

22. Jan. 1985

Diss. ETH 7688

# Processing, Utilization and Economics of MESQUITE pods as a Raw Material for the Food Industry

A dissertation submitted to the  
SWISS FEDERAL INSTITUTE OF TECHNOLOGY ZÜRICH  
for the degree of  
Doctor of Technical Sciences

presented by

DANIEL MEYER  
dipl. Lm.-Ing. ETH  
born 18. 6. 1957  
citizen of Villmergen (AG)

accepted on the recommendation of  
Prof. Dr. H. Neukom, examiner  
PD Dr. F. Escher, co-examiner

*21. Jan. 1985*

*H. Neukom*

Juris Druck + Verlag Zürich  
1984



ISBN 3 260 05076 0

A WEED IS A PLANT, WHOSE VIRTUES  
HAVE NOT YET BEEN DISCOVERED

#### ACKNOWLEDGMENTS:

It was a real challenge, but also a pleasure to do this work on MESQUITE-pods. It is thanks to several people that I got this chance:

My teacher Prof. Dr. H. Neukom from ETH Zuerich, who gave me the most possible academic liberty and trusted me to perform the work to the best of my knowledge.

The heads of the Western Regional Research Laboratory (WRRC) of the U.S.D.A. in Berkeley CA, Dr. H. Binger, Dr. A. Morgan jr., Dr. R. Saunders and R. Becker who accepted me as foreigner and made me feel at home. Their open-mindedness was very helpful for the success of this work.

My parents who gave me their financial as well as their moral support during my years of education.

I would also like to thank the staff of the WRRC, who performed the routine chemical analysis and all the others who were always willing to give me a helping hand. The same is valid for colleagues and staff of the Department of Food Science at the ETH Zuerich. Many thanks especially to Dr. Escher as the co-examiner.

Buehler Ltd. in Uzwil and Buehler-Miag Inc. in Minneapolis were most helpful throughout the milling aspects.

Last but not least I need to express my feelings to Marie-Louise and our friends and neighbours in the San Francisco Bay Area whose friendship was most important to my well-being during the two years in the United States. Its thanks to them (and to the daily winds) that I have to say:

"I left my heart in San Francisco....."

TABLE OF CONTENTS:

1. INTRODUCTION .....7

1.0. Overview .....7

1.1. Botany of MESQUITE.....8

1.1.1. Taxonomy, patterns of variation.....8

1.1.2. Adaption to enviromental conditions.....8

1.1.3. Pods.....10

1.1.4. Fruit growth and dispersal.....10

1.2. MESQUITE in the ecosystem.....14

1.2.1. From weed to blessing.....14

1.2.2. Feed for animals.....14

1.2.3. The role of MESQUITE in ancient  
and modern cultures.....17

1.3. Objectives of this work.....19

2. EXPERIMENTAL PART AND RESULTS.....22

2.1. Methods and material.....22

2.1.1. General analytical methods.....22

2.1.2. Specification of pods.....23

2.2. Pod structure and terminology.....24

2.3. Milling and separation process.....26

2.3.1. Process description.....27

2.3.1.1. Drying.....27

2.3.1.2. Breaking.....29

2.3.1.3. Milling.....31

2.3.1.4. Separation A.....32

2.3.1.5. Seed cleaning.....33

2.3.1.6. Seed splitting.....34

2.3.1.7. Separation B.....35

2.3.1.8. Fine-milling.....37

2.3.2. Flow sheet and process yield.....37

2.4. Chemical composition of the pods.....40

2.4.1. Detailed analysis of the fractions.....40

2.4.1.1. Fraction A.....40

2.4.1.2. Fraction B.....45

2.4.1.3. Fraction C.....47

2.4.1.4. Fraction D.....49

2.4.2. Chemical variation among different pods.....51

2.5. Uses and applications of pod fractions.....	57
2.5.1. Objectives.....	57
2.5.2. Uses and applications of various fractions.....	57
2.5.2.1. Fraction A.....	57
2.5.2.1.1. Sucrose extraction.....	58
2.5.2.1.2. Composite flours.....	66
2.5.2.1.2.1. Leavened bread.....	66
2.5.2.1.2.2. Chapatis and crackers....	70
2.5.2.1.2.3. Flakes.....	74
2.5.2.1.2.4. Tortilla chips.....	86
2.5.2.2. Fraction B.....	94
2.5.2.3. Fraction C.....	98
2.5.2.3.1. Gum preparation.....	98
2.5.2.3.2. Viscosity studies with the galactomannan.....	107
2.5.2.3.3. Interaction with xanthan..	111
2.5.2.4. Fraction D.....	113
2.5.2.5. Storage and shelf life.....	119
3. PROPOSAL FOR A MESQUITE PROCESSING PLANT.....	121
3.1. Objectives.....	121
3.2. Process description.....	121
3.3. Plant lay-out and equipment list.....	123
3.4. Equipment and engineering specifications.....	126
3.4.1. Milling and separation.....	126
3.4.2. Energy requirements and supply.....	134
3.5. Budget.....	135
3.6. Economics.....	136
4. CONCLUSIONS.....	141
5. SUMMARY.....	146
6. LITERATURE.....	149
Curriculum vitae.....	159

## 1. INTRODUCTION

### 1.0. Overview

MESQUITE (Prosopis spp.) is a leguminous plant that occurs all around the world in arid and semi-arid zones. The plant grows wild, requires very little water and is capable to fix nitrogen.

Depending on the specie, as well as the specific climatic situation, MESQUITE develops as a small brush or as a tree of a height of several meters.

MESQUITE produces an annual crop of pods which fall to the ground when ripe. The pods were an important staple food for former cultures in North- and South-America as well as in Asia. The pods were usually ground in mortars and the flour processed into several different products, such as flatbreads or fermented drinks.

In modern times the importance of MESQUITE as a food or feed became nil, due to several reasons:

- a) MESQUITE is a weed that -if not controled- can infest grassland in semiarid regions.
- b) MESQUITE pods have a very complex and tough morphological structure; no attempts have ever been made to develop a milling and separation process for the pods.
- c) MESQUITE pods as an agricultural crop could never match the purely economical criterias of a modern crop.

Only in the last couple of decades man has begun to look at plants (and animals) as part of a complete ecological system where a "weed" suddenly becomes an important factor in the system.

When chemical studies revealed that MESQUITE pods contain a very high amount of sucrose as well as high-protein and galactomannan-rich seeds, some researchers started to consider its use as a food crop again. The increasing under-supply of food in lesser developed countries in arid zones also led to increased efforts to the establishment of local crops.

Therefore, this work concentrated on the development of a milling and separation process for MESQUITE pods, and on its utilization as a food raw-material. It has been the intention to come up with a immediately realizable model for MESQUITE processing and utilization along with the consideