistical reliability (Silva et al., 1981a). Also, small numbers of hard-to-cook beans in an otherwise cooked sample can seriously lower the quality of that sample of beans to consumers (Bourne, 1972). Therefore testing methods must be able to measure the cooking time of individual beans within a sample. Methods which attempt to ensure statistical reliability by testing large samples

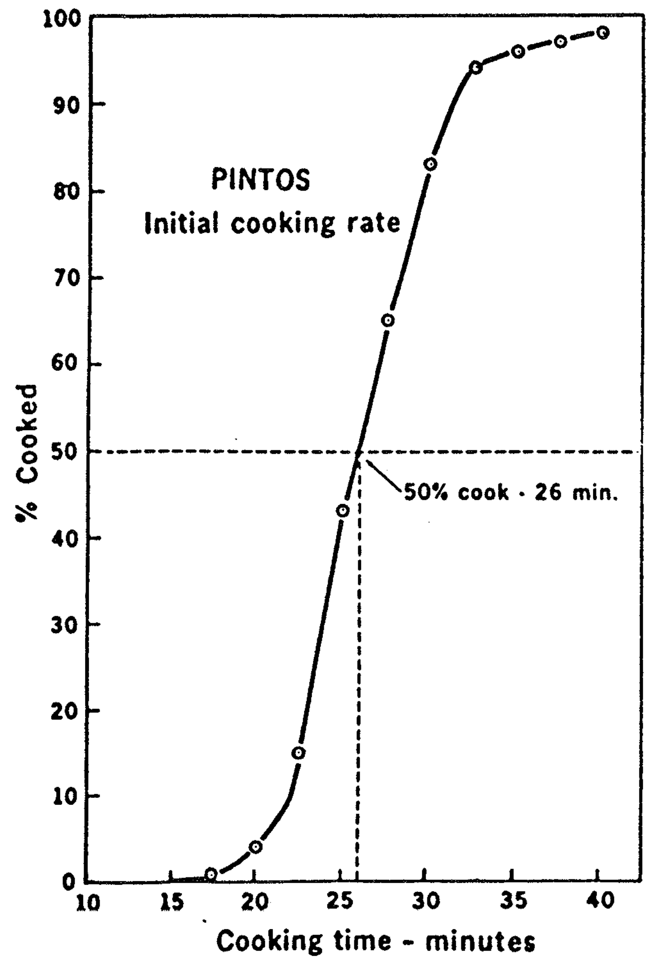

Figure 2-3. Typical cookability curve for pinto beans (Phaseolus vulgaris L.) as determined by Mattson Bean Cooker (Morris, 1964).

Table 2-1. Puncture test on individual cooked pea beans[1]

Cook Time (min)	Puncture Force[2] Highest (g)	Lowest (g)	Mean (g)
30	1525	280	523
60	503	68	201
90	372	70	165
120	262	39	139
150	236	32	123
180	301	52	129
240	200	35	96
300	207	30	89

[1]from Bourne, M.C., (1972).
[2]determined using Instron with 1/8 in diameter flat faced steel punch.

rather than individual beans can mask the very important effect of individual bean cooking times on the overall sample cooking time (Bourne, 1972).

As has been mentioned the hardshell condition does not occur in all of the individual beans in a sample but usually affects only a portion of the beans. The individual beans in the hardshell fraction usually have prolonged cooking times compared to the non-hardshell fraction. Morris *et al*. (1950) reported that cooking soaked samples that contain some hardshell beans until the latter are palatable may require such a long cook that the non-hardshell beans disintegrate. Blanching or hot-soaking, the brief boiling or steaming of beans prior to soaking, can eliminate the hardshell condition and the prolonged cooking time associated with it (Jackson and Varriano-Marston, 1981; Muneta, 1964; Morris *et al*., 1950). There are no reports in the literature comparing the cooking time of the hardshell and non-hardshell fractions after blanching, although Dawson et al. (1952) showed that blanched beans took 15-30 minutes longer to cook than comparable bean samples soaked for 18 hours in cold water.

2.3 MEASURING COOKABILITY

Cooking time has traditionally been measured by one of two general methods. The first involves measuring the force required to compress, puncture or shear beans cooked for a predetermined length of time. Force measurements are usually obtained with an Instron, Ottawa Texture Measuring system (OTMS) or Kramer Shear Press (Voisey and Larmond, 1971). Force measurement can be made on beans in quantity (50-500g), depending upon the size of the test cell used, (Voisey and Larmond, 1971; Quast and da Silva, 1977) or by testing beans individually (Moscoso *et al*., 1981; Silva *et al*., 1981a; Molina *et al*., 1976; Bourne, 1972). The force measuring method has the advantage that it has been shown to be related to sensory assessment (Aguilera and Steinsapir, 1985; Silva *et al*., 1981a), and sensory assessment, according to Bourne (1982), is the ultimate method of calibrating instrumental methods of measuring texture.

Usual force measuring procedures have been based on an instrumental measurement of the texture which corresponds to that which panelists consider to represent the properly cooked degree of hardness. Sensory panels have been used to identify the texture level that is considered to be properly cooked. Beans from the same sample have then been cooked for the same length of time as those considered cooked by the panelists and the texture determined by measuring the amount of force required to deform, puncture or extrude them with one of the force measuring devices. Once this standard has been established, for one variety of bean, then the cooking time for any sample of that variety can be identified by cooking a large quantity of beans and removing smaller samples at regular time intervals. The texture of these samples has been instrumentally measured and the mean force to shear or deform the beans has then been plotted against the cooking time as shown in Figures 2-4 and 2-5. If the force level that corresponds with the properly cooked level ("eating soft") has already been established by sensory evaluation, the cooking time for the sample can be calculated from the plot as illustrated in Figure 2-5, reading the time required to reach the "eating soft" texture from the "x" axis. Testing force to compress a quantity of "cooked" beans, however, while relatively rapid, does not give an indication of the range of cookability of the individual beans within the sample and testing force to puncture a sufficiently representative number of individual beans can be a time consuming process.

The second general method involves measuring the time required to cook large numbers of individual

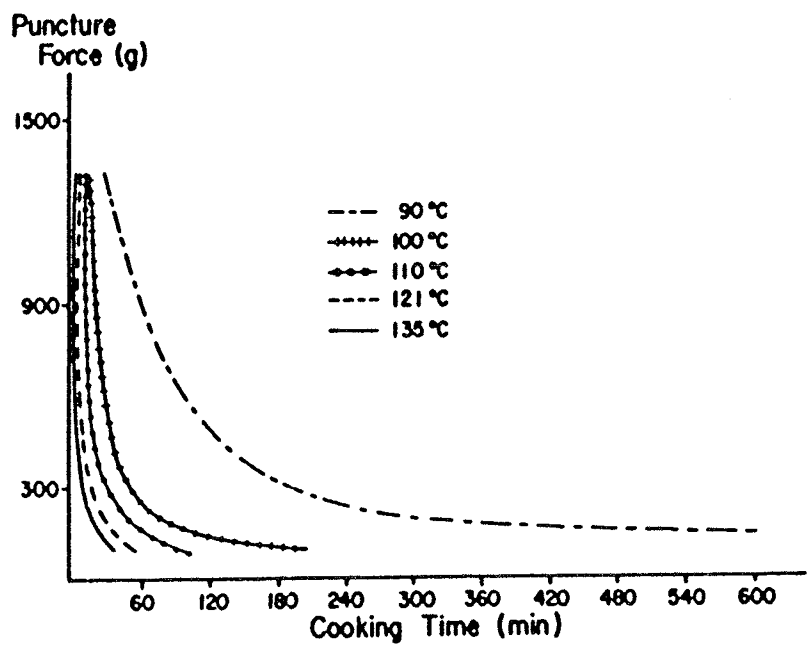

Figure 2-4. Puncture force vs. cooking time for black beans (<u>Phaseolus</u> <u>vulgaris</u> L.) cooked at different temperatures (Silva <u>et</u> <u>al</u>., 1981a).

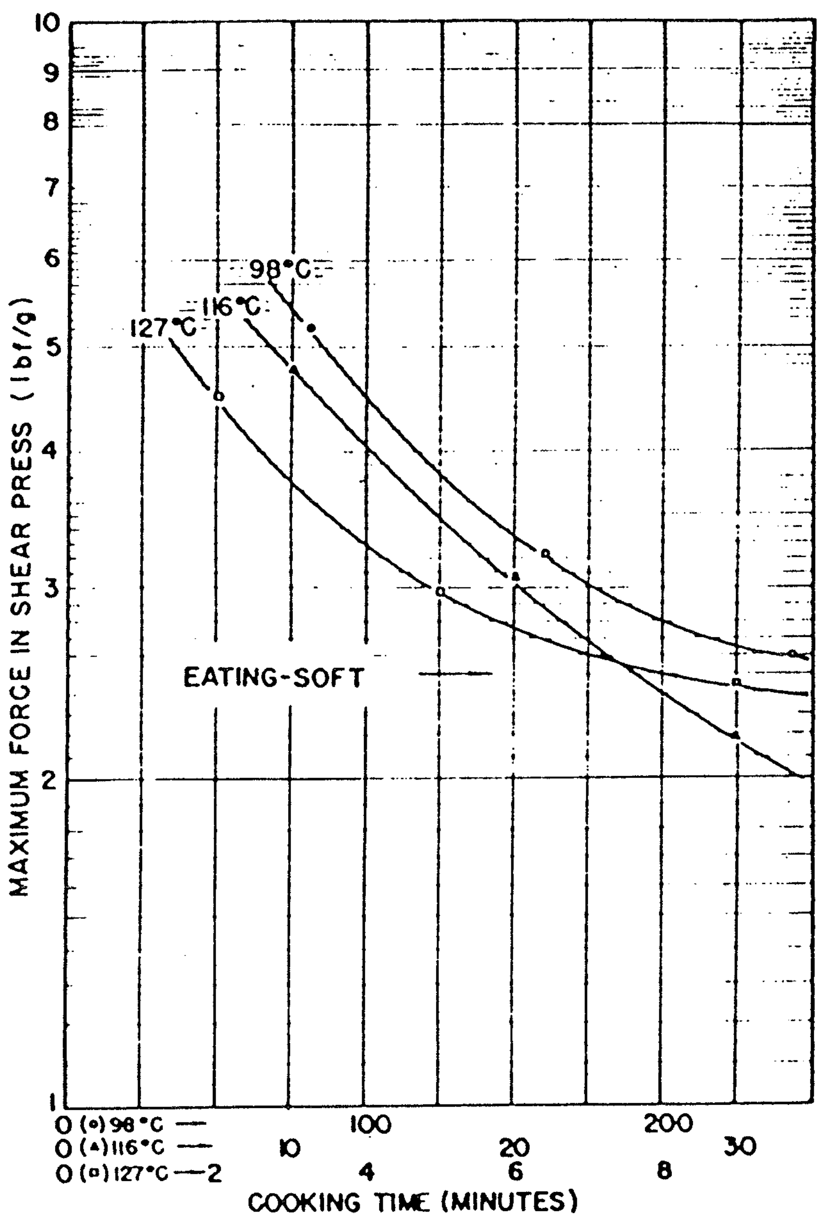

Figure 2-5. Degree of cooking of black beans (*Phaseolus vulgaris* L.) as a function of time and temperature (Quast and da Silva, 1977)

beans to a defined degree of softness. The Mattson Bean Cooker (MBC), first developed by Mattson (1946) or one of its variants, has commonly been used for this second method of cookability assessment (Jackson and Varriano-Marston, 1981; Morris, 1964). This instrument is designed to test the cooking time of individual beans by measuring the time required for plungers of specific weight and diameter to puncture individual beans while they are actually cooking in the cooking water.

The MBC consists of a rack and a set of identical plungers (Figure 2-6). The number of plungers is usually 25 but the use of a 100 plunger model was reported by Burr *et al*., (1968) and Morris (1964). Chhinnan (1985) reported a prototype 25 plunger model with an electronic device to monitor plunger movement. This model promises to overcome one of the major drawbacks of the MBC, that is, the need for continuous monitoring.

To operate the MBC, the presoaked beans are placed on the bottom plate of the rack so that each bean has a plunger resting upon it. The rack, plungers and beans are then suspended in a pot or large beaker and immersed to a specified level with distilled water which is heated to boiling and heat is adjusted to maintain a slow boil. When a plunger

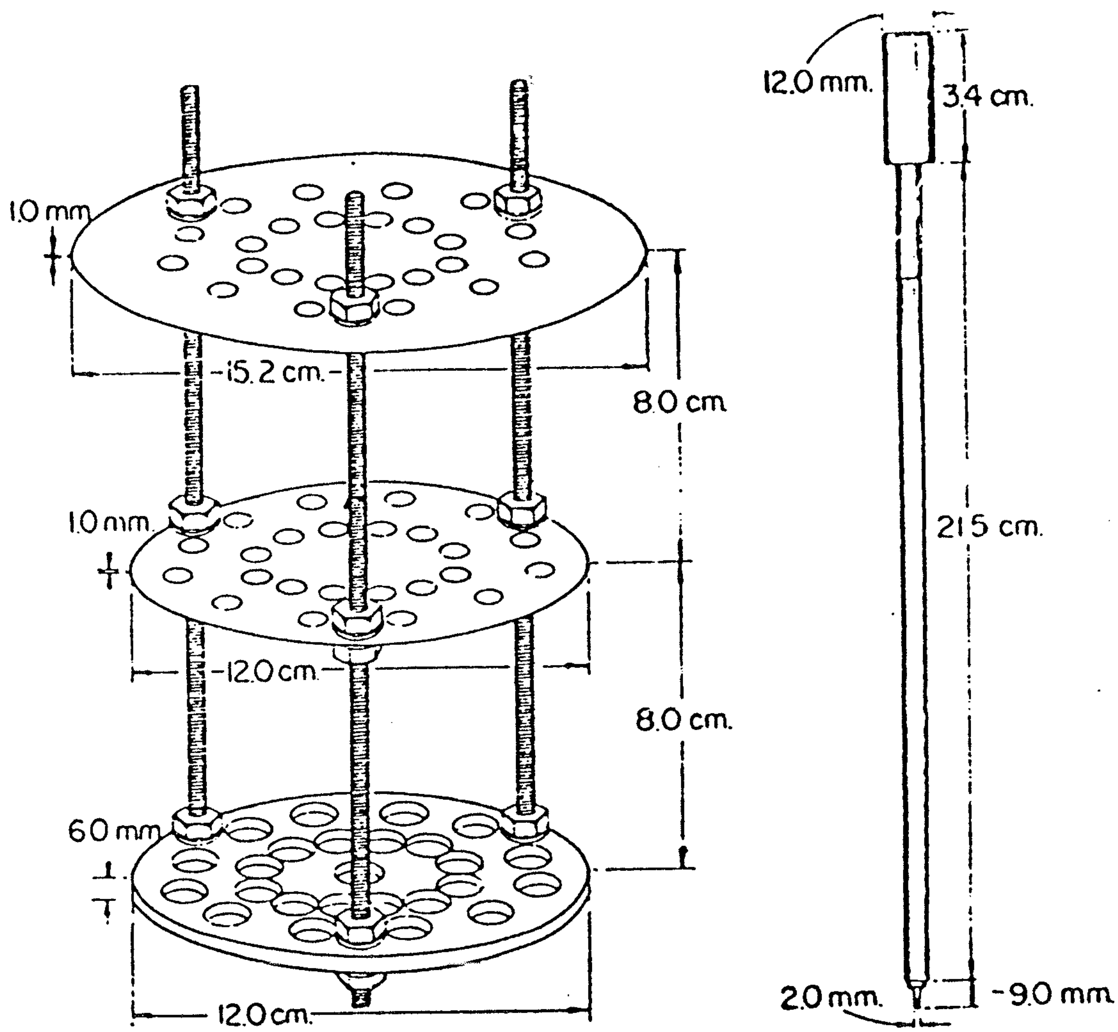

Figure 2-6. Dimensions of rack and plungers of Mattson Bean Cooker (Jackson and Varriano-Marston, 1981).

penetrates a bean, that bean is considered cooked. The number of beans cooked, (plungers dropped) is recorded at 5 minute intervals and the data are usually reported as the cumulative total of beans cooked at each time interval (Jackson and Varriano-Marston, 1981; Morris, 1964).

Because the MBC method tests large numbers of beans individually, it can indicate the amount of within sample variability. Cooking times of different bean samples have been compared using the cooking time required to reach the 50% cooked point as the reference point (Jackson and Varriano-Marston, 1981; Morris, 1964). The 50% point has been used because it is the most reliably defined point on the cookability curve (Morris, 1964). Figure 2-7 and Figure 2-3 show the usual method of estimating the 50% cooked point from typical cookability curves. A free hand curve is drawn through the data points and the 50% cooked point is estimated graphically.

2.4 FACTORS AFFECTING COOKABILITY

Genetic variation, environmental, soil and handling factors related to growing location, storage conditions and duration of storage as well as chemical composition (moisture content, fat, protein, ash and phytic acid) may all affect

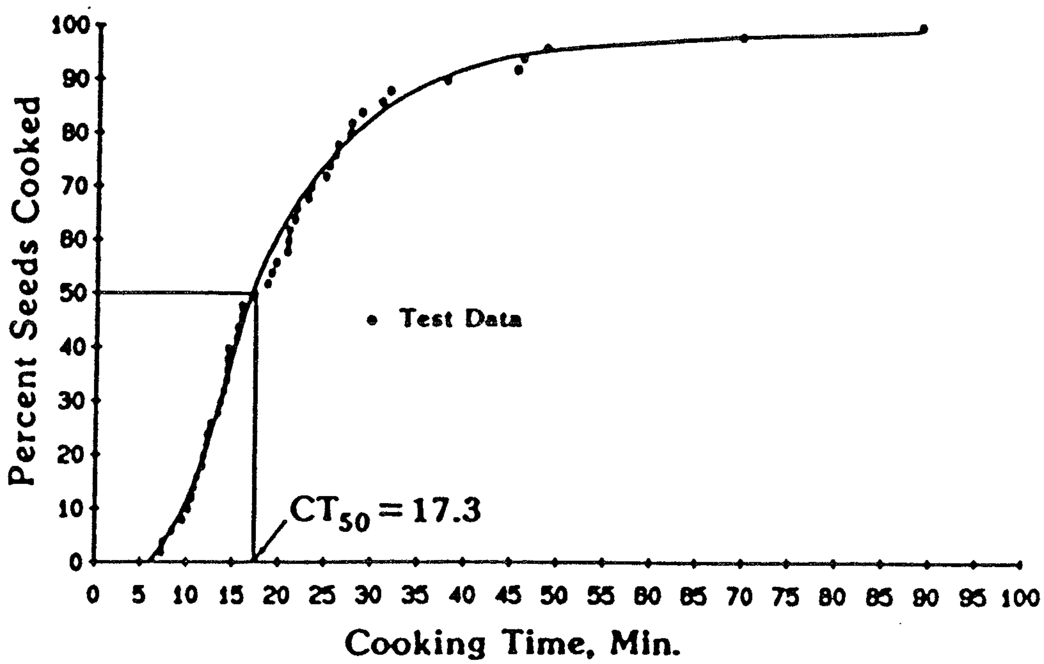

Figure 2-7. Cookability curve for Cowpeas as determined by the MBC, and estimation of the reference point (CT_{50}) using the 50% cooked point (Chhinnan, 1985).

cookability of edible dry beans. The type of soaking water used during hydration and the hydration method used can also affect cookability. The following discussion will deal with effect of genetic variation between the three navy bean cultivars Seafarer, Fleetwood and Exrico on cookability. It will also discuss the effect of location, storage and chemical composition on the cookability of those cultivars. Both aspects of cookability, hardshell and the hard-to-cook phenomenon will be discussed. The reader must bear in mind that many of the above factors interact with each other and that much of the literature does not distinguish between all of the factors which may influence cookability. There are few studies of the cookability of navy beans and only one of the above mentioned cultivars, the Seafarer has been studied for cookability. Most of the literature on the factors affecting the cookability of Phaseolus beans has been conducted on other varieties. There are no studies on the cookability of any variety of Phaseolus bean grown in Manitoba. Because storage conditions play such a significant role in the cookability of navy beans, it is always necessary to distinguish between stored and fresh samples. It is unfortunate that many studies do not properly specify growing location or properly identify the cultivar of the variety being tested. Comparison of results is also complicated by methodological differences. Some studies have used the blanch or hot-soaking treatment while others have not and some studies have used instrumental methods which have not been appropriately related to sensory methods.

2.4.1 Effect of Genetic Variation on Bean Cookability

It is well known that edible dry beans from different Genii have different cookabilities. The usual cooking times of some cultivars of navy beans can be as short as 30 minutes while some garbanzo (Genus *Cicer*) beans can take as long as several hours to cook. Within the navy variety, diffent cultivars can have different cooking times. Voisey and Larmond, (1971) assessed the cooking time of four cultivars of navy beans, Seaway, Sanilac, Seafarer and an experimental cultivar 779-629. All samples were grown in the same location, harvested and handled in the same manner and tested when fresh. Several instrumental measurements of texture indicated that the Sanilac and 799-629 produced similar results and cooked significantly faster than both Seaway and Seafarer. Voisey and Larmond (1971) did not report the presence of hardshell.

Gloyer (1928b) and Lebedeff (1943) both reported that hardshell was related to genetic factors. Gloyer (1928b) crossed a red kidney cultivar, Wells, with a white kidney cultivar. The original Wells red kidney was high yielding, but showed high levels of hardshell. Two new cultivars of red kidney, Geneva and York resulted from the cross. Pure lines were established in the F_4 generation. By selecting strains of the Geneva and York that were free of hardshell, hardshell was eliminated from the two cultivars in four years. In sensory testing, both the Geneva and York cultivars were found to have cooking qualities superior to those found in Wells when cooked for the same length of time, indicating that the Geneva and York cooked faster. Lebedeff (1943) , studying navy beans grown in Puerto Rico concluded that hardshell was probably inherited, but was greatly influenced by environmental factors, particularily those affecting moisture content of the seed.

Quenzer et al. (1978) assessed three cultivars of pinto beans grown at three locations (two in Texas and one in Idaho) for texture (shear values) and sensory preference after 90 minutes of cooking. They reported that cultivar did not play as significant role as location on texture or preference. Bhatty *et al*. (1983) studying two cultivars of lentils (*Lens culinaris*) reported that location of growth had a much greater influence on cooking quality than did cultivar.

The literature concerning the effect of genetic variation seems to agree that while the genetic variation between Genii, species and varieties has a significant effect on cookability , the genetic variation between cultivars of the same variety plays a less significant role than growing location.

2.4.2 Effect of Growing Location on Cookability

The effect of growing location is the result of the combined effects of many variables, including seeding date, harvest date, soil type, climatic conditions, crop treatment (fertilizer, herbicide, pesticide), harvest conditions and post harvest treatment (drying, handling). Since the investigation of the effects of these variables is beyond the scope of this study, the effect of growing location will be discussed as a general effect only. Unfortunately there are no studies of effect of growing location on any of the three cultivars which are the focus of this investigation. There are some reports on the effect of growing location on freshly harvested navy beans and other edible dry beans. Snyder (1936) studied navy beans (cultivar unspecified) grown at three locations in Michigan, one location in Colorado and one location in Nebraska and reported that the percent of beans uncooked after 75 minutes of cooking ranged from 15 to 28%. Quenzer _et al_. (1978) working with three cultivars of pinto beans found that location affected sensory acceptance . Bhatty _et al_. (1983) determined the effect of growing location on two cultivars of lentil grown at 14 locations in Saskatchewan, by measuring the texture of samples cooked for 60 minutes. Bhatty concluded that there was a strong influence of growing location on cooking quality. Measurement of shear force for one cultivar grown at 12 locations ranged from 3 kg to 5.8 kg and from 3.1 kg to 4.8 kg for the other cultivar grown at the same 12 locations. These studies indicate that the effects of the factors related to growing location are likely to influence cookability more than the effect of cultivar.

Because hardshell is not often present in fresh navy beans and its incidence seems to be related to the interaction between growing location and storage conditions (Bourne, 1964; Gloyer, 1928a), the effect of this interaction on hardshell will be discussed in the following section.

2.4.3 Effect of Storage and Duration of Storage on Cookability

Storage conditions play a major role in the problem of poor cookability. Both hardshell and hard-to-cook beans occur more often in stored beans than in fresh, and usually the degree of poor cookability increases as storage time increases. The effects of genetic difference, and of growing location interract with the effects of storage. Because many studies have failed to specify cultivar and growing location when comparing the effects of storage conditions, conflicting conclusions have been reported.

Burr *et al*. (1968) studied navy (cv.Sanilac) beans grown in the 1961 and 1963 crop years. Fresh beans were measured for cooking time then stored at various temperatures and relative humidities (R.H.). Sanilacs with a moisture content of 14.2% initially required 27 minutes to cook but after 11 months of storage at 32.2°C required 450 minutes, a 17 fold increase in cooking time. Beans stored at 32.2°C but with lower moisture contents, and beans held at 21.1°C, even at higher moisture content had less dramatic loss of cookability. The MBC using the 50% cooked comparison point was used to test cookability and also the beans were blanched before soaking, so that the extent of hardshell was masked. Burr _et al_. (1968) also found that pintos and limas behaved in a similar fashion. Muneta (1964) reported a study of four varieties of _Phaseolus_ (pinto, great northern, michilite and small red). Each variety was grown at two locations. Storage was at room temperature for 18 months. The samples with higher moisture contents took longer to cook, and they concluded that growing location had a condiderable effect on the cooking time of dry beans after extended storage. Cooking time of the fresh samples was not recorded and samples were blanched before cooking so the extent of hardshell was not reported.

Antunes and Sgarbieri (1979) studied the Rosinha G2 variety (_Phaseolus vulgaris_ L.) to determine its cooking time and its percent of hardshell under laboratory storage conditions (25^{o}C, 65 to 70% R.H.), refrigerator conditions (12^{o}C, 52% R.H.) and simulated tropical conditions (37^{o}C, 76% R.H.). Samples were not blanched before soaking. Refrigerator storage showed no change in percent of hardshell after six months. The laboratory storage sample rose from less than 5% hardshell to over 50%

hardshell, while under the simulated tropical conditions there was a slight rise in hardshell after 2 months, which then fell to 0% after 4 months of storage. A six member expert sensory panel assessed adequate cooking time for each storage condition and storage time. Under refrigerator conditions, cooking time rose from 60 to 90 minutes. Under laboratory conditions cooking time rose from 60 to 116 minutes. For the simulated tropical conditions, cooking time rose from 60 to 300 minutes. It was not specified if the hardshell beans were included or were discarded before testing.

Hughes and Sandsted (1975) studied the effect of storage on California light red kidney beans (Phaseolus vulgaris L.). Samples were stored at 1°C, 12 C and 24°C in all combinations with 30% and 80% R.H. for a period of one year. They found that storage temperature had only a slight influence on the time required to cook beans after storage for one year at 30% R.H., but that cooking time for beans stored at 80% R.H. increased with increases in storage temperature. There was little or no difference in the cooking time for beans stored at either 30 or 80% R.H. at 1°C. Gloyer (1928a) reported that Phaseolus beans stored in a heated laboratory under conditions of low R.H. developed hardshell. He also reported that when the beans were removed out of doors where the temperature was lower and the R.H. higher, the hardshell was eliminated, indicating that the hardshell condition was reversible. Jackson and Varriano-Marston (1981) reported that the cooking time of black beans (50% cooked) was much increased by storage for one year in laboratory conditions and that black beans stored for 55 days at 41°C and 75% R.H. did not cook after 6 hours of cooking. Morris and Wood (1956) reported no change in quality of beans (_Phaseolus_ and _Lunatus_) stored at -23.3°C. Morris (1964) reported no effect on the cooking time for limas and Sanilacs stored at 4.4°C for 9 months and Snyder (1936) reported no effect after storage for 15 to 17 months at 7.2°C.

In general the literature seems to agree that: refrigerator storage at -1°C to 4°C and over a range of R.H. has little affect on cookability; refrigerator storage from 4° to 12°C has only a moderate effect at all humidities; freezer storage < -10°C has no effect on cookability at any R.H.; heated laboratory conditions (>20°C and low R.H.) increase hardshell but not necessarily cooking time; simulated tropical conditions (>25°C and >75% R.H.)

increase cooking time due to the hard-to-cook phenomenon but do not increase incidence of hardshell.

No studies comparing the effects of different storage regimes on two or more cultivars of navy or any other types of edible dry bean were found in the literature. The effect of storage on Manitoba grown beans has not been investigated and there are no reports on the effects of prairie outdoor ambient storage conditions for beans grown in western Canada. Freezer storage conditions were mentioned only by Morris and Wood (1956) who found that freezer storage had no effect on cookability.

2.4.4 Effect of Chemical Composition on Cookability

Moscoso (1981) and Stanley and Aguilera (1985) have extensively reviewed the effects of chemical composition on cookability. Five components of chemical composition will be discussed here. These are moisture content, protein, ash, fat and phytic acid.

Moisture content, protein and ash have only indirect, ambiguous or poorly understood effects upon cooking time. Several researchers have reported that the cooking time correlated with moisture content. Morris and Wood (1956) reported that beans stored with a low moisture content (<10%) did not undergo changes in cookability after one year of storage at 25°C. Hughes and Sandsted (1975) and Burr et al. (1968) reported that high moisture content in beans stored at high temperature was related to poor cooking quality. Muneta (1964) and Snyder (1936) reported no correlation between moisture content and cookability.

Protein content does not seem to affect cooking time directly but several studies have shown that storage conditions which can cause prolonged cooking times in beans, such as conditions of high temperature and high humidity, can also decrease protein efficiency ratio (PER) (Sgarbieri and Whitaker, 1982) and increase the nitrogen solubility of beans (Molina et al., 1976). The relationship, if, any between these changes in protein characteristics and prolonged cooking time is presently unknown.

Takayama et al. (1965) found that triglycerides, phosphatides and crude lipid content correlated to a small degree with cooking time. Correlations did not rise above 0.2 and none were significant. Muneta (1964) postulated that the texture of beans could be affected by the oxidation and polymerization of lipids. Thus increased lipid content could contribute to poor cookability by increasing the extent of oxidation and polymerization during storage conditions of high temperature and high humidity.

Phytate, myo-inositol hexakisphosphate, is a storage form of phosphate found in all legume seeds in concentrations varying from 0.3 to as high as 2.5% on a dry basis (Stanley and Aguilera, 1985). It is a strong chelating agent and binds ionically to divalent and monovalent cations. Mattson (1946) reported that hard-to cook peas contained 50% less phytate than normal cooking peas. Mattson also found that removal of phytate by soaking or enzymatic action could induce prolonged cooking time. It was postulated that in normal cooking peas and beans, phytate acts in the middle lamella to chelate calcium and magnesium cations, thus reducing the pectate cross link bonds allowing the dissolution of the middle lamellar tissue. Jones and Boulter (1983) working with black beans and Kon and Sanshuck (1981) working with navy beans also reported that reduction in phytate correlated with increased cooking time. Crean and Haisman (1963), however, reported that the influence of phytate on texture is small because free magnesium and calcium ions are too numerous to be chelated by the phytate in the cotyledon and therefore the influence of phytate on cooking time is small. Rosenbaum and Baker (1969) reported that the diffusion of water through the cotyledon and hence the solubility of the lamelar tissue has the most influence on cooking time.

The role of magnesium and calcium ions in the cooking process seems complex and poorly understood, although it is clear that the ash content of beans seems to play some role in the cooking process.

The subject of the relationship of chemical composition and cooking time is indeed very complex particularily when other factors not discussed here such as polyphenols and lignins are considered. It is obvious there is need for much more research in this field

CHAPTER 3

DEVELOPMENT OF A MODIFIED MATTSON BEAN COOKER PROCEDURE BASED ON SENSORY PANEL COOKABILITY EVALUATION

3.1 ABSTRACT

Mattson bean cooker procedures described in the literature were modified to reproduce the sensory evaluation of the cooking time of navy beans. Neither the plunger types nor the 50% cooked point comparison method described in the literature measured cooking time in a manner consistent with sensory evaluation. Plungers modified to 48 g in weight and to a 5 mm flat-faced penetrating end provided cookability curves that corresponded with cookability curves provided by a 9 member trained sensory panel. Preference testing by the 9 member panel indicated that the preferred cooked percentage was 93.7% SD 8.68%. Therefore it was decided that the 92% cooked point provided a better comparison point than the usual 50% cooked point. Averaging the time required to attain the 92% cooked point for four replications of 25 beans each, provided a method of comparing the cooking times of bean samples that reflected the within-sample variability.

3.2 INTRODUCTION

Edible dry beans, also referred to as grain legumes or pulses, play a major role in human nutrition. Total world production is estimated to be at least 50 million metric tons per year (FAO, 1977). Some authorities consider this estimate to be low by as much as 20 - 50%, because in much of the developing world, the crop is grown and consumed locally, and thus is not officially reported (Kay, 1979). The Phaseolus vulgaris L. varieties account for 30% of the total pulse crop. Edible dry beans are an important export crop amounting to 2,770,000 metric tons in 1980 (FAO, 1982)

Research into methods of improving both the production and quality of pulses is presently being conducted by researchers in Canada and the United States as well as in many international centres such as CIAT (Centro International de Agricultura Tropical), INCAP (Instituto de Nutricion de Centro America y Panama) and ICARDA (International Center for Agricultural Research in the Dry Areas). Because navy beans are grown commercially in Western Canada, consumed by Canadian consumers and have a potential export market, plant breeders and legume marketers have expressed interest in improving the quality of navy beans grown in Western Canada. The navy bean belongs, along with the red kidney, black, pinto and pink bean to the Tribe Phaseolae, Genus Phaseolus. The Genus Phaseolus is often called the "common bean". Such pulses as the faba, garbanzo, lentil and field pea belong to a separate Tribe, the Fabae.

Cooking time is one of the major criteria involved in the evaluation of pulse quality. Each type of edible dry bean has a particular cooked texture which is considered acceptable or "cooked" by consumers and the term "cookability" refers to the cooking time required to reach that texture. Cookability will be influenced by the range of cooking times of individual beans within a sample. Poor cookability, the result either of long cooking time required to soften the majority of beans within a sample, or of extended cooking time required because of a small but significant proportion of hard-to-cook beans in an otherwise good cooking sample, is a major problem with pulses because it can cause loss of nutrients, increased consumption of energy and consumer rejection (Bressani et al., 1963).

Prolonged cooking time or poor cookability can occur because of two separate but sometimes related phenomena, "hardshell" and the "hard-to-cook" condition. These are identified by the stage at which they occur during preparation, whether at the hydration stage when the soaking seed physically imbibes water or at the cooking stage, when heat and moisture cause the seed to soften. These stages can occur simultaneously if the bean is not hydrated prior to cooking. "Hardshell" is a condition in which the seed fails to imbibe within a reasonable length of time during the soaking stage (Bourne, 1967); while the hard-to-cook phenomenon is a condition in which the bean has prolonged cooking time during the cooking stage itself often after having imbibed normally (Burr et al., 1968; Molina et al., 1976). The terms are not synonymous and much confusion has resulted in the literature because of the ambiguous use of these terms (Stanley and Aguilera, 1985). Hardshell beans often have prolonged cooking times although this is not always the case, while hard-to-cook beans will often exhibit hardshell but do not always do so (Jackson and Varriano-Marston, 1981).

Because hardshell and the hard-to-cook phenomenon usually affect beans in a sample unequally, time of hydration and cooking time can vary widely both within and between samples (Bourne, 1972; Morris, 1964). The phenomenon of within-sample variability complicates cookability measurement and the comparison of bean samples. The testing of large numbers of beans is required to ensure statistical reliability (Silva et al., 1981a). Also small numbers of hard-to-cook beans in an otherwise cooked sample can seriously lower the quality of that sample of beans to consumers (Bourne, 1972). Therefore, testing methods must be able to measure the cooking time of the individual beans within a sample. Methods which attempt to ensure statistical reliability by testing large samples rather than individual beans, can mask the very important effect of individual bean cooking time on the overall sample cooking time (Bourne, 1972).

Cooking time has traditionally been measured by one of two general methods. The first involves measuring the force required to compress, puncture or shear beans cooked for a predetermined length of time. Force measurements are usually obtained using either an Instron, Ottawa Texture Measuring System (OTMS) or Kramer Shear Press (Voisey and Larmond, 1971). Force measurement can be made on beans in quantity (50-500 g samples), (Voisey and Larmond, 1971; Quast and da Silva, 1977; or by testing beans individually (Moscoso et al., 1984; Silva et al., 1981a; Molina et al., 1976; Bourne, 1972).

According to Bourne (1982), sensory assessment is the ultimate method of calibrating instrumental methods of measuring texture. The force measuring method has the advantage that instrumentally determined force can be related to sensory assessment of hardness by testing force required to compress, puncture, deform etc. samples considered cooked to an acceptable degree by a small laboratory panel (Silva _et al_., 1981a; Aguilera and Steinsapir, 1985). However, testing force to compress a quantity of "cooked" beans, while relatively rapid does not give an indication of the range of cookability of the individual beans within the sample and testing testing force to puncture a sufficiently representative number of individual beans can be a time consuming process.

The second general method involves measuring the time required to cook large numbers of individual beans to a defined degree of softness. The Mattson Bean Cooker (MBC), first developed by Mattson (1946), or one of its variants, has commonly been used for this second method of cookability assessment (Morris, 1964; Jackson and Varriano-Marston, 1981). The MBC as first developed by Mattson (1946) and as used by Morris (1964) consisted of 100 plungers held in position by supporting racks so that the plunger points rested on the supported uncooked beans. A 25 plunger model was described by Jackson and Varriano-Marston (1981). Chhinnan (1985) reported a prototype 25 plunger model with an electronic device to monitor plunger movement. The instrument is designed to test the cooking time of individual beans by measuring the time required for plungers of specific weight and diameter to puncture individual beans while they are actually cooking in the cooking water. Because this method tests large numbers of beans individually, it can be used to indicate the amount of within sample variability. Cooking times of different bean samples have been compared using the cooking time required to reach the 50% cooked point as the reference point (Morris, 1964; Jackson and Varriano-Marston, 1981). However, cooking time as measured by the MBC has not been related to the cooking time as determined by sensory analysis.

The objectives of the study were to design plungers that would consistently reproduce the results determined by sensory analysis and secondly to determine an MBC method for calculating comparative cooking times, based on sensory panelists' cooking point preference.

3.3 MATERIALS AND METHODS

3.3.1 Experimental Design

In order to test the ability of the MBC to reproduce sensory results, the sensory assessment procedure used was designed to measure cooking time in a manner that was as similar as possible to the MBC assessment procedure. Both the panel and the MBC measured the number of beans cooked at timed intervals during the cooking process. These data were expressed as percent cooked at each cooking time and plotted as cookability curves. Sensory and MBC curves were compared to assess the level of agreement between the methods.

The study was designed to modify the MBC procedures described in the literature to be predictive of sensory panelists' assessment of the cooking time of navy beans. The study was divided into two phases, the first involved the use of a five member sensory panel and the second the use of a nine member sensory panel.

The five member panel was used in a preliminary study designed to assess which of several plunger types provided the best indication of cookability as determined by a sensory panel for navy beans. A plunger type (65g, 2mm) described in the literature and two proposed plunger types (37.5 g, 2mm; 49.75

g, 5 mm) were tested. Beans from the "Commercial" sample were used in this part of the study. The 49.75g, 5 mm plunger was shown to provide the best indication of sensory assessment of cookability. A second preliminary experiment was conducted using the five member sensory panel to assess the ability of the 49.75 g, 5mm plunger to assess the cookability of samples of navy beans with a known range of cookabilities. Three samples of navy beans (Commercial, Seafarer'78-Brandon, Seafarer'77-Brandon) were selected because of their varying cookabilities.

The second phase of the study involved the use of a nine member sensory panel and the use of a slightly lighter plunger type (48g, 5mm) to determine if this plunger was a better predictor of sensory panelists assessment of cookability. It was recognized that a larger panel consisting of nine panelists, replicated three times would provide more reliable results than the five member panel, replicated two times. Three freshly harvested samples (Seafarer'83-Brandon, Seafarer'83-Winnipeg, Exrico'83-Winnipeg) which were known to have varying cookability were used for this portion of the study.

A preference test was also conducted by the nine member sensory panel to assess whether the use of the 50% cooked point for comparison of the cookability of bean samples was justified in the light of sensory panelists assessment of cookability. The texture which the panelists prefer was considered as the "cooked" sample. Because cookability is defined in terms of the cooking time to reach a texture that is considered "cooked" or "done", then the percent cooked level of the preferred sample can be used as a comparison point for comparing the cookabilities of bean samples.

3.3.2 Materials

3.3.2.1 Bean Selection

Table 3-1 describes the origin and storage condition of the beans used in the study. One sample of navy beans was purchased at a local supermarket, and the remaining five treatments were obtained from the Manitoba Department of Agriculture Research Station, Brandon, Manitoba, and from the Plant Science Department of the University of Manitoba. The retail ("Commercial") sample was not classified by cultivar. Of the other five treatments four were Seafarer and one Exrico. The "Commercial", Seafarer'78-Brandon and Seafarer'77-Brandon samples had unknown storage conditions. Freshly harvested samples were stored

Table 3-1. Origin and storage conditions of navy beans

Sample Description	Sample Origin	Storage Conditions
"Commercial"	Unknown	Unknown
Seafarer '77-Brandon	M.D.A.[1]	Unknown
Seafarer '78-Brandon	M.D.A.	Unknown
Seafarer '83-Brandon	M.D.A.	4°C.
Seafarer '83-Winnipeg	U.M.[2]	4°C.
Exrico '83-Winnipeg	U.M.	4°C.

[1]Manitoba Dept. of Agriculture
[2]University of Manitoba

in paper bags at 4°C for one to four weeks.

3.3.2.2 Soaking Methods

Samples were rinsed in lukewarm tapwater in a standard kitchen sieve prior to soaking. Beans were soaked in distilled water at 20°C (1:4 ratio of bean to water) for approximately 16 hours.

3.3.3 MBC Methods

The MBC used in this study, consisted of a brass rack and 25 identical brass plungers, as described by Jackson and Varriano-Marston (1981) (Figure 3.1) with the lowest platform modified so that the perforations in the plate were 3 mm in diameter. Plungers were designed so that the weight and penetrating tip diameter were adjustable. All plungers consisted of 5 mm rods with threaded upper ends to which hollow brass cylinders could be attached. Lead shot could be placed inside the hollow cylinders to standardize the plunger weights. Plunger tips were flat faced and either 5 mm or 2 mm in diameter. The four plungers tested had the following weights and tip diameters: 65 g, 2 mm; 37.5 g, 2 mm; 49.75 g, 5 mm; and 48 g, 5 mm. The force exerted by these plungers was 20.70, 11.94, 2.48 and 2.44 g/mm^2 respectively.

3.3.3.1 Standard operation of MBC

For each replication, 25 beans were placed on the appropriate spot on the bottom plate of the MBC, so that the plunger would pass through the bean at right angles to the cotyledon. Each weighted plunger was then gently placed on the corresponding bean and the rack placed in a 2 l beaker or a coffee

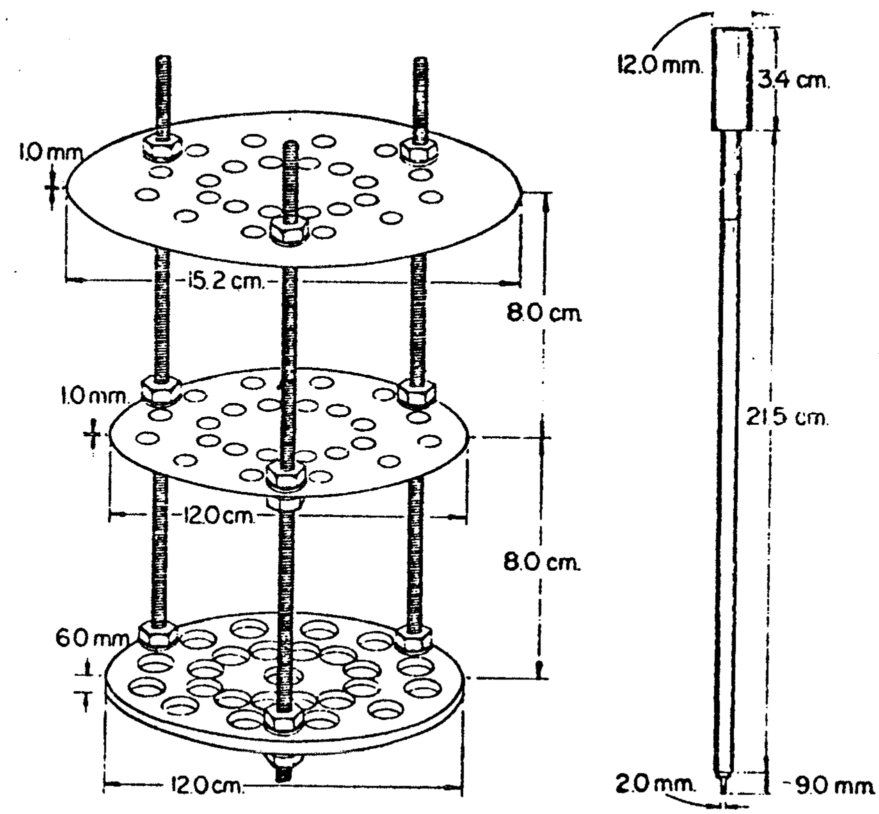

Figure 3-1. Dimensions of rack and plungers of Mattson Bean Cooker (Jackson and Varriano-Marston, 1981).

pot (Pyrex model 7759), which was filled with distilled water at 20°C to a level that was 34 mm above the bottom plate (Figure 3-2). This was placed on direct heat and the water was brought quickly to a boil on high heat in 5-7 minutes. The time when boiling commenced was recorded (0 time) and the heat was reduced so that a slow boil was maintained throughout the cooking period.

From the start of boiling, at five minute intervals the number of plungers dropped were counted. Cooking continued until all of the plungers dropped or until 90 minutes had elapsed which ever came first. Cumulative totals of plungers dropped were recorded. Four replications were completed for each treatmemt. The cumulative results from all four replications were plotted as percent cooked vs. cooking time to produce a cookability curve.

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Figure 3-2. Mattson Bean Cooker, cooking pot and different plunger types.

3.3.4 Sensory Methods

Panelists were selected from staff and graduate students of the Department of Foods and Nutrition, University of Manitoba because of their availabilty, interest and experience in sensory evaluation. Training sessions, with discussion, were conducted using bean samples cooked to varying degrees, to enable the panelists to identify cooked navy bean characteristics and to give panelists experience at distinguishing cooked from uncooked beans. Two separate panels were established. One, consisting of five members, carried out the preliminary sensory testing to establish the initial plunger design. This panel did not always consist of the same five members and on two occasions consisted of four panelists only. The second panel, composed of the same nine members, was used in the final experiment to more thoroughly evaluate the 48 g, 5 mm plunger and to give an indication of the preferred cooking point. Two replications were performed in each case by the five member panel, and three by the nine member panel.

At each panel session, panelists were presented with beans from one treatment only, cooked for six cooking times (Tables 3-2 and 3-3). These times were selected based on previously conducted preliminary

Table 3-2. Cooking times for samples tested by five member sensory panel

Sample	Cooking Times (min)
"Commercial"	20, 30, 40, 50, 60, 70
Seafarer '77-Brandon	20, 30, 40, 50, 60, 70
Seafarer '78-Brandon	30, 40, 50, 60, 70, 80

Table 3-3. Cooking times for samples tested by nine member sensory panel

Sample	Cooking Times (min)
Seafarer '83-Brandon	10, 20, 30, 40, 50, 60
Seafarer '83-Winnipeg	20, 30, 40, 50, 60, 70
Exrico '83-Winnipeg	30, 40, 50, 60, 70, 80

experiments and were considered to represent a range of cooking times in which the entire sample would be cooked. Panelists were asked to test 20 beans individually from each cooking time and indicate the number of beans cooked and the number uncooked. Panelists were instructed to include in the cooked category all beans from those just cooked to those over cooked. Split as well whole beans were to be included for assessment. The ballot used by the panelists is shown in Figure 3-3. The ballot used by the five member panel did not include a preference section.

For the five member panel, 250 g of beans were used, while for the nine member panel, 400 g of dry beans were used. For both panels, beans were divided into six equal portions and placed in six pyrex cooking pots each containing 600 ml (five member panel) and 800 ml (nine member panel) distilled water. Start of cooking time was staggered so that all samples reached the end of their cooking period at the same time. Six, three digit coded sample cups containing 25-30 beans each, were presented to the panelists using a random order of presentation. Trays were set up as shown in Figure 3-4. Opaque red coloured pyrex sample cups were used to maintain the warmth of the samples.

BEAN TEXTURE EVALUATION

INSTRUCTIONS:

1) <u>% COOKED</u>:
Evaluate 20 beans at random from each sample and record on ballot the numbers that you consider, according to your judgement, to be "undercooked" or "cooked".

<u>Note</u>: The "cooked" category should include all beans that are just barely cooked to overcooked. It does <u>not</u> indicate only the perfectly cooked beans.

<u>Note</u>: Choose at random from all of the beans in the sample. Do <u>not</u> choose only the whole beans. Include the partial beans and beans with split skins.

2) <u>PREFERENCE</u>:
From each sample select a spoonful (approx. 10 beans) and chew all at once. Evaluate for overall texture preference. Circle the sample number of the sample that you preferred.

<u>SAMPLE BALLOT</u>

SAMPLE	NUMBER OF BEANS UNDERCOOKED	NUMBER OF BEANS COOKED
204	////	~~////~~ ~~////~~ ~~////~~ /
892	~~////~~ ////	~~////~~ ~~////~~ /

Figure 3-3. Sample of ballot used by nine member sensory panel.[1]

[1] The same ballot, but without the Preference section was used by the five member sensory panel.

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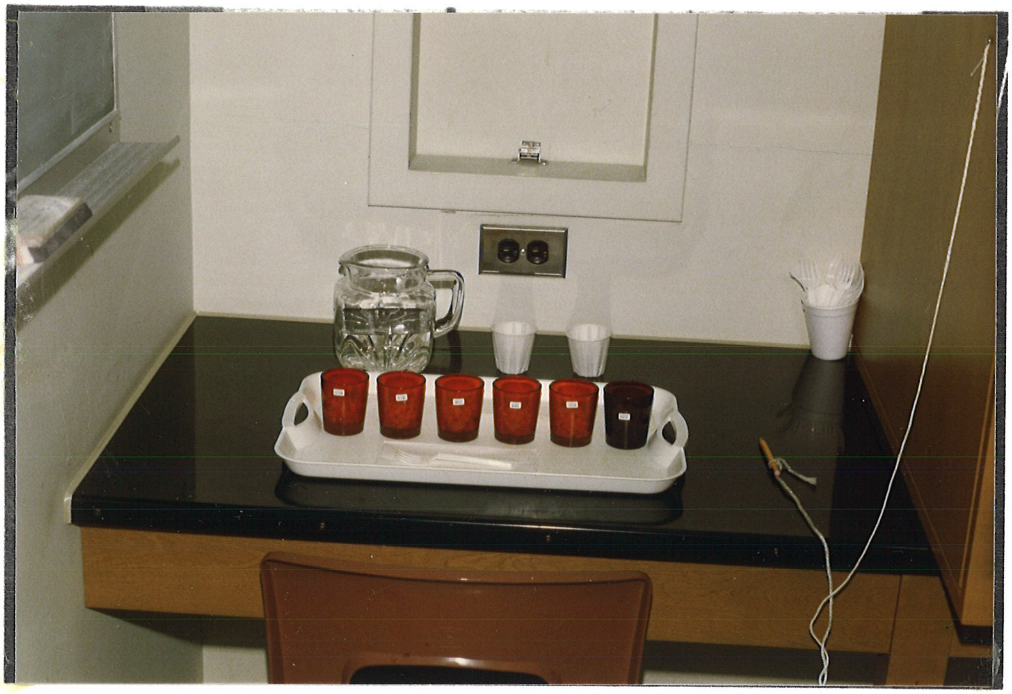


Figure 3-4. Sample presentation to panelists.

Evaluations were conducted in a sensory panel room equipped with individual testing booths and with controlled lighting and testing conditions.

For each navy bean sample tested, the mean percent cooked value for all panelists for all replications was calculated for each of the six cooking times. Results were plotted as the percent cooked versus cooking time to produce cookability curves.

3.3.5 Statistical Methods

A chi-squared analysis of the data from the nine member panel was done to assess whether the results from all 9 panelists could be pooled to give statistically accurate mean % cooked levels for each cooking time.

The cumulative mean percent cooked and standard deviation for each cooking time for four replications were calculated for the MBC results obtained using the 49.75 g; 5 mm plunger and the 48 g; 5 mm plunger.

The mean percent cooked and standard error of the mean (SEM) at each cooking time was calculated for the 5 member and 9 member panel results.

For the preference test, conducted by the nine member sensory panel, the results for each sample judged as preferred was converted into percent cooked by multiplying the fraction of 20 cooked by 100. The mean of all 81 judgements (9 panelists x 3 treatments x 3 replications) was calculated along with the standard deviation. Means for each panelist, replication and treatment were also calculated.

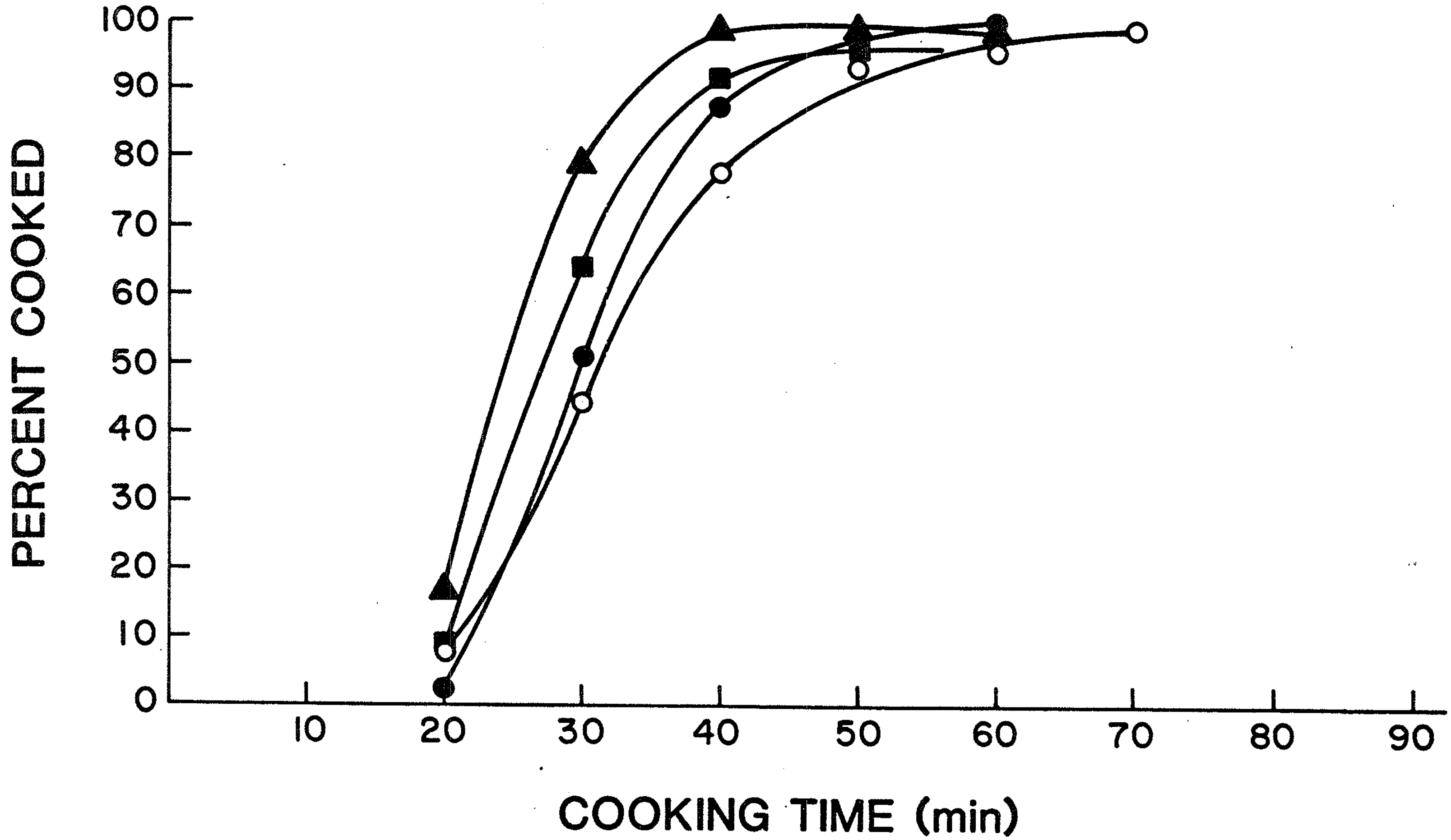
3.4 RESULTS AND DISCUSSION

3.4.1 Preliminary Comparison of MBC Cookability Curves Obtained Using Three Plunger Types with Five Member Sensory Panel Cookability Curves

MBC plungers of three different designs (65 g, 2 mm; 37.5 g, 2mm; 49.75 g, 5 mm.) were initially tested on the sample of "Commercial" beans, and the cookability curve produced by each of the plungers was compared to the curve as determined by a 5 member sensory panel (Figure 3-5). The 65 g, 2 mm plunger was selected to represent the lightest of the plunger types described in the literature. The most common type was the 82 g, 2 mm plunger reported by Jackson and Varriano-Marston (1981). The 65 g plunger would apply even less force than the 82 g plunger. The 37.5 g, 2 mm and 49.75 g, 5mm plungers were proposed as types of plungers that might prove to be more predictive of sensory panelists assessment of cookability. The 48 g, 5 mm plunger was a refinement of the 49.75 g plunger that the preliminary portion of the experiment indicated was the most predictive of the five member panel results. Values for percent beans cooked at each cooking time, when determined with the 65 g, 2 mm

Figure 3-5. Cookability curves for "Commercial" navy beans as determined by a 5 member sensory panel and by the MBC using 3 plunger types.

- ▲ - plunger - 65.00 g; 2 mm
- ■ - plunger - 37.50 g; 2 mm
- ● - plunger - 49.75 g; 5 mm
- ○ - 5 member sensory panel



100
90
80
70
60
50
40
30
20
10
0
PERCENT COOKED
10
20
30
40
50
60
70
80
90
COOKING TIME (min)

diameter plungers, were much greater than when determined by the sensory panel. It was therefore concluded that this plunger did not as effectively reproduce the sensory panelists cookability curves as the lighter, larger diameter plungers. Percent cooked values when determined using the two lighter weight plungers, were closer to the sensory values at each cooking time. The 37.5 g, 2mm diameter plunger, however, produced a cookability curve which intersected the sensory curve at the 95% cooked point. The 49.75 g, 5mm plungers gave a cookability curve similar in shape to the curve determined by sensory analysis. Of the plunger designs tested, therefore, this was considered to provide the best indication of sensory values for navy beans.

3.4.2 Preliminary Comparison of MBC Cookability Curves Obtained Using a 49.75 g, 5 mm Plunger with Five Member Sensory Panel Cookability Curves for Three Samples of Navy Beans

Three samples of navy beans, "Commercial", Seafarer'77-Brandon and Seafarer'78-Brandon were tested with the MBC using the 49.75 g, 5 mm plunger and results were compared with those obtained for the same samples using sensory evaluation by the five member sensory panel.

Samples selected for this test had previously been shown to vary in cookability. As shown in Figure 3-6, MBC curves were similar, for each sample to that samples' sensory cookability curve. Percent beans cooked at each cooking time was greater for the "Commercial" sample than for the Seafarer'78-Brandon sample, and for both of these samples than for the Seafarer'77-Brandon sample. Curves for each sample as determined by either sensory or instrumental analysis showed no overlapping values. Times to cook to the 50% cooked point, as determined from the cookability curves were 30 minutes for the "Commercial" sample, as determined by both methods of analysis, 38 and 37 minutes for the Seafarer'78-Brandon sample by sensory and instrumental analysis respectively and 49 and 47 minutes for the Seafarer'77-Brandon by sensory and instrumental methods. Table 3-4 compares the mean percent cooked and standard error as measured by the sensory and instrumental methods at each cooking time for the three samples. It was concluded that for samples with distinctly different cookabilities, the MBC using 49.75 g 5 mm plungers gave results that closely approximated sensory values, especially as cooking progressed above 75% cooked, although cooking times to reach percent

Figure 3-6. Cookability curves for three samples of navy beans as determined by the MBC with 49.75 g, 2 mm plungers and by a 5 member sensory panel.

● - MBC - "Commercial"
○ - Panel - "Commercial"
▲ - MBC - Seafarer-'78
△ - Panel - Seafarer-'78
■ - MBC - Seafarer-'77
□ - Panel - Seafarer-'77

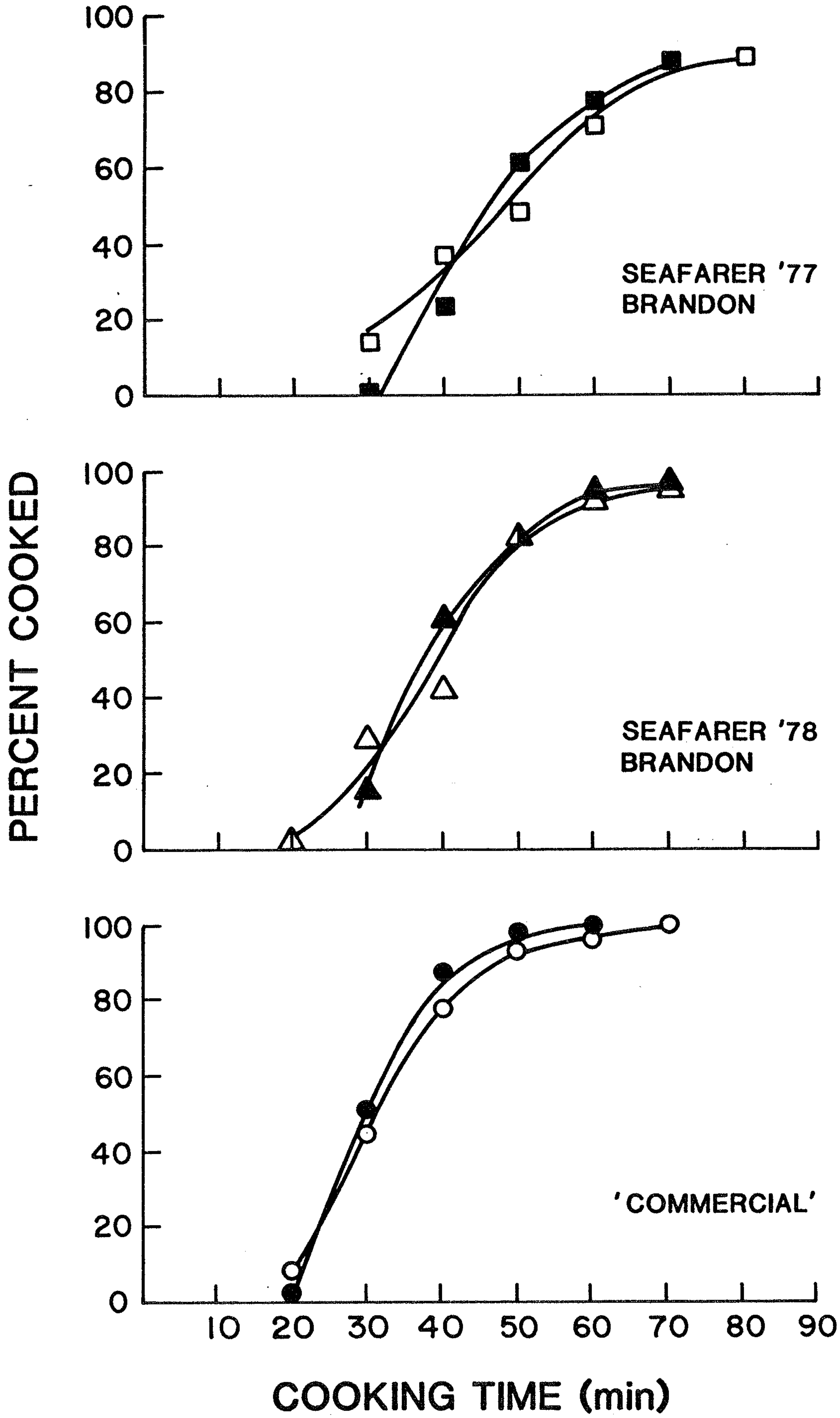

SEAFARER '77
BRANDON
SEAFARER '78
BRANDON
'COMMERCIAL'
PERCENT COOKED
COOKING TIME (min)
0
20
40
60
80
100
10
20
30
40
50
60
70
80
90

Table 3-4. Mean percent cooked as measured by sensory[1] and instrumental[2] methods at different cooking times for Commercial, Seafarer'78-Brandon and Seafarer'77-Brandon navy beans

Cooking Time (min)	Sensory Mean % cooked	Sensory SE	Instrumental Mean % cooked	Instrumental SE
Commercial				
20	8.50	4.95	2.00	2.31
30	44.50	21.92	51.00	6.83
40	78.50	2.12	88.00	6.53
50	93.50	3.54	98.00	2.31
60	96.00	2.83	100.00	0.00
70	99.50	0.71	100.00	0.00
Seafarer'78 Brandon				
20	1.25	0.00	0.00	0.00
30	28.13	6.19	15.00	2.00
40	42.50	19.45	61.00	6.00
50	83.13	0.88	83.00	6.83
60	93.13	6.19	95.00	3.83
70	95.63	4.12	97.00	2.00
Seafarer'77 Brandon				
30	14.25	9.55	1.00	2.00
40	37.38	5.13	23.00	8.87
50	48.63	10.78	62.00	19.18
60	71.50	4.95	77.00	15.45
70	86.25	1.77	88.00	6.53
80	89.13	3.01	---	---

[1]five member sensory panel.
[2]MBC using 49.75 g, 5 mm plungers.

cooked values above 50% were slightly less using the instrument than were obtained using the sensory panel.

3.4.3 Comparison of the MBC Cookability Curves Obtained Using a 48 g, 5mm Diameter Plunger with Nine Member Sensory Panel Cookability Curves for Three Samples of Freshly Harvested of Navy Beans

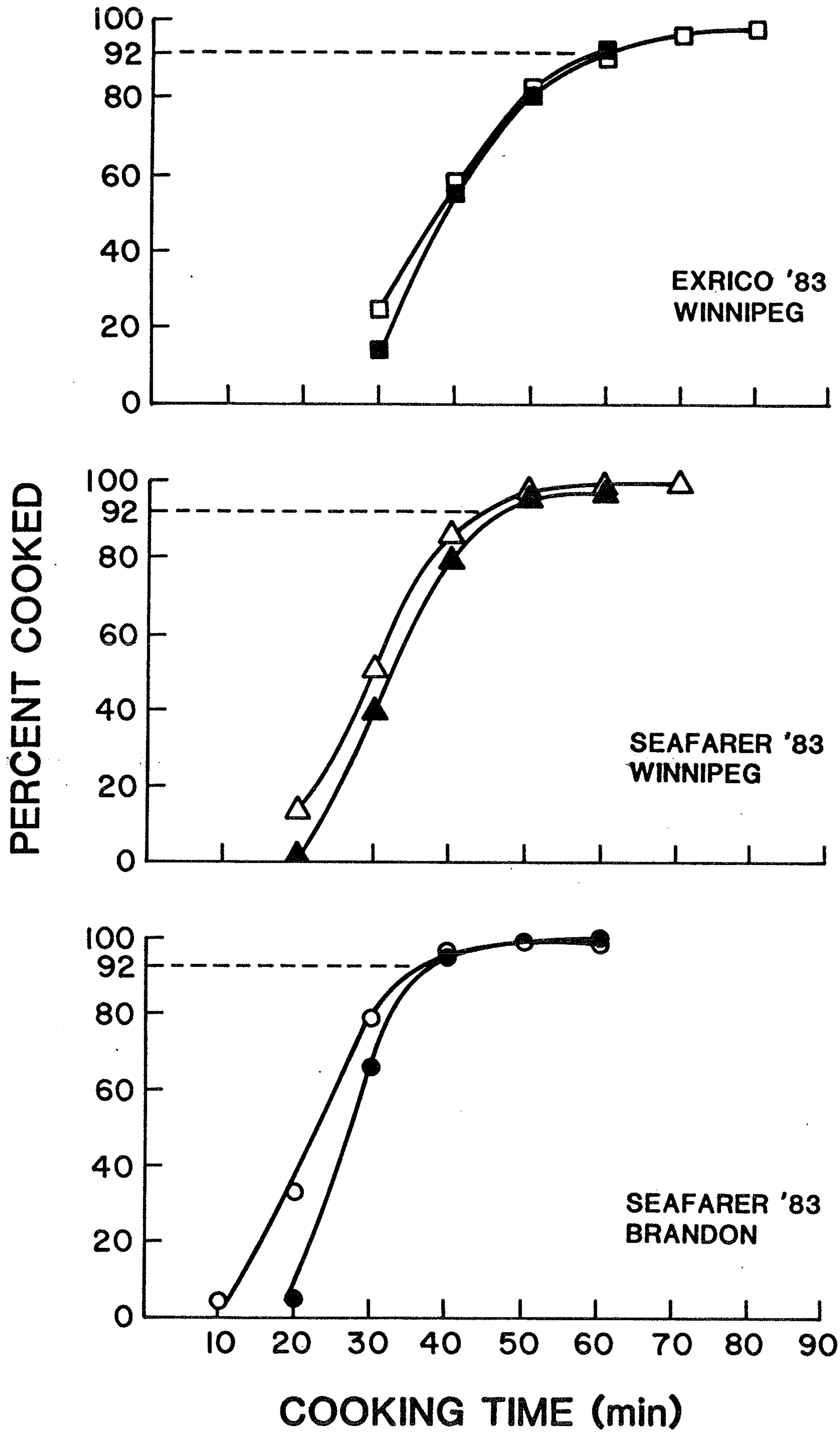
As shown in the previous experiment, the MBC with 49.75 g, 5 mm plungers effectively reproduced sensory cookability curves, however it was thought that the instrumental results might even more closely approximate sensory results if the weight of the plungers were slightly reduced. For this reason, the 5 mm diameter plungers were adjusted to 48 g.

Sensory assessment was carried out by a nine member trained sensory panel and three replications were conducted for each of the three freshly harvested samples of beans. Some variation in cookability was expected among the samples, which were of two cultivars grown at two different locations. Samples tested were Seafarer'83-Brandon, Seafarer'83-Winnipeg and Exrico'83-Winnipeg.

The cookability curves determined for these three samples using the MBC and the sensory panel are shown in Figure 3-7 and mean percent cooked with

Figure 3-7. Cookability curves for 3 samples of navy beans as determined by the MBC with 48 g, 5 mm plungers and by a 9 member sensory panel.

● - MBC - Seafarer-1983-Brandon
○ - Panel - Seafarer 1983-Brandon
▲ - MBC -Seafarer-1983-Wpg
△ - Panel - Seafarer-1983-Wpg
■ - MBC - Exrico-1983-Wpg
□ - Panel - Exrico-1983-Wpg


PERCENT COOKED
100
92
80
60
40
20
0
EXRICO '83
WINNIPEG
SEAFARER '83
WINNIPEG
SEAFARER '83
BRANDON
10
20
30
40
50
60
70
80
90
COOKING TIME (min)

standard error of the mean (sensory) and standard deviation (instrumental) are shown in Table 3-5. These curves show very close agreement between the MBC and sensory panel values, with almost identical results when the percent cooked values were greater than 85%. Table 3-5 also indicates the close agreement.

In this experiment the sensory panel was also asked to indicate the sample which had the most preferred texture, from among the six cooking time samples presented to them. Results of the preference test are shown in Table 3-6. Mean percent cooked preference was 93.70 $\pm$ 8.68%, an indication that comparison of cooking times for navy bean samples might suitably be made using cooking time to reach a percent cooked value in the 85-100% range.

Comparisons of bean cookability using data obtained with the MBC, have previously been based on cooking time to reach the 50% cooked point (Morris, 1964; Jackson and Varriano-Marston, 1981). The appropriatness of the 50% cooked point for cookability comparison must be questioned, as panelists clearly indicated their texture preference for beans cooked to the 85-100% range. Figure 3-8 shows cookability curves for three samples of

Table 3-5. Mean percent cooked as measured by sensory[1] and instrumental[2] methods at different cooking times for Seafarer'83-Brandon, Seafarer'83-Winnipeg and Exrico'83-Winnipeg navy beans

Cooking Time (min)	Sensory Mean % Cooked	Sensory SE	Instrumental Mean % Cooked	Instrumental SE
Seafarer'83 Brandon				
10	4.62	5.78	0.00	0.00
20	32.59	9.20	5.00	3.83
30	79.44	7.77	66.00	10.58
40	97.57	0.32	96.00	3.27
50	98.14	0.85	99.00	2.00
60	99.63	0.32	100.00	0.00
Seafarer'83 Winnipeg				
20	14.06	7.39	1.00	2.00
30	51.11	5.64	39.00	12.81
40	86.67	4.19	81.00	3.83
50	97.04	0.85	96.00	3.27
60	99.07	0.85	98.00	2.31
70	99.44	0.56	99.00	2.00
Exrico'83 Winnipeg				
30	24.64	12.48	14.00	5.16
40	59.22	13.30	56.00	9.79
50	83.61	6.29	81.00	5.03
60	90.18	3.69	93.00	3.83
70	97.22	2.42	97.00	2.00
80	98.88	0.96	98.00	2.31

[1]nine member sensory panel.
[2] MBC using 48 g, 5mm plungers.

Table 3-6. Percent beans identified as cooked in the preferred sample by a nine member sensory panel for Seafarer'83-Brandon, Seafarer'83-Winnipeg and Exrico'83-Winnipeg navy beans

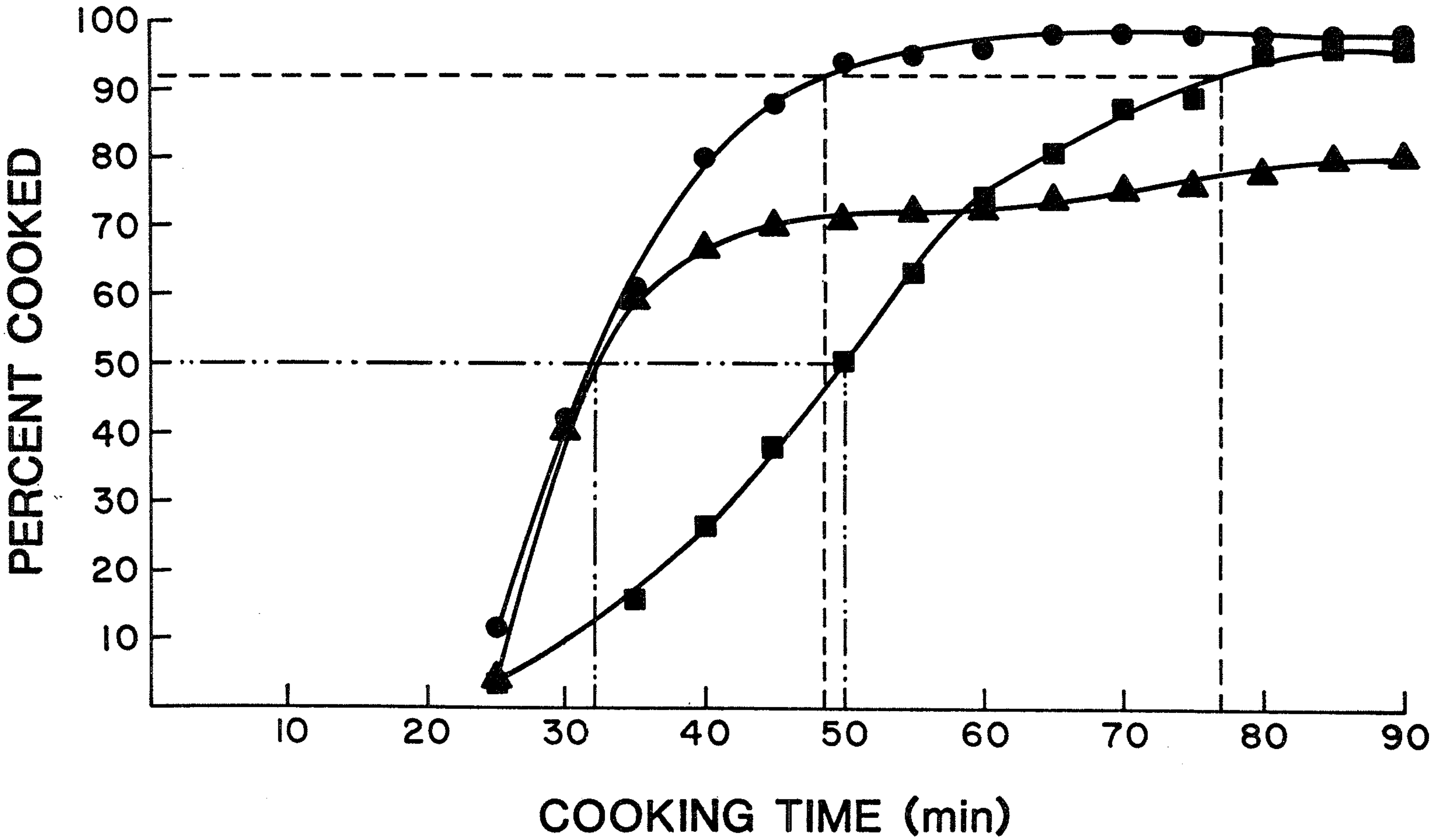
	Type of Navy Bean									
	Seafarer'83 Brandon			Seafarer'83 Winnipeg			Exrico'83 Winnipeg			
	Reps.			Reps.			Reps.			
Panel -ist	1	2	3	1	2	3	1	2	3	Panel -ist Mean
1	100	95	90	100	95	100	100	100	85	96.11
2	100	90	95	90	95	95	85	100	100	94.44
3	100	100	100	95	95	95	80	95	100	95.56
4	75	100	65	65	80	80	80	80	80	78.33
5	100	100	100	100	100	100	100	100	100	100.00
6	95	95	100	100	95	100	100	100	95	97.97
7	90	95	100	85	100	90	100	100	77.5	93.05
8	100	95	100	100	100	100	75	100	100	96.67
9	90	90	100	100	100	85	100	90	77.5	92.50
Rep. Mean	93.3	95.6	94.4	92.8	95.6	93.9	91.1	96.1	90.6	
Sample Mean		94.44			94.07			92.59		

Overall Mean - 93.70%

Overall Standard Deviation - 8.68%

Figure 3-8. Cookability curves for three samples of Fleetwood navy beans as determined by the MBC with comparison of cooking time required required to reach 50% cooked point and 92% cooked point.

● - 0 month
■ - blanched-9 month-freezer
▲ - unblanched-9 month-freezer


PERCENT COOKED
100
90
80
70
60
50
40
30
20
10
10
20
30
40
50
60
70
80
90
COOKING TIME (min)

Fleetwood navy beans grown at the same location but undergoing different storage and soaking treatments (Chapter 5). These curves indicate that the use of the 50% cooked point rather than the 92% cooked point will result in very different cooking times for the same sample. Also it indicates that for two of the samples (0 month and unblanched-9 month) the use of the 50% cooked point indicates that cooking times were very similar while use of the 92% cooked point indicates that the cooking times were very different. If it could be shown that relative times to cook to the 50% cooked point were always in the same ratio as times to cook to the 85-100% cooked point, then cooking times to the 50% cooked point could be used for comparison. However, Figure 3-8 also shows that if the 0 month and blanched samples were compared using the 50% cooked point, cooking times would be 33 and 50 minutes respectively. Using the 92% cooked point, cooking times would be 49 and 77 minutes respectively. This demonstrates the difficulty in using the 50% cooked point as a relative measurement of cookability since in one case tha difference in cooking time is 19 minutes while in the other it is 28 minutes.

Since cookability is defined in terms of the cooking time required for beans to reach a texture at which panelists consider the beans to be "cooked" or "done", then it seems appropriate to use this comparison point when using the MBC to compare cooking times of bean samples.

The preference test clearly indicates that the comparison point should be in the 85-100% cooked region. Since the panel preference was for samples that were 93.70% cooked, a similar value for the MBC would be most suitable for comparing cookability with this instrument. Since the MBC consisted of 25 plungers, it was decided that the time at which the 23'rd plunger dropped (92% cooked) would be the most appropriate comparison point. The 92% cooked point is also approximately mid-way between 85-100% cooked.

The time required to reach the 92% cooked point can be calculated in two ways. Cumulative totals for the four replications can be calculated and plotted as cookability curves, and the time to reach the 92% cooked point can be derived from the graph. This method does not however give an indication of the range of cooking times between replications. This can be overcome by measuring the time required for the 23'rd bean to cook for each replication and calculating the mean cooking time. This method is more useful when comparing the cooking times of samples of beans because the within sample variability can be expressed. The two methods will give similar results in most cases except in the case where one replication differs greatly from the others, in which case the difference in cooking time as measured by the two methods would be slightly different.

3.4.4 The Ability of the MBC with Plunger Type 48 g, 5 mm to Reproduce Sensory Results

The preference test indicated that 85-100% cooked was the most important part of the cookability curve. It was also very significant that the cookability curves of the MBC and the sensory panel agreed most in the 85-100% cooked regions of the curves. The difference between the percent cooked as measured by the MBC and by the panel, differed at most by 6% and was generally less than 2% at any given cooking time between 85-100% cooked.

The chi squared analysis of the sensory data indicated that for all cooking times that corresponded with 85-100% cooked, the percent cooked preferred by all panelists for all three replications could be pooled at each cooking time, to give statistically accurate mean percent cooked levels at the 5% level (Appendix A).

Unfortunately because the MBC data was cumulative and dependent (the same 25 beans were used throughout each MBC test), while the percent cooked values as determined by the panel were independent (separate sub-samples of beans were cooked to each cooking time). Therefore statistical correlation could not be performed on the data. The two methods were plotted seperately as percent cooked vs. cooking time and compared visually (Figure 3-7). The narrow range of the standard error of the instrumental and sensory measurements also indicated that the instrumentally determined cookability curves effectively reproduced the sensory cookability curves.

In summary, the experiment accomplished its stated objectives. The results indicated that the plunger types described in the literature did not reproduce sensory results when measuring the cooking time of navy beans, but that the modified 48 g,5 mm plunger did reproduce sensory results. The study also indicated that the use of a 50% cooked reference point as suggested in the literature could be misleading and that a 92% cooked reference point is a better indicator of cookability. It was concluded that the mean cooking time for the 23'rd (92%) plunger to drop for all four replications provided a good method for comparison of cooking time.

Further research should be conducted to use this approach in adapting the MBC for evaluating other varieties of *Phaseolus vulgaris* beans.

CHAPTER 4

EFFECT OF CULTIVAR, GROWING LOCATION AND CHEMICAL COMPOSITION ON THE COOKABILITY OF FRESHLY HARVESTED MANITOBA GROWN NAVY BEANS

4.1 ABSTRACT

Cookabilities of three cultivars of navy beans grown at three locations in Manitoba were compared using the Mattson Bean Cooker with 48 g, 5 mm plungers. 4 replications of 25 bean each were conducted. Samples were tested within 10 days of harvest. When cookabilities of Seafarer, Fleetwood and Exrico navy beans grown at Brandon, Morden and Winnipeg were compared, effect of growing location was greater than the effect of cultivar. Cooking times for all three cultivars were significantly longer ($P<0.05$) when grown at the Winnipeg location. Exrico beans grown at the Winnipeg location took significantly longer to cook ($P<0.05$) than Fleetwood or Seafarer, but at other locations cultivars had similar cooking times. Post-harvest drying was not found to affect cooking time of the Seafarer-Winnipeg samples. Cooking times of the artificially dried and field dried samples were not found to be significantly different ($P<0.05$). There

was no incidence of hardshell in any of the freshly harvested navy bean samples. There was no evident relationship found between moisture content, fat, protein, ash or phytic acid and cooking time.

4.2 INTRODUCTION

New cultivars of pulses being developed in western Canada are evaluated regularily for agronomic qualities but are not systematically assessed for length of cooking time. The problem of prolonged cooking time which is frequently encountered with navy beans (*Phaseolus vulgaris* L.) grown in western Canada, has stimulated research into the factors involved.

Each variety of edible dry bean has a particular cooked texture which is considered acceptable or "cooked" to consumers and the term "cookability" refers to the cooking time required to reach that texture (Moscoso, 1981). Prolonged cooking or poor cookability can occur because of two separate but sometimes related phenomena, "hardshell" and the "hard-to-cook condition". "Hardshell" is a condition in which the seed fails to imbibe within a reasonable length of time during the soaking stage (Bourne, 1967), while the hard-to-cook phenomenon is a condition in which the bean has prolonged cooking time during the cooking stage itself, often after having imbibed normally (Molina _et al_., 1976; Burr _et al_., 1968).

Genetic , environmental, handling factors related to growing location, as well as chemical composition (moisture, fat, protein, ash and phytic acid) all affect the cookability of freshly harvested navy beans. Beans of different Genera and of different varieties within the family _Leguminosae_ may range in cooking times, even when freshly harvested, from less than 30 minutes to several hours. Although hardshell, the second aspect of cookability, has not commonly been reported in freshly harvested _Phaseolus_ beans, it has been related to interaction between genetic variation, growing location and storage conditions (Bourne, 1967; Gloyer, 1928a).

Within the navy variety, different cultivars have also been shown to have different cooking times. Voisey and Larmond, (1971) assessed the cooking time of four cultivars of navy beans, Seaway, Sanilac, Seafarer and an experimental cultivar 779-629. All samples were grown in the same location, harvested and handled in the same manner and tested when fresh. Instrumental measurements of texture indicated that the Sanilac and 799-629 cooked significantly faster than did the Seaway and Seafarer.

Quenzer _et al_. (1978) assessed three cultivars of pinto beans grown at three locations (two in Texas and one in Idaho) for texture (shear values) and sensory preference after 90 minutes of cooking. They reported that cultivar did not have as significant an effect as did location on the texture or preference of the beans. Bhatty _et al_. (1983) studying two cultivars of lentils (_Lens culinaris_) reported that growing location had a much greater influence on cooking quality than did cultivar. Snyder (1936) studied navy beans (cultivar unspecified) grown at three locations in Michigan, one location in Colorado and one location in Nebraska and reported that the percent beans uncooked after 75 minutes of cooking ranged from 15 to 28% indicating an effect of location on cooking time.

The effect of growing location is the result of the combined effects of many variables, including seeding date, harvest date, soil type, climatic conditions, crop treatment (fertilizer, herbicide, pesticide), harvest conditions and post harvest treatment (drying, handling). However, for this study, the effect of growing location will be discussed as a general effect only.

Moscoso (1981) and Stanley and Aguilera (1985) have extensively reviewed the effects of chemical composition on cookability. Moisture content, protein and ash have only indirect, ambiguous or poorly understood effects upon cooking time. Morris and Wood (1956) reported that beans stored with a low moisture content (<10%) did not undergo changes in cookability after one year of storage at 25°C. Hughes and Sandsted (1975) and Burr _et al_. (1968) reported that high moisture content in beans stored at high temperature (>21.1°C) was related to poor cooking quality. Muneta (1964) and Snyder (1936) reported no correlation between moisture content and cookability. Protein content has not been shown to affect cooking time directly, but several studies have shown that storage conditions which can cause prolonged cooking times in beans, such as conditions of high temperature and high humidity, can also decrease protein efficiency ratio (PER) (Sgarbieri and Whitaker, 1982) and increase the nitrogen solubility of beans (Molina _et al_., 1976). The relationship between these changes in protein characteristics and prolonged cooking time is presently unknown.

Takayama _et al_. (1965) found that triglyceride, phosphatide and crude lipid content correlated to a small degree with cooking time, although correlations did not rise above 0.2 and none were significant. Muneta (1964) postulated that texture of beans may be affected by oxidation and polymerization of lipids. Thus increased lipid content could contribute to poor cookability by increasing the extent of oxidation and polymerization during storage conditions of high temperature and high humidity.

Phytate, myo-inositol hexakisphophate, is a storage form of phosphate found in all legume seeds in concentrations varying from 0.3 to as high as 2.5% on a dry basis (Stanley and Aguilera, 1985). Mattson (1946) reported that hard-to-cook peas contained much less phytate (50% less) than normal cooking peas. Mattson also found that removal of phytate by soaking or enzymatic action could induce prolonged cooking time. It was postulated that in normal cooking peas and beans, the phytate, which is a strong chelating agent and binds ionically to divalent and monovalent cations, acts in the middle lamella to chelate calcium and magnesium cations, thus reducing the pectate crosslink bonds and allowing the dissolution of the middle lamellar tissue. Jones and Boulter (1983) working with black beans and Kon and Sanshuck (1981), working with navy beans, reported that reduction in phytate correlated with increased cooking time. However, Crean and Haisman (1963) and Rosenbaum and Baker (1969) reported that phytate did not play a significant role in the prolonged cooking time of beans.

The roles of other specific minerals, polyphenols, pectins and lignin may also be important in the chemical processes that contribute to poor cookability in beans. Further investigation of these factors as well as of interactions between phytate, calcium and magnesium is needed.

The objectives of the study were, first to determine the effects of cultivar and growing location on the cookability of Manitoba grown navy beans, secondly to assess the effect of chemical composition on cookability and thirdly to assess the effect of post harvest drying on cookability.

4.3 MATERIALS AND METHODS

Ten 200 g samples of navy beans were obtained from the 1983 Manitoba Co-operative Field Bean Trials. The ten samples consisted of 3 pure line (one genotype) cultivars (Seafarer, Fleetwood and Exrico), each grown in 3 locations (Winnipeg, Brandon and Morden). Four samples were obtained from Winnipeg. The three samples from the Brandon location were field dried, while three of the four samples from Winnipeg were artificially dried in a hot air drier. The fourth Winnipeg sample was a field dried Seafarer sample harvested under drier harvest conditions, one week later than the other three samples. The three Morden samples were air dried at room temperature.

The Seafarer is an early maturing bush-bean cultivar that is widely grown in Manitoba. Fleetwood and Exrico are late maturing bush-bean cultivars that are commonly grown in southern Ontario but are not commercially grown in Manitoba (Robertson and Frazier, 1982; McVetty, 1985).

All samples were tested for cooking time within 10 days of harvest, that is within three days of receipt. All samples were stored under refrigeration (4°C) until tested. Cooking times were determined using the Mattson Bean Cooker (MBC) equipped with 48 g, 5 mm plungers as described in Chapter 3. Four replications of the MBC test (25 beans each) were conducted on each sample, using a total of 100 beans. Cooking time was determined by averaging the time required to reach the 92% cooked point for each of the four replications.

A factorial analysis of variance was used to detect significant differences in cooking times due to cultivar and location. Mean cooking times for the three cultivars were compared for each location separately by one way analysis of variance, and mean cooking times for the three locations were compared separately for each cultivar by one way analysis of variance.

Cooking times for the artificially dried and field dried Seafarer-Winnipeg samples were compared using a t-test. Also, one way analysis of variance was used to compare cooking time of the field dried Seafarer-Winnipeg sample with the Seafarer-Morden and Seafarer-Brandon samples.

Moisture content on an "as is" basis was determined using the AACC Method 44-15A 1983, two stage method. Fat was determined using Soxhlet extraction. Protein was determined from Kjeldahl nitrogen (Nx6.25) using AACC Method 46-12, 1983, using titanium oxide as a catalyst. Ash determinations were carried out at 600°C for 2 hours using AACC Method 08-03, 1983. Phytic acid was determined by the method of Latta and Eskin (1980) with the following revisions. The samples were extracted by placing one gram of sample in a 20 mm x 125 mm screw-top tube to which 20 ml of 0.65 N HCl was added. Tubes were capped tightly and placed horizontally in a shaker for one hour. After centrifugation, 5 ml of supernatant was diluted to 25 ml and 2 ml of this was put onto a prepared ion exchange column containing 0.4 g of resin. Inorganic phosphorus and impurities were eluted with 10 ml of 0.1 N NaCl. Phytate was eluted with 10 ml of 0.7 N NaCl To each tube containing 10 ml of elutant 3.3 ml of Wade Reagent was added. The tubes were covered with parafilm and mixed. After centrifugation the absorbance of the supernatant was measured at 500 nm.

Percent hardshell was determined by counting the number of seeds which failed to imbibe during the soaking stage and by calculating this as a percent of the total number soaked.

4.4 RESULTS AND DISCUSSION

4.4.1 Effect of Cultivar and Location

Mean cooking times, standard deviations and proximate analysis for each of the ten samples are listed in Table 4-1. No hardshell was detected, confirming reports in the literature that hardshell is not usually encountered in samples of freshly harvested beans (Gloyer, 1928a; Bourne, 1967).

Factorial analysis of variance on the data for the three cultivars grown at three locations (excluding the Winniper field-dried sample) indicated a highly significant effect of both cultivar and location, with no significant interaction between cultivar and location (Table 4-2). When grown at the Winnipeg location the cultivar Exrico had the longest mean cooking time, 65.50 minutes, cooking time for the Fleetwood cultivar was shorter, 51.25 minutes and cooking time for the Seafarer was shortest at 49.25 minutes. This pattern was repeated at all three growing locations. However, when one-way analysis of variance and Tukey mean separation tests were conducted to compare mean cooking times of the three cultivars at each growing location separately, a significant difference ($P\leq 0.05$) was detected only

Table 4-1. Cooking times, proximate composition and phytic acid content of freshly harvested navy beans

Sample		Cooking Time[3] (min)		Proximate composition				
Cultivar[1]	Location[2]	Mean	SD	Moisture[4] %	Fat %	Protein %	Ash %	Phytic Acid %
S	M	33.75	3.09	9.60	1.70	23.26	4.34	1.70
S	B	34.75	2.87	12.76	1.54	28.79	3.87	1.58
F	B	39.50	4.51	11.53	1.38	27.83	3.86	1.31
F	M	39.75	2.22	10.52	1.66	24.09	4.16	1.34
E	B	40.75	3.20	12.52	1.52	29.42	4.12	1.42
E	M	44.00	8.04	9.94	1.70	26.32	4.46	1.69
S	W	44.50	1.91	12.58	1.51	27.37	4.03	1.51
S	W[5]	49.25	7.07	8.26	1.57	26.88	4.02	1.44
F	W[5]	51.25	1.71	10.20	1.58	27.80	3.99	1.25
E	W[5]	65.50	10.75	12.14	—	30.46	4.27	1.40

[1]Cultivar: S = Seafarer; F = Fleetwood; E = Exrico;
[2]Location: W = Winnipeg; B = Brandon; M = Morden;
[3]Mean cooking time of four replications by MBC procedure with plungers 48 g; 5 mm.
[4]Moisture content on an "as is basis". All other data as a percentage of dry weight.
[5]Mechanically dried

Table 4-2. Factorial analysis of variance of cooking times of three navy bean cultivars grown at three locations

Source of Variation	df	MS	F
Replication	3	11.29	0.33
Cultivar	2	357.53	10.38**
Location	2	1102.11	32.00**
C x L	4	51.36	1.49
Error	24	34.44	
Total	35		

**P<0.01.

between the mean cooking times of the cultivars Exrico and Seafarer at the Winnipeg location. Analysis of variance is shown in Table 4-3 and Tukey mean separation results are shown in Figure 4-1. It could not be concluded that there was a significant effect of cultivar on cooking time, however, the slightly but consistently longer cooking times of the cultivar Exrico at two of the locations and the significantly longer cooking time for the cultivar grown at the Winnipeg location (15 minutes) indicated that cultivar can influence cooking time in some cases; and had more replications been performed, more significant differences might have been found.

As can also be seen in Figure 4-1, cooking times for all cultivars were longer when grown at the Winnipeg location than when the same cultivars were grown at Brandon and Morden. One way analysis of variance and Tukey mean separation tests conducted to compare cooking times at the three locations for the three cultivars separately confirmed that cooking time was significantly greater for all cultivars at the Winnipeg location than at the other two locations. Analysis of variance is shown in Table 4-4 and Tukey mean separation is shown in Figure 4-2. The Seafarer beans grown at Winnipeg

Table 4-3. One way analysis of variance F-values for the effect of cultivar[1] on cooking times of navy beans grown at three locations

Source of Variation	df	Location Winnipeg F	 Brandon F	 Morden F
Cultivar	2	5.58*	3.09	4.04
Error	9			
Total	11			

[1]Exrico, Fleetwood and Seafarer
*P<0.05

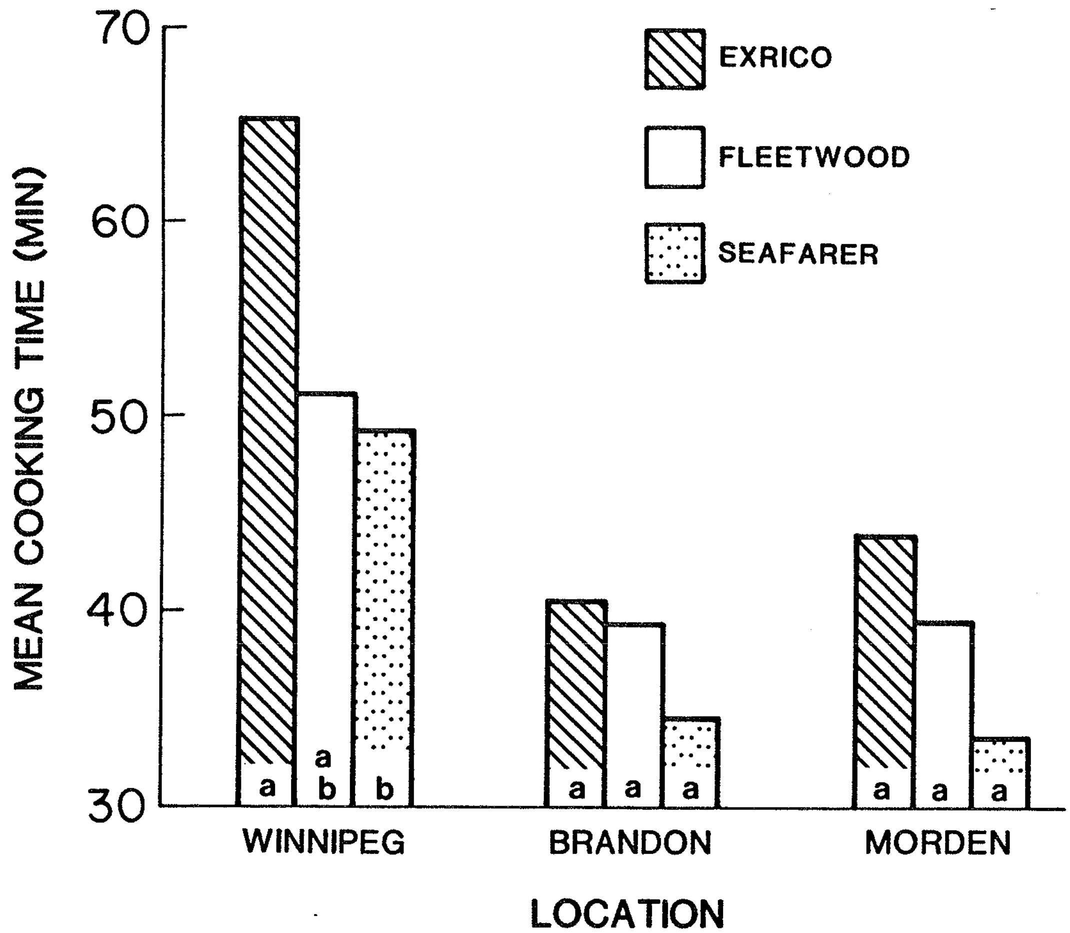


Figure 4-1. Comparison of mean cooking times of three cultivars of navy beans for three locations.

ab means at the same location with the same letter are not significantly different ($P<0.05$) by Tukey mean separation.

Table 4-4. One way analysis of variance F-values for the effect of growing location[1] on the cooking times of three cultivars of navy beans

Source of Variation	df	Cultivar Exrico F	Fleetwood F	Seafarer F
Location	2	11.38**	19.19**	13.26**
Error	9			
Total	11			

[1]Winnipeg, Brandon and Morden.
**P<0.01

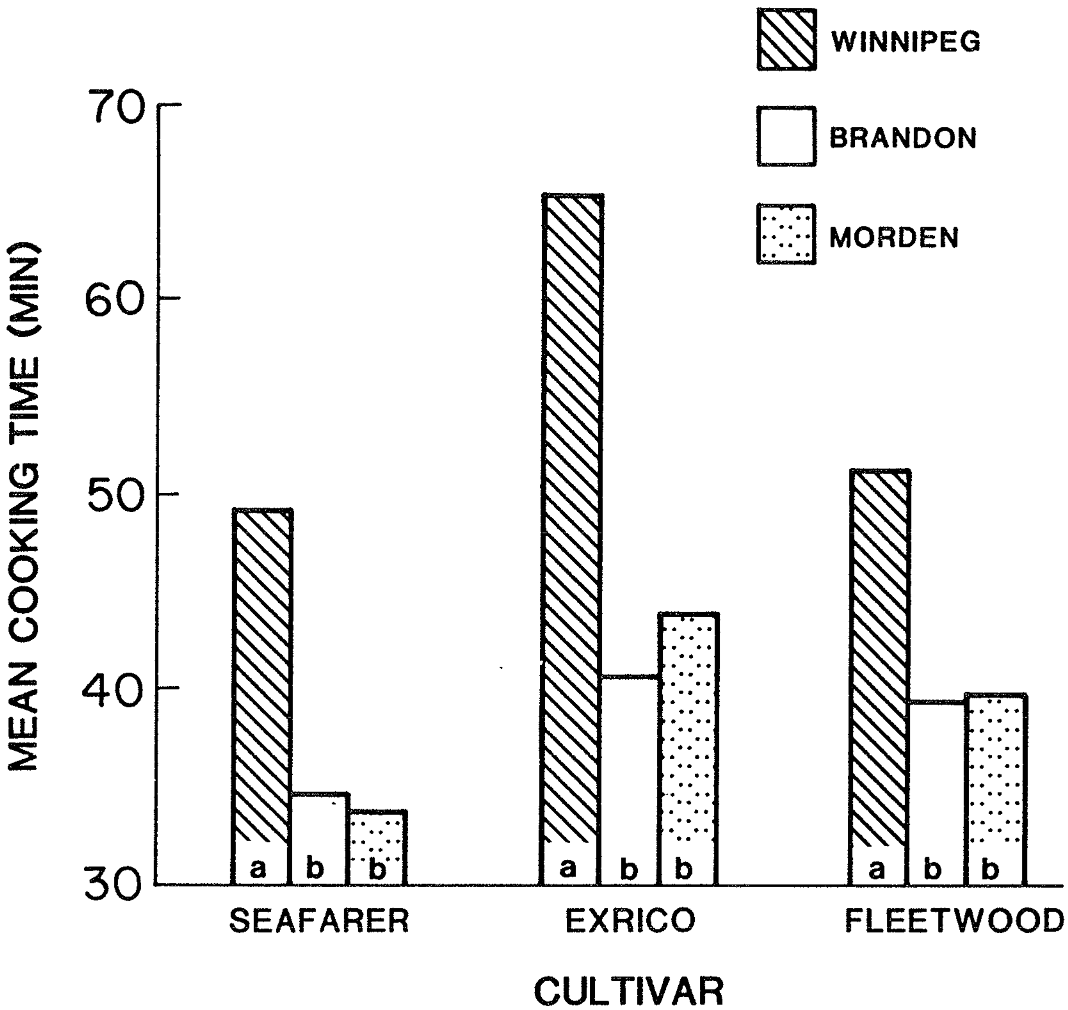


Figure 4-2. Comparison of mean cooking times of navy bean samples grown at three locations for three cultivars.

ab means for the same cultivar with the same letter are not significantly different ($P<0.05$) by Tukey mean separation.

had a significantly longer mean cooking time, 49.25 minutes, than those from either Brandon, 34.75 minutes, or Morden, 33.75 minutes. The pattern was the same for the Exrico and Fleetwood cultivars. It was concluded that there was a significant effect of growing location on cooking time. These results, therefore confirm the results of the studies of Quenzer *et al*. (1978) and Bhatty *et al*. (1983) who reported that differences in growing locations are likely to produce greater variability in cooking time than are differences between cultivars.

4.4.2 Effect of Post-Harvest Drying

A large number of factors related to growing location and harvesting condition could be responsible for the reported variation in cooking time. One factor that was isolated in this study was the effect of post-harvest drying. Because the harvest period at the Winnipeg location was very wet, the samples from this location were dried artificially in a hot air drier to reduce the moisture content, which was above 13%, to a more acceptable level (<13%), to prevent mould growth during storage. Therefore the moisture contents of the Seafarer beans grown at Winnipeg were lower than the moisture contents of the Seafarer beans grown at the other locations (Table 4-1) which were not dried under high heat. The beans from Brandon were not treated at all while samples from Morden were air dried at room temperature. An initial look at Table 4-1 would seem to indicate a slight relationship between cooking time and moisture content. However, when a sample of Seafarer beans from the Winnipeg location which was harvested approximately a week later under drier weather conditions and was not artificially dried, was compared to the artificially dried samples, mean cooking times were not significantly different between the artificially dried and field dried samples (Appendix-Table B-7), even though the field dried sample had a moisture content that was considerably higher (12.58% vs. 8.26%). Analysis of variance and Tukey mean separation tests indicated, however, that the field dried Seafarer sample from Winnipeg was significantly different ($P \leq 0.05$) from the Seafarer samples grown at Morden and Brandon (Table 4-5) as were the artificially dried Seafarer sample (Table 4-4). Therefore it was concluded that the cause of the longer cooking time for the Winnipeg grown Seafarer beans was not the drying method, but was due to growing location. Muneta (1964) and Snyder (1936) also found that moisture content at harvest did not significantly affect cookability of fresh

Table 4-5 Analysis of variance of cooking time of field dried Seafarer-Winnipeg, Seafarer-Brandon and Seafarer-Morden navy beans.

Sources of Variation	df	MS	F
Location	2	141.09	19.68**
Error	9	7.17	
Total	11		

**P<0.01

Tukey Mean Separation

Locations:	Winnipeg	Brandon	Morden
Means:	44.50 a	34.74 b	33.75 b

SE = 1.34
LSD (P<0.05) = 1.34 x 3.95 = 5.29

beans.

4.4.3 Cooking Time and Chemical Composition

Results of the proximate analysis along with mean cooking times are shown in Table 4-1. There was no evident relationship between any of the components measured and mean cooking time.

The most important conclusions to be drawn from this portion of the experiment were that moisture content did not seem to influence cooking time, and that the results of the phytic acid analysis did not support the results of the studies by Jones and Boulter (1983) or Kon and Sanshuck (1981) who found that reduction in phytate correlated with increased cooking time, and supported the work of Crean and Haisman (1963) and Rosenbaum and Baker (1969) who reported that phytate did not play a significant role in the prolonged cooking time of beans.

CHAPTER 5

THE EFFECT OF STORAGE CONDITION AND DURATION OF STORAGE ON THE COOKING TIME OF TWO CULTIVARS OF NAVY BEANS GROWN AT THREE LOCATIONS IN MANITOBA

5.1 ABSTRACT

The cookabilities of Seafarer and Fleetwood cultivars grown at Winnipeg, Brandon and Morden locations and stored for 9 months under freezer, prairie outdoor ambient (POA) and simulated semi-tropical (SST) conditions were measured at three month intervals. Cookability was measured using the MBC with 48 g, 5 mm plungers. 4 replications of 25 beans each were conducted. The Fleetwood samples had much longer cooking times (a minimum of 40 minutes longer) after freezer storage while the Seafarer samples were not significantly affected. The Fleetwood samples showed a high incidence of hardshell (12% to 32%) while the Seafarer had 0% hardshell under freezer storage. Under POA storage conditions, the Fleetwood samples had 16% to 20% hardshell and prolonged cooking time under frozen outdoor (February-3 month) conditions but were unaffected at 6 and 9 months (May,

August). Seafarer samples were unaffected by POA storage conditions. Under SST conditions, Fleetwood samples were unaffected, while the Seafarer showed a slight rise in cooking times of 12 to 15 minutes over the 9 month period. Neither cultivar showed any incidence of hardshell under SST conditions. The samples grown at the Winnipeg location had consistently longer cooing times than the samples grown at the other locations.

5.2 INTRODUCTION

New cultivars of pulses being developed in western Canada are evaluated regularly for agronomic qualities but are not systematically assessed for length of cooking time. The problem of prolonged cookability which is frequently encountered with stored navy beans and other *Phaseolus* varieties grown in western Canada, can cause loss of nutrients, increased consumption of energy and consumer rejection.

Each variety of edible dry bean has a particular cooked texture which is considered acceptable or "cooked" to consumers and the term "cookability" refers to the cooking time required to reach that texture (Moscoso, 1981). Prolonged cooking or poor cookability can occur because of two separate but sometimes related phenomena, "hardshell" and the "hard-to-cook condition." "Hardshell" is a condition in which the seed fails to imbibe within a reasonable length of time during the soaking stage (Bourne, 1967), while the hard-to-cook phenomenon is a condition in which the bean has prolonged cooking time during the cooking stage itself often after having imbibed normally (Molina et al., 1976; Burr et al., 1968).

Storage conditions play a major role in the problem of poor cookability. Both hardshell and hard-to-cook beans occur more often in stored than in fresh beans, and usually the degree of poor cookability increases with storage time. Because the effects of genetic difference, and of growing location interact with the effects of storage, and many studies have failed to specify cultivar and growing location when comparing the effects of storage conditions, conflicting conclusions have often been reported.

Burr et al., (1968) studied navy (cv. Sanilac) beans grown in the 1961 and 1963 crop years. Fresh beans were measured for cooking time, then stored at various temperatures and relative humidities (R.H.). Sanilacs with a moisture content of 14.2%

initially required 27 minutes to cook but after 11 months of storage at 32.2°C required 450 minutes, a 17 fold increase in cooking time. At lower moisture contents, but at high temperature, (32.2°C) and for all samples held at 21.1°C, loss of cookability was less dramatic. Cooking times were measured with the MBC using the 50% cooked comparison point, and also the beans were blanched before soaking, so that the extent of hardshell was masked (see chapter 6 for further discussion). Burr et al. (1968) also found that pintos and limas behaved in similar fashion. Muneta (1964) reported a study of four varieties of *Phaseolus* (pinto, great northern, michilite and small red). Each variety was grown at two locations. Storage was at room temperature for 18 months. The samples with higher moisture contents took longer to cook and Muneta (1964) also concluded that growing location had a considerable effect on the cooking time of dry beans after extended storage. It was not specified if the same cultivar of each variety was grown at both locations. Cooking time of the fresh samples was not recorded and samples were blanched before cooking so that the extent of hardshell was not reported.

Antunes and Sgarbieri (1979) studied the Rosinha G2 variety (*Phaseolus vulgaris* L.) to determine cooking time and percent hardshell under laboratory storage conditions (25°C, 65-70% R.H.), refrigerator conditions (12°C, 52% R.H.) and simulated tropical conditions (37°C, 76% R.H.). Samples were not blanched before soaking. Refrigerator storage showed no change in percent hardshell after six months. The laboratory storage sample rose from less than 5% hardshell to over 50% hardshell, while under simulated tropical conditions there was a slight rise in hardshell after 2 months which then fell to 0% after 4 months of storage. A six member expert sensory panel assessed adequate cooking time for each storage condition. Under refrigerator conditions, cooking time rose from 60 to 90 minutes, and under laboratory conditions cooking time rose from 60 to 116 minutes. For the simulated tropical conditions, cooking time rose from 60 to 300 minutes. It was not specified whether the hardshell beans were included or were discarded before testing.

Hughes and Sandsted (1975) studied the effect of storage on California light red kidney beans (<u>Phaseolus vulgaris</u> L.). Samples were stored at 1°C, 12°C and 24°C in all combinations with 30% and 80% R.H. for a period of one year. They found that storage temperature had only a slight influence on the time required to cook beans after storage for one year at 30% humidity, but that the cooking time for beans stored at 80% R.H. increased with increases in storage temperature. There was little or no difference in the cooking time for beans stored at either 30 or 80% R.H. at 1°C. Gloyer (1928a) reported that *Phaseolus* beans stored in a heated laboratory under conditions of low R.H. developed hardshell. He also reported that when the beans were removed out-of-doors where the temperature was lower and the R.H. higher, the hardshell was eliminated, indicating that the hardshell condition was reversable. Jackson and Varriano-Marston (1981) reported that the cooking time of black beans (50% cooked) was much increased by storage for one year under laboratory conditions, and that black beans stored for 55 days at 41°C and 75% R.H. did not cook after six hours of cooking. Morris and Wood (1956) reported no effect on the cooking time for limas and Sanilacs stored at -23.3° C. Morris (1964) reported no effect on the cooking time for limas and Sanilacs stored at 4.4°C for 9 months and Snyder (1936) reported no effect after storage for 15-17 months at 7.2°C.

In general the literature seems to agree that: regrigerator storage at 1°C to 4°C and over a range of R.H. has little effect on cookability; refrigerator storage from 4-12^{o}C has only a moderate effect at all humidities; Freezer storage < -10^{o}C has no effect on cookability at any R.H.; heated laboratory conditions (>20^{o}C and low R.H.) increase hardshell but not necessarily cooking time; simulated tropical conditions (>25^{o}C and >75% R.H.) increase cooking time but do not increase incidence of hardshell.

It is unfortunate that the literature does not contain any studies comparing the effects of different storage regimes on different cultivars of navy or on any other types of dry beans. Also there are no studies on the effect of prairie outdoor ambient storage conditions. Freezer storage was mentioned only by Morris and Wood (1956) who found that it had no effect.

The objectives of the study were to examine the effect of three storage conditions (freezer, prairie outdoor ambient and simulated semi-tropical) and duration of storage (3, 6 and 9 months) on the cookability of two navy bean cultivars (Seafarer and Fleetwood) grown at three locations in Manitoba (Brandon, Morden and Winnipeg). The effect of these factors on cookability, both on hardshell and on the hard-to-cook phenomenon, were assessed.

5.3 MATERIALS AND METHODS

5.3.1 Materials

Six samples of navy beans (*Phaseolus vulgaris* L.) were obtained from the 1983 Manitoba Co-operative Field Bean Trials. They consisted of two pure line (self-pollinated, one genotype) cultivars (Seafarer and Fleetwood) grown at three locations (Winnipeg, Brandon and Morden).

5.3.2 Storage Conditions

Because all of the samples were not harvested at the same date, all samples were stored under refrigerator conditions (4°C) upon arrival until the commencement of the storage study. Fifty gram samples of each cultivar from each growing location were stored for 3, 6 and 9 month periods under the following conditions: Freezer (-10°to -25°C, unknown R.H.); prairie outdoor ambient (outdoor ambient weather conditions at Winnipeg, Manitoba, from November, 1983 to August, 1984); simulated semi-tropical (20°C, 65% R.H.). The prairie outdoor ambient (POA) conditions were chosen to represent typical on-farm storage conditions on the Canadian prairies, and the simulated semi-tropical (SST) conditions were chosen as the best possible representation of storage conditions in semi-tropical third world countries, the likely recipients of exported western Canadian navy beans.

All samples were stored in kraft paper bags except those stored under freezer conditions, which were stored in sealed plastic bags to prevent freezer burn, then placed in a sealed plastic pail. POA samples were stored in ventilated plastic pails to allow equilibriation with the ambient temperature and humidity. The SST samples were stored under controlled conditions on an open shelf to allow equilibriation with the controlled atmosphere of the storage room.

5.3.3 Measurement of Hardshell

Fifty gram samples were placed in a 250 ml beaker containing 150 ml distilled water and soaked for 12-16 hours at 20°C (room temperature). At the end of the soaking period, the number of unimbibed beans (hardshell beans) was counted and recorded as percent of sample.

5.3.4 Measurement of Cooking Time

Cooking time was measured using the Mattson Bean Cooker (MBC) procedure described in Chapter 3. The plunger type used weighed 48 g, with a 5 mm diameter flat face. Four replications of 25 beans each (100 beans in total) were tested for each sample. Cooking time was determined by averaging the time required to reach the 92% cooked point for the four replications of the test. Samples were cooked to a maximum of ninety minutes.

Cooking time was measured upon receipt of the samples, at the start of the storage period (0 month) and after three, six and nine months of storage.

5.3.5 Statistical Analysis

The experiment was designed as a 2x3x3x4 factorial with censored data (2 cultivars x 3 growing locations x 3 storage methods x 4 storage times). Data was considered censored because cooking continued to a maximum of 90 minutes.

Factorial analysis of variance was conducted to detect differences in cooking times due to cultivar, location, storage method and storage time. Factorial analysis of variance was also conducted to detect significant differences in cooking times due to location, storage method and storage time for each cultivar separately.

One way analysis of variance (with Tukey mean separation) was conducted to detect significant differences in cooking time due to location at each separate storage time. One way analysis of variance (with Tukey mean separation) was also conducted to detect differences in cooking time due to storage time for each location separately.

Mean cooking times of freshly harvested samples and samples at the start of the storage study (0 month) were compared for significant difference by t- test.

5.4 RESULTS AND DISCUSSION

5.4.1 Effect of Refrigerator Storage

Mean cooking times and standard deviations are shown for each cultivar at each growing location when the samples were freshly harvested, and also at the start of the storage study (0 month),in Table 5-1. Although comparison by t-test did not indicate a significant difference between the freshly harvested and 0 month samples at any location, cooking times for the Fleetwood samples increased more than did cooking times for the Seafarer samples. Fleetwood samples from Brandon and Morden increased in cooking times from 39.50 to 48.25 minutes and from 39.75 to 47 minutes respectively. This is an indication that the two cultivars may react differently to refrigerator storage. A larger sample size or longer storage time might have resulted in significantly longer cooking times. Although these results do not contradict, neither do they confirm reports in the literature that refrigerator storage does not affect cooking time (Snyder, 1936; Hughes and Sandsted, 1975).

5.4.2 Storage Study

The initial factorial analysis of variance indicated a highly significant effect of cultivar,

Table 5-1 Mean cooking times of navy beans at time of harvest and at start of storage study (0 month)

		Fresh[1]		0 Month[2]	
Cultivar	Location	Mean	SD	Mean	SD
Seafarer	Winnipeg	49.25a	7.09	46.00a	1.41
Seafarer	Brandon	34.75a	2.87	38.75a	4.57
Seafarer	Morden	33.75a	3.10	36.50a	4.65
Fleetwood	Winnipeg	51.25a	1.71	52.00a	15.35
Fleetwood	Brandon	39.50a	4.51	48.25a	4.50
Fleetwood	Morden	39.75a	2.22	47.00a	7.70

[1]Tested on following dates:
Seafarer Winnipeg - Sept 21/83
Seafarer Brandon - Sept 13/83
Seafarer Morden - Oct. 3/83
Fleetwood Winnipeg - Sept 23/83
Fleetwood Brandon - Sept 14/83
Fleetwood Morden - Oct 5/83

[2]Tested on following dates:
Seafarer - all samples - Nov 18/83
Fleetwood - all samples - Nov 21/83

a means in row followed by the same letter are not significantly different ($P<0.05$) by Student's t-test.

storage method, storage time and location (Table 5-2). The highly significant interaction between cultivar and storage method, cultivar and storage time as well as between cultivar and location indicated that it was necessary to conduct analysis of variance to detect differences in cooking time due to storage method, storage time and location for each cultivar separately. F values and levels of significance for both cultivars are shown in Table 5-3.

Mean cooking times and percent hardshell under each storage condition are shown separately in Tables 5-4, 5-5 and 5-6. Mean cooking times and standard deviations are presented for both cultivars under each storage condition separately in Figures, 5-1, 5-2 and 5-3. These tables and figures clearly indicate that there was a different effect on the two cultivars of each storage condition.

5.4.2.1 <u>Effect of freezer storage</u>

Mean cooking times and percent hardshell of the two cultivars under freezer storage conditions are given Table 5-4. Cooking times of the Seafarer samples were largely unaffected by freezer storage. Only one sample, the Winnipeg-6 month sample had a significantly longer cooking time ($P<0.05$) than the 0 month sample. This result seems anomalous and

Table 5-2. Factorial analysis of variance F-values for the effect of cultivar, storage method, storage time and location on cooking times of stored Seafarer and Fleetwood navy beans

Source of Variation	df	F
Cultivar	1	628.38***
Storage Method	2	89.94***
Storage Time	3	67.74***
Location	2	58.58***
C x SM	2	138.21***
C x ST	3	46.37***
C x L	2	7.84***
SM x ST	6	31.63***
SM x L	4	0.91
ST x L	6	2.27*
C x SM x ST	6	38.08***
C x SM x L	4	2.77*
C x L x ST	6	1.75
SM x ST x L	12	1.14
C x SM x ST x L	12	2.15*

***P<0.001.
**P<0.01.
*P<0.05.

Table 5-3. Factorial analysis of variance F-values for the effects of storage method, storage time and location on cooking times of Seafarer and Fleetwood navy beans

Source of Variation	df	Seafarer F	Fleetwood F
Storage Method	2	5.93**	156.12***
Storage Time	3	21.16***	71.06***
Location	2	93.51***	10.04***
SM x ST	6	2.76*	47.34***
SM x L	4	1.76	1.86
ST x L	6	3.83**	1.31
SM x ST x L	12	3.18***	1.05

***P<0.001
**P<0.01
*P<0.05

Table 5-4 Effect of freezer storage on mean cooking times and percent hardshell of Seafarer and Fleetwood navy beans

		Mean Cooking Time (min)			
Cultivar	Location	0 Month	3 Month	6 Month	9 Month
Seafarer	Winnipeg	46.00a	49.50a	68.00b	46.00a
Seafarer	Brandon	38.75a	34.75a	41.00a	41.75a
Seafarer	Morden	36.50a	35.25a	38.75a	40.75a
Fleetwood	Winnipeg	52.00a	90.00b	84.75b	90.00b
Fleetwood	Brandon	48.25a	80.50b	86.75b	90.00b
Fleetwood	Morden	47.00a	90.00b	90.00b	90.00b

		Percent Hardshell			
Cultivar	Location	0 Month	3 Month	6 Month	9 Month
Seafarer	Winnipeg	0	0	0	0
Seafarer	Brandon	0	0	0	0
Seafarer	Morden	0	0	0	0
Fleetwood	Winnipeg	0	20	12	20
Fleetwood	Brandon	0	20	28	28
Fleetwood	Morden	0	17	18	32

ab means in row with the same letter are not significantly different ($P>0.05$) by Tukey mean separation.

Table 5-5 Effect of prairie outdoor ambient storage on mean cooking times and percent hardshell of Seafarer and Fleetwood navy beans

		Mean Cooking Time (min)			
Cultivar	Location	0 Month	3 Month	6 Month	9 Month
Seafarer	Winnipeg	46.00a	51.50a	51.75a	50.25a
Seafarer	Brandon	38.75ab	36.00a	46.25b	44.25ab
Seafarer	Morden	36.50a	36.25a	42.75a	43.50a
Fleetwood	Winnipeg	52.00a	90.00b	55.75a	54.75a
Fleetwood	Brandon	48.25a	90.00b	50.75a	46.75a
Fleetwood	Morden	47.00a	90.00b	50.00a	43.00a

		Percent Hardshell			
Cultivar	Location	0 Month	3 Month	6 Month	9 Month
Seafarer	Winnipeg	0	0	0	0
Seafarer	Brandon	0	1	0	0
Seafarer	Morden	0	0	0	0
Fleetwood	Winnipeg	0	16	1	0
Fleetwood	Brandon	0	16	1	0
Fleetwood	Morden	0	20	4	0

ab means in row with the same letter are not significantly different ($P<0.05$) by Tukey mean separation.

Table 5-6 Effect of simulated semi-tropical storage on mean cooking times and percent hardshell of Seafarer and Fleetwood navy beans

		Mean Cooking Time (min)			
Cultivar	Location	0 Month	3 Month	6 Month	9 Month
Seafarer	Winnipeg	46.00a	54.75ab	53.75ab	61.00b
Seafarer	Brandon	38.75ab	38.50a	49.00b	46.25ab
Seafarer	Morden	36.50a	44.00a	42.00a	47.25a
Fleetwood	Winnipeg	52.00a	57.25a	57.75a	60.25a
Fleetwood	Brandon	48.25a	44.00a	45.00a	46.50a
Fleetwood	Morden	47.00a	50.75a	52.50a	49.75a

		Percent Hardshell			
Cultivar	Location	0 Month	3 Month	6 Month	9 Month
Seafarer	Winnipeg	0	0	0	0
Seafarer	Brandon	0	0	0	0
Seafarer	Morden	0	0	0	0
Fleetwood	Winnipeg	0	0	0	0
Fleetwood	Brandon	0	0	0	0
Fleetwood	Morden	0	0	0	0

ab means in row with the same letter are not significantly different ($P<0.05$) by Tukey mean separation.

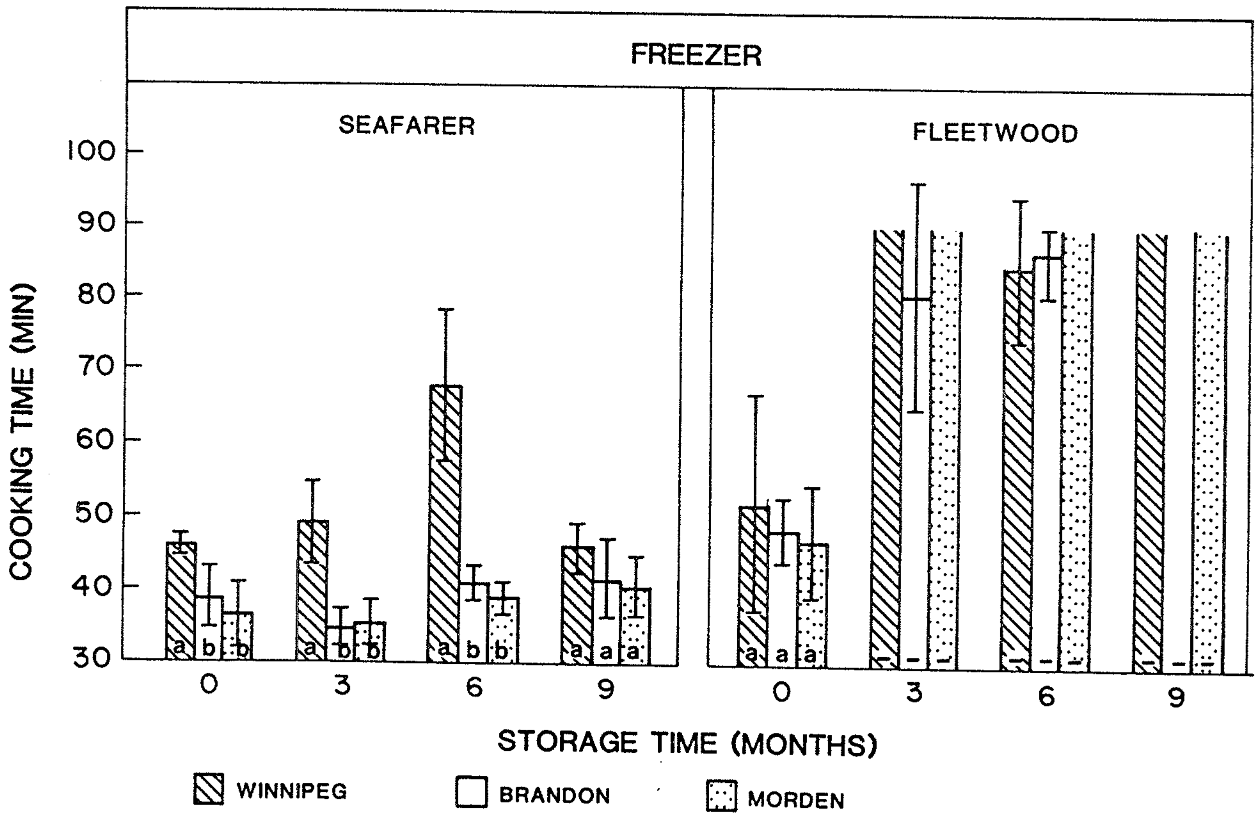


Figure 5-1. Mean cooking times and standard deviations of two navy bean cultivars grown at three locations, stored under freezer[1] storage conditions.

ab means within a storage time designated by the same letter are not significantly different (P<0.05) by Tukey mean separation.

[1]-10°C to -25°C; unknown R.H.

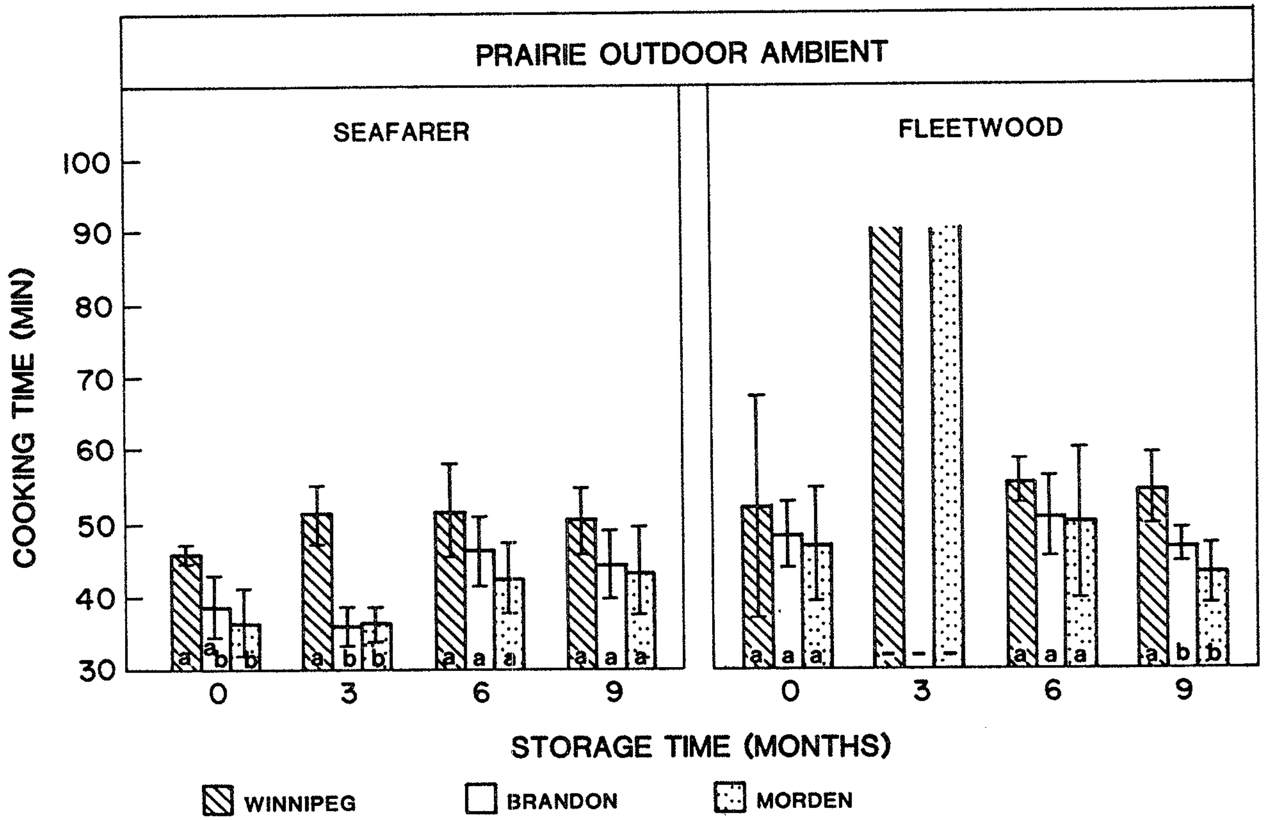


Figure 5-2. Mean cooking times and standard deviations of two navy bean cultivars, grown at three locations, stored under prairie outdoor ambient[1] storage conditions

ab means within a storage time designated with the same letter are not significantly different ($P<0.05$) by Tukey mean separation.

[1]ambient outdoor weather conditions at Winnipeg Manitoba

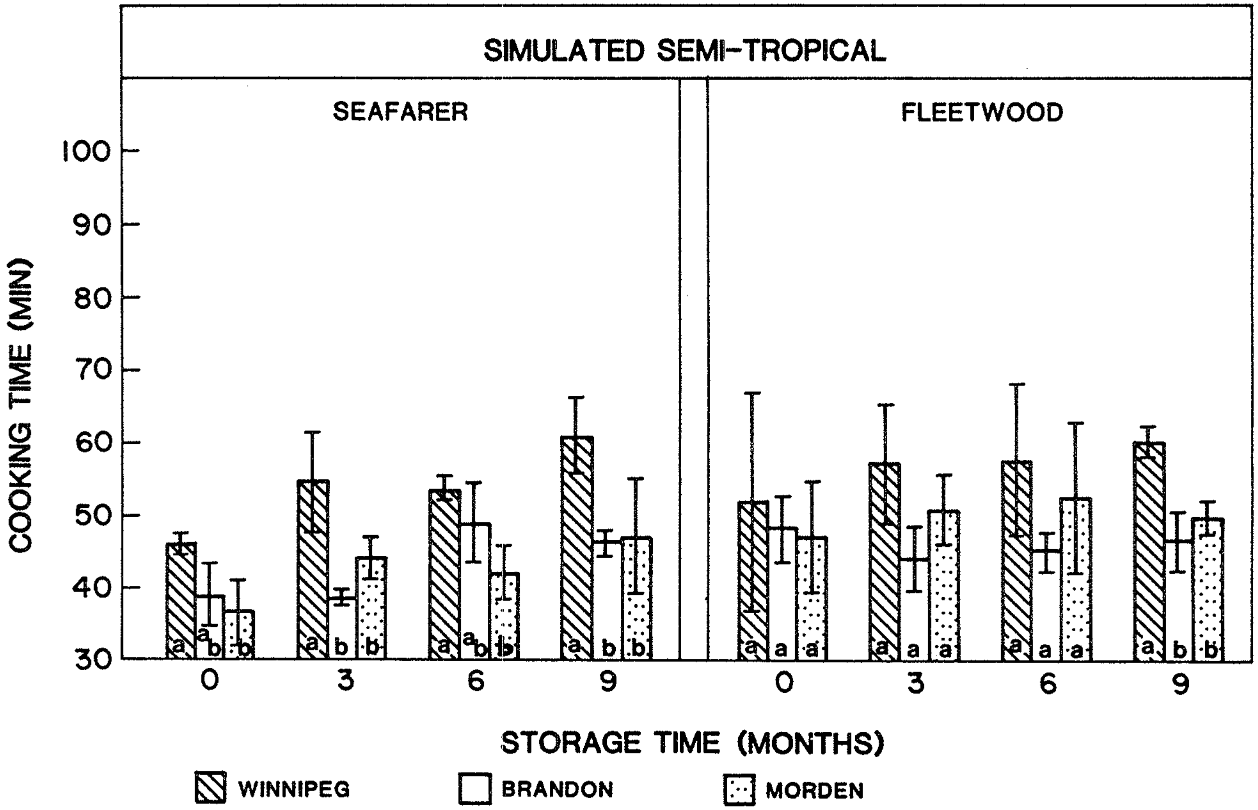


Figure 5-3. Mean cooking times and standard deviations of two navy bean cultivars grown at three locations and stored under simulated semi-tropical[1] storage conditions

ab means within a storage time designated by the same letter are not significantly different ($P<0.05$) by Tukey mean separation.
[1]20°C, 65% R.H.

cannot be explained, particularily since the 9 month sample was not significantly different from the 0 month sample. This anomalous cooking time is also the cause of the interaction between the effect of storage time and location (as well as the interaction between storage method storage time and location) shown in Table 5-3. The Fleetwood samples, however, showed a significant effect of freezer storage, with cooking times rising at least 32 and up to 53 minutes from the cooking time at 0 month. All samples stored for 3, 6 and 9 months were significantly different from their respective 0 month samples (Figure 5-1). The two cultivars showed a different effect of freezer storage on percent hardshell as well. The Seafarer samples had no hardshell for any sample whereas the freezer stored Fleetwood samples ranged from 12 to 32% hardshell.

These results do not confirm the results of Morris and Wood (1956) who reported that freezing does not affect cooking time. It should be noted however, that Morris and Wood blanched the samples before soaking to eliminate hardshell. Since the prolonged cooking times found in this study were associated with hardshell, comparison of the two studies may not be possible. This shows how blanching can mask the effect of hardshell on cooking time (this aspect of cookability is discussed further in Chapter 6).

5.4.2.2 Effect of prairie outdoor ambient storage

Mean cooking times and percent hardshell of the two cultivars under POA storage conditions are given in Table 5-5. Again the different reaction of the two cultivars to the same storage conditions is evident (Figure 5-2). In terms of cooking time the Seafarer samples were almost unaffected, except for the Brandon sample which showed a significant difference in cooking time between the 3 month and 6 month samples. It is important to note however, that neither of these samples differed from the 0 month sample. The Fleetwood samples however showed a dramatic and significant increase in cooking time after 3 months of storage which coincided with the cold winter month of February. Cooking times increased from between 47 to 52 minutes to a minumum of 90 minutes for all three locations. These samples thus behaved in a similar fashion to the Fleetwood-freezer samples. As warmer weather returned from May to August (6 and 9 months respectively) cooking times returned to levels not significantly different from 0 month.

In terms of hardshell, the Seafarer samples were unaffected by POA storage conditions, while the Fleetwood samples had 16 to 20% at 3 months and 1 to 4% at 6 months. Thus as in the case of the Fleetwood-freezer samples, prolonged cooking time was associated with raised levels of hardshell.

Because there are no reports in the literature concerning the effect of POA storage on cooking time of any edible dry beans it is not possible to comment on this aspect of the experiment in relation to past experiments. The difference in the effect of the POA conditions on the percent hardshell confirms the reports of Gloyer (1928b) and Lebedeff (1943) that hardshell is an inherited genetic condition influenced by storage condition. Also the ability of the Fleetwood samples to recover from 16 to 20% hardshell after storage under warmer conditions for several months, supports Gloyer's report (1928a) that changing storage conditions (in that case from warm-dry conditions to cool-moist conditions) could eliminate hardshell in *Phaseolus vulgaris* L. beans.

5.4.2.3 *Effect of simulated semi-tropical storage*

Mean cooking times and percent hardshell of the two cultivars under SST conditions are shown in

Table 5-6. The differing effect of storage condition is again illustrated, but in this case it was the Fleetwood samples that were unchanged while the Seafarer samples showed a slight increase in cooking time (Figure 5-3). The Seafarer samples showed an increase in cooking time from 46 to 61, 38.75 to 46.5 and 36.5 to 47.25 minutes at Winnipeg, Brandon and Morden respectively. From 0 month to 9 month, increases in cooking time were significant ($P<0.05$) at the Winnipeg and Brandon locations. There was no incidence of hardshell for either cultivar.

The SST conditions used in this study were not as high in temperature or relative humidity as those reported in the literature for tropical storage, but there was an indication that the Seafarer samples behaved similarily to the *Phaseolus* beans as reported by Hughes and Sansted, (1975); Burr *et al*., (1968) and Morris, (1964). There are no reports concerning any cultivars or varieties that did not increase in cooking time under tropical storage as was the case with the Fleetwood samples. This may have been a result of the lower temperature and R.H. and shorter storage time used in this study.

The lack of hardshell occurring in this portion of the study confirms the report of Antunes and

Sgarbieri (1979) that high temperature and high humidity does not induce hardshell.

5.4.2.4 Effect of location

Figures 5-1, 5-2 and 5-3 show the effect of growing location on cooking time. Cooking times of the samples grown at the Winnipeg location were consistantly longer than those grown at Brandon and Morden, which were not significantly different ($P<0.05$) from each other at any storage time. The Winnipeg samples had significantly longer cooking times ($P<0.05$) at six of the ten storage times for the Seafarer samples and at two of the ten for the Fleetwood samples (significant difference could not be calculated for four of the Fleetwood storage times because the data was censored).

These results are consistent with the results reported previously (Chapter 4), that freshly harvested navy beans had significantly longer cooking times at the Winnipeg location. These results also support the studies by Quenzer et al. (1978) and Bhatty et al. (1983), working with pinto beans and lentils respectively who reported that differences in growing location produced differences in cooking time.

5.4.3 Limitations to Research

There were two limitations to the research. One was the censoring of the data by limiting cooking to a maximum of 90 minutes. This resulted in the inability to assess the effect of location for several storage times but was justified as a time saving device. It was decided that a maximum cooking time of 90 minutes was significantly longer than any of the 0 month cooking times and thus provided adequate measurement of change in cooking time from the start of the storage study.

The second limitation was an infestation of the grain beetle *Bruchus rufimanus* which occurred in the Winnipeg SST samples during the fourth month of storage. This resulted in the loss of one replication of the MBC cooking test (Seafarer-Winnipeg). The infestation was eliminated by freezing of all the SST samples at -10°to -25°C for 48 hours. It is not known if this treatment had any effect on the overall results for the SST smaples but no effect is suspected as the treatment was of such short duration and no differect in cooking times or percent hardshell was noticed for the 6 and 9 month samples which showed the same general pattern as the 3 month samples.

CHAPTER 6

THE EFFECT OF BLANCHING ON THE COOKING TIME OF THE HARDSHELL AND NON-HARDSHELL FRACTIONS OF NAVY BEANS AFTER FROZEN STORAGE

6.1 ABSTRACT

Samples of Fleetwood navy beans grown at three locations were stored under freezer conditions for a period of nine months. The cookabilities of the hardshell and non-hardshell fractions in blanched and unblanched samples were assessed and compared. Standard Mattson bean cooker procedures were used to assess cookability. Blanching reduced incidence of hardshell from as high as 32% to 0%, and reduced the cooking time of the hardshell fraction in all three samples. The cooking time of the non-hardshell fraction was prolonged between 5 to 25 minutes.

6.2 INTRODUCTION

The problem of "hardshell" or the failure of the seed to imbibe water within a reasonable length of time during the soaking stage (Bourne, 1967), occurs frequently in stored edible dry beans. The hardshell condition usually does not occur in all of the individual beans in a sample but usually affects only a portion of the beans. The individual beans in this hardshell fraction usually have prolonged cooking times compared to the non-hardshell fraction and as a result this greatly increases the within-sample variability of cooking time. Morris et al. (1950) suggested that cooking soaked samples that contain some hardshell beans until the latter are palatable may require such a long cooking time that the non-hardshell beans disintegrate.

It has been reported that "blanching", bringing the beans to a boil briefly prior to soaking, can eliminate the hardshell condition and the prolonged cooking time associated with it (Jackson and Varriano-Martson, 1981; Bourne, 1967; Muneta, 1964; Morris et al., 1950). Although it is accepted that blanching is effective in the treatment of hardshell and can shorten the cooking time of the hardshell fraction there are no reports in the literature on the effect of blanching on the cooking time of the non-hardshell fraction. Dawson et al. (1952) reported that blanched beans took 15-30 minutes longer to cook than comparable bean samples soaked for 18 hours in cold water. This has led to speculation that blanching may affect the non-hardshell portion as well as the hardshell fraction. The investigation of this possibility was the objective of this experiment.

The MBC testing procedure as described in Chapter 3 provides a method by which the cooking time of individual beans as well as the cooking time of the whole sample can be measured. Thus the MBC provided a method of measuring and comparing the cooking times of the hardshell and non-hardshell fractions.

The occurrence of levels of hardshell of up to 32% in samples of navy beans (*Phaseolus vulgaris* L. cv. Fleetwood) after nine months of storage in freezer conditions provided an opportunity to assess the effect of blanching on both the hardshell and non-hardshell fractions in samples of beans that exhibit hardshell.

6.3 MATERIALS AND METHODS

Three samples of navy beans (*Phaseolus vulgaris* L. cv. Fleetwood) were obtained from the 1983 Manitoba Co-Operative Field Bean Trials. The samples were grown at Winnipeg, Morden and Brandon. Samples were stored in a refrigerator (4°C.) until placed in frozen storage. The samples were placed in polyethylene freezer bags, the bags were sealed and placed in a freezer (-10° to -25°C) for nine months. Cooking time and incidence of hardshell was measured at the start of storage (0 month).

After nine months of storage, one half of each sample (120-150 beans) was soaked overnight using the usual cold-soak method, soaking for 12-16 hours in distilled water at room temperature (20°C). The other half of the sample was placed in a small beaker with 200 ml of distilled water, briefly brought to a boil (3-5 seconds), then removed from heat and allowed to soak in the same water for 12-16 hours.

Incidence of hardshell was measured by counting the unimbibed seeds at the end of the soaking stage and calculating the percent hardshell for the sample.

Cooking time was measured using the MBC procedure described in Chapter 3 and comparative cooking times for each sample were calculated as the mean time to reach 92% cooked for the four replications conducted. Cookability curves were plotted for each sample.

To identify the hardshell fraction during the cooking stage the unimbibed beans were placed on a separate identified section of the MBC bottom rack. Samples were cooked to a maximum of 90 minutes.

6.4 RESULTS AND DISCUSSION

Table 6-1 shows the incidence of hardshell and the cooking times of the samples at the start of storage and after nine months of storage. The hot-soak treatment was evidently effective in eliminating hardshell. It was also effective in reducing the sample cooking time for the Brandon and the Morden stored samples. For the unblanched Brandon and Morden samples, the 92% cooked point was not reached after 90 minutes of cooking. In the case of the blanched Brandon and Morden samples the 92% cooked point was reached. In the case of the Winnipeg blanched sample it was hypothesized that the 92% cooked point would have been reached with approximately another 20 minutes of cooking whereas the unblanched Winnipeg sample would have required a much longer cooking time to reach the 92% cooked point.

Figure 6-1 clearly indicates how blanching affects the hardshell and non-hardshell fractions of these samples. In all three cases the stored bean samples had considerably longer cooking times (cooking time to reach 92% cooked) than the freshly harvested beans. For the Brandon and Morden samples, the hardshell fraction of the blanched treated beans cooked much more quickly than the

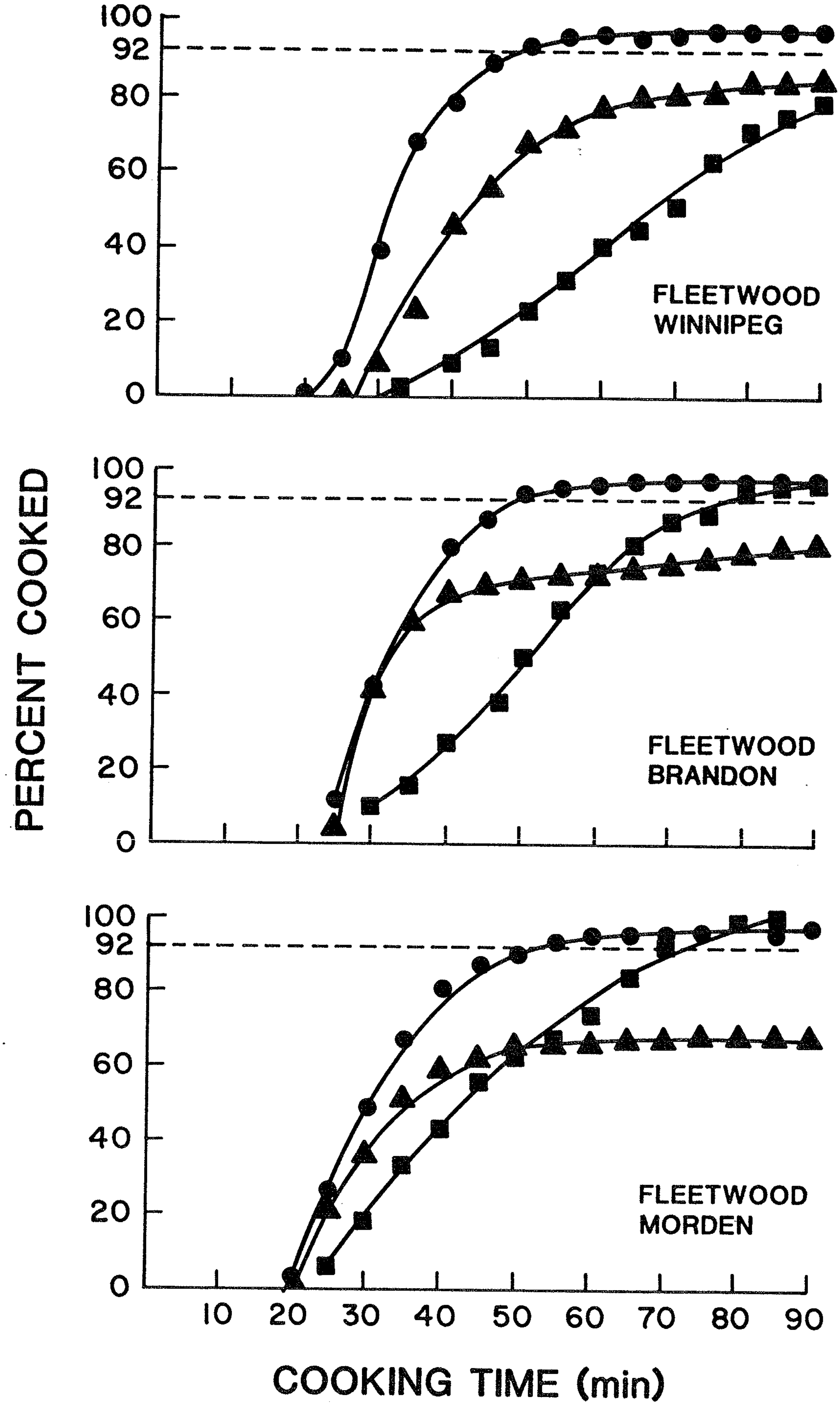
Table 6-1. Incidence of hardshell and sample cooking times[1] for Fleetwood navy beans at start of storage and after two soaking treatments following nine months of freezer storage

Sample Growing Location	0 month cold soak		9 month cold soak		9 month blanched	
	hard-shell %	cook time (min)	hard-shell %	cook time (min)	hard-shell %	cook time (min)
Winnipeg	0	52.00	20	>90	0	>90
Brandon	0	48.25	28	>90	0	71.75
Morden	0	47.00	32	>90	0	69.75

[1]time to 92% cooked.

Figure 6-1. Cookability curves for blanched and unblanched Fleetwood navy bean samples grown at three locations.

○ - 0 month
■ - blanched-9 month-freezer
▲ - unblanced-9 month-freezer


PERCENT COOKED
100
92
80
60
40
20
0
FLEETWOOD
WINNIPEG
FLEETWOOD
BRANDON
FLEETWOOD
MORDEN
10
20
30
40
50
60
70
80
90
COOKING TIME (min)

hardshell fraction in the cold-soak samples (this is assuming that the hardshell fraction had the same size for both the cold-soaked and the blanched samples). Because the hardshell fraction was placed on marked sections of the MBC the prolonged cooking time of these beans was easily noticed during cooking as the beans in the marked section required considerably longer cooking times. This is also evident when the slope of the cookability curve of the stored cold-soaked samples is examined. The slope of the curve is similar to that of the fresh cold-soaked sample until the entire non-hardshell fraction is cooked, at which point the slope is reduced to almost zero because the hardshell fraction does not cook. It was also interesting that some of the beans in the hardshell fraction did reach the cooked point as evidenced by the slight rise in the cookability curve as cooking time progressed.

The figures also show that the blanching treatment affects the non-hardshell fraction as well as the hardshell fraction. For all three locations, the non-hardshell fraction required longer cooking times after blanching. This is shown in Figure 6-1 as evidenced by the shift to the right of the cookability curves. The effect was more pronounced in the Winnipeg and Brandon samples than in the Morden samples.

The results of this experiment could have some serious implications regarding the traditional use of the MBC to measure cooking time of *Phaseolus* beans. This is of course assuming that other varieties of Phaseolus behave similarily to the Fleetwood navy beans used in this study and also that the hardshell induced by freezing is similar to the hardshell induced by other forms of storage such as under conditions of high temperature and low humidity. Several researchers have used the blanching method to eliminate hardshell before measuring cooking time (Jackson and Varriano-Marston, 1981; Burr *et al*., 1968; Morris, 1964). If the beans being tested in those experiments behaved as the navy beans in this experiment, then the earlier results would not be representative of cooking times for unblanched beans. One cannot assume that the same samples would have similar cooking times if they had not been blanched.

The problem of blanching and the problem of using the 50% cooked point as the comparison point (discussed in Chapter 3) point out the need for more research into the effects of different practices and techniques used when assessing the cookability of beans.

CHAPTER 7

GENERAL DISCUSSION

7.1 THE MBC TESTING METHOD

The results of the experiment described in Chapter 3 indicated that the plunger types described in the literature did not reproduce sensory results when measuring the cooking time of navy beans, but that modified 48 g, 5 mm plunger did reproduce sensory panel results. The study also showed that the 50% cooked method of comparing cooking times was not adequate and that the 92% cooked method reproduced sensory assessment of preference of "cooked texture". It was concluded that the determination of sample cooking time by averaging the time required to reach the 92% cooked point for the four replications of the test provided the best method of comparing the cooking time of different navy bean samples because the within-sample variability could be expressed and the samples statistically compared. The comparing of the cookability curves of bean samples as described in the literature does not enable the within sample variability of the samples to be compared statistically.

It was recognized that the 9 member sensory panel was not a consumer panel and as a result these results might not represent the assessment of Manitoba consumers. The use of the nine member panel does give some indication of consumer assessment and does represent a great improvement over methods reported in the literature which did not use sensory methods at all.

The MBC does provide a portable easy-to-use method that can be used by plant breeders and marketers to measure the cooking time of navy beans.

7.2 EFFECT OF BLANCHING ON THE MEASUREMENT OF COOKING TIME

The results of the experiment described in Chapter 6 indicated that blanching prior to soaking can affect the measurement of cooking time by prolonging the cooking time of the non-hardshell fraction. This confirmed the report of Dawson *et al*. (1952) who reported on this phenomenon. If the prolonging of cooking time of the non-hardshell fraction occurs regularily (not just in the Fleetwood samples used here and with hardshell caused by other forms of storage) the results of studies which used the blanching technique are cast into doubt, particulararily those that used the 50% cooked point comparison method (Jackson and Varriano-Marston, 1981; Burr *et al*. 1968; Morris, 1964).

7.3 EFFECT OF LOCATION ON COOKABILITY

The results of the experiments reported in Chapters 4 and 5 indicated that location has a significant effect on the cooking time of the cultivars of navy beans studied. The cooking time of the freshly harvested samples was significantly longer at the Winnipeg location for all three cultivars tested. These results confirmed the reports of Bhatty *et al*. (1983) and Quenzer *et al*. (1978), who reported that growing location had a significant effect on the cooking time of lentils and pinto beans respectively. The significant effect of location was also evident with the stored beans, with the samples from the Winnipeg location having consistantly longer cooking times for both cultivars. Storage condition did not seem to affect the cooking times of samples from the different locations differently, indicating no interaction between the two factors.

Hardshell was not observed in the freshly harvested beans and growing location did not seem to affect incidence of hardshell.

7.4 EFFECT OF CULTIVAR ON COOKABILITY

Cultivar had a greater effect on the cookability of stored than on the cookability of freshly harvested beans. This was the case for both aspects of cookability, cooking time and hardshell. The two cultivars tested reacted very differently to the three storage conditions. The results of the thesis generally support the reports in the literature that storage condition has a significant interaction with cultivar,and that genetic differences influence the incidence of hardshell,(Gloyer, 1928a; Lebedeff, 1943). Because there are no reports in the literature comparing cultivars of the same variety, grown at the same location no comparison with results in the literature can be made regarding cooking time.

7.5 EFFECT OF STORAGE CONDITION ON COOKABILITY

7.5.1 Freezer Conditions

Freezer storage conditions had no significant effect on the Seafarer samples but the Fleetwood samples were highly affected both in terms of hardshell and cooking time. Incidence of hardshell increased from 0% to between 12% and 32%. Cooking time increased between 32 to 53 minutes (or more in the case of the censored data.) All samples of Fleetwood beans had significantly longer ($P<0.05$) cooking times after 3, 6 and 9 months of storage than at the start of the storage study (0 month).

These results therefore did not confirm the results of Morris and Wood (1956),(working with limas and Sanilacs), who reported no effect of freezing on cooking time. However because they used the blanching technique prior to soaking it may not be possible to compare the results of the present study with those of the previous studies.

7.5.2 Prairie Outdoor Ambient Storage Conditions

The Seafarer samples were largely unaffected by POA storage, whereas the Fleetwood samples were. During the cold winter storage period (3 month), cooking times for the samples from the three locations increased from between 47 to 52 minutes to a minumum of 90 minutes. These samples thus behaved very similarily to the Fleetwood samples stored inthe freezer. Incidence of hardshell was similar for the POA samples with a high incidence for the Fleetwood 3 month samples.

The ability of the Fleetwood samples to recover from a high incidence of hardshell and prolonged cooking time, after storage in warmer weather, supports the report of Gloyer (1928a) who found that Phaseolus beans could recover from hardshell induced by hot dry storage, when stored under cool moist conditions. It is not known if the hardshell induce by freezing is the same as hardshell induced by hot, dry conditions.

7.5.3 Simulated Semi-tropical Storage Conditions

The two cultivars also reacted differently to the SST storage condition, with the Fleetwood samples being unchanged, while the Seafarers showed a slight rise in cooking time. There was no incidence of hardshell for either cultivar. The lower temperature and R.H. used than were used in studies reported in the literature may be the reason why changes in cooking time were not as pronouced as those in the literature (Hughes and Sandsted, 1975; Burr *et al.*, 1968; Morris, 1964). There are no reports of studies comparing the effect of tropical storage on cooking times of different cultivars of any edible dry beans.

7.6 GENERAL CONCLUSIONS

Bearing in mind the discussion above and the fact that samples from only one year were studied in this thesis, the following conclusions can be drawn. The samples from the Winnipeg location had generally longer cooking times. Fleetwood samples may show less increase in cooking time when stored under tropical conditions than would Seafarer beans. Fleetwood beans should not be cooked shortly after being removed from freezer conditions.

Blanching should not be routinely carried out on bean samples prior to testing for cookability. Post-harvest drying did not affect cooking time significantly. The modified MBC procedure provided a relatively simple easy-to-use method for measuring and comparing the cooking time of navy beans.

CHAPTER 8

GENERAL RECOMMENDATIONS FOR FURTHER RESEARCH

8.1 MBC PROCEDURE IMPROVEMENTS

An MBC with 50 or 100 plungers, with an electronic, automatic device to record movement of plungers penetrating the seeds, (as described by Chhinnan, 1985), would provide a more efficient method of evaluating large numbers of seeds. This would enable the testing of large numbers of seeds without the uniterrupted attention of the operator and would greatly facilitate further investigation into the problems of poor cookability of edible dry beans.

The same type of sensory panel evaluation described in this thesis could be applied to the further modification of MBC testing procedures to measure the cooking time of other varieties of *Phaseolus vulgaris* L. beans and perhaps of other species of edible dry beans.

Further research should be conducted with the MBC procedure to determine if other types of edible dry beans besides the Fleetwood beans studied in this experiment are affected similarily by blanching prior to soaking. If the prolonging of cooking time in the non-hardshell fraction occurs commonly in other types of edible dry beans after blanching, there may be serious implications regarding the use of blanching as a regular procedure in the evaluation of cooking time.

8.2 FURTHER RESEARCH REGARDING THE FACTORS WHICH EFFECT COOKABILITY

Because the MBC procedures modified as described in this study provide an efficient method of determining cooking time, they should facilitate further research into the factors which effect cookability. Some of the areas that should be investigated are as follows.

Research should be conducted to determine whether there is a method of storage that does not affect cooking time. This would enable the storage of beans for future study and would be of great benefit to researchers. The effect of genetic variation could be studied by assessing other cultivars, varieties and species of edible dry beans. Further investigation could be conducted into the effect of location by isolation of some of the great number of factors related to growing location. The effect of environmental conditions could also be studied by studying the effect of crop year on cookability.

Futher experimentation into the effects of storage should be conducted by assessing the effect of longer storage times. Also storage conditions that can be expected in third world countries could be much more accurately simulated. The effect of storage on other types of edible dry beans could be assessed to enable the identification of the genetic and other factors which interact with storage conditions to affect cookability.

Further research is also required on the relationship of chemical composition to changes that occur during storage. The relationships between minerals (magnesium, calcium), phytate, fat, polyphenols, pectins and lignin, all of which are thought to play a role in the cookability of edible dry beans, and storage changes should be investigated. Because samples of beans can easily be assessed for cookability by the MBC procedure, large numbers of samples can be assessed and cooking time related to chemical composition.

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Table A-1. Chi squared table for three samples of navy beans tested by 9 member sensory panel.

Sample	Cooking Time (min)	Chi Squared Value	Minimum Expected Value	Probability
SB[1]	10	25.00	1.00	0.0000
SB	20	38.39	1.47	0.0013
SB	30	9.52	11.28	0.8906
SB	40	0.56	18.60	1.0000
SB	50	0.47	18.16	1.0000
SB	60	0.03	19.30	1.0000
SW[2]	20	23.49	0.51	0.1014
SW	30	36.21	4.13	0.0027
SW	40	7.18	12.65	0.9696
SW	50	0.49	18.49	1.0000
SW	60	0.15	18.86	1.0000
SW	70	0.09	19.56	1.0000
EW[3]	30	28.33	0.95	0.0289
EW	40	28.43	6.71	0.0281
EW	50	5.39	13.96	0.9934
EW	60	2.77	16.22	0.9999
EW	70	0.91	18.67	1.0000
EW	80	0.24	18.79	1.0000

[1]Seafarer'83-Brandon.
[2]Seafarer'83-Winnipeg.
[3]Exrico'83-Winnipeg.

Table B-1. One way analysis of variance for the effect of cultivar on cooking time of navy beans grown at Winnipeg location

Sources of Variation	df	MS	F
Cultivar	2	314.09*	5.58*
Error	9	56.28	
Total	11		

*P<0.05

Tukey Mean Separation

Cultivar:	Exrico	Fleetwood	Seafarer
Means:	65.50 a	51.25 ab	49.25 b

SE = 3.75
LSD = 3.75 x 3.95= 14.81

Table B-2. One way analysis of variance for the effect of cultivar on the cooking times of navy beans grown at Brandon location

Source of Variation	df	MS	F
Cultivar	2	40.09	3.09
Error	9	12.94	
Total	11		

no significant difference at P<0.05.

Table B-3. One way analysis of variance for the effect of cultivar on the cooking times of navy beans grown at Morden location

Source of Variation	df	MS	F
Cultivar	2	106.09	4.04
Error	9	26.39	
Total	11		

no significant difference at P>0.05.

Table B-4. One way analysis of variance for the effect of growing location on cooking times of Seafarer navy beans

Source of Variation	df	MS	F
Location	2	301.00	13.26**
Error	9	22.69	
Total	11		

**P<0.01.

Tukey Mean Separation

Locations:	Winnipeg	Brandon	Morden
Means:	49.25 a	34.75 b	33.75 b

SE = 2.38
LSD (P<0.05) = 9.40

Table B-5. One way analysis of variance for the effect of growing location on the cooking times of Exrico navy beans

Source of Variation	df	MS	F
Location	2	732.59**	11.38**
Error	9	63.53	
Total	11		

**P<0.01.

Tukey Mean Separation

Location:	Winnipeg	Brandon	Morden
Means:	65.50 a	44.00 b	40.75 b

SE = 3.99

LSD (P<0.05) = 3.99 x 3.95 = 15.76

Table B-6. One way analysis of variance for effect of growing location on the cooking times of Fleetwood navy beans

Source of Variation	df	MS	F
Location	2	180.25**	19.19**
Error	9	9.39	
Total	11		

**P<0.01

Tukey Mean Separation

Locations:	Winnipeg	Brandon	Morden
Means:	51.25 a	39.75 b	39.50 b

SE = 1.53
LSD (5%) = 1.53 x 3.95 = 6.04

Table B-7. Comparison of mean cooking times of artificially dried and field dried Seafarer navy beans grown at location Winnipeg

df	t value (5%)	Test Statistic
3	4.303	1.90

Samples are not significantly different ($P<0.05$)

Table C-1. One way analysis of variance F-values for the effect of storage time on the cooking time of Seafarer navy beans grown at three locations and stored under three storage conditions[1]

Storage Condition	Source of Variation	Winnipeg F	Brandon F	Morden F
Freezer	Storage Time	11.43**	2.39	1.44
POA[2]	Storage Time	1.38	5.01*	2.70
SST[3]	Storage Time	8.35**	7.86**	3.02

*P<0.05
**P<0.01
[1]df for storage time=3; df for error=12.
[2]Prairie Outdoor Ambient.
[3]Simulated Semi-Tropical.

Table C-2 One way analysis of variance F-values for the effect of storage time on the cooking time of Fleetwood navy beans grown at three locations and stored under three storage conditions[1]

Storage Condition	Source of Variation	Winnipeg F	Brandon F	Morden F
Freezer	Storage Time	15.43**	9.29**	12.45**
POA[2]	Storage Time	19.24**	129.31**	42.31**
SST[3]	Storage Time	0.46	0.87	0.43

**P<0.01
[1]df for storage time=3; df for error=12.
[2]Prairie Outdoor Ambient.
[3]Simulated Semi-Tropical.

Table C-3. One way analysis of variance F-values for the effect of location on the cooking times of Seafarer navy beans at each storage time under three storage conditions[1]

Storage Condition	Source of Variation	0 Month F	3 Month F	6 Month F	9 Month F
Freezer	Location	5.63*	17.01**	26.44**	1.27
POA[2]	Location	5.63*	33.08**	2.74	2.02
SST[3]	Location	5.63*	13.99**	8.24**	9.73**

*P<0.05
**P<0.01
[1]df for location=2; df for error=9.
[2]Prairie Outdoor Ambient.
[3]Simulated Semi-Tropical.

Table C-4. One way analysis of variance F-values for the effect of location on the cooking times of Fleetwood navy beans at each storage time under three storage conditions[1]

Storage Condition	Source of Variation	0 Month F	3 Month F	6 Month F	9 Month F
Freezer	Location	0.24	——[4]	——	——
POA[2]	Location	0.24	——	0.69	9.72**
SST[3]	Location	0.24	2.30	2.17	24.30**

**P<0.05
[1]df for location=2; df for error=9.
[2]Prairie Outdoor Ambient.
[3]Simulated Semi-Tropical.
[4]Calculation of F-values was not possible because of censored data.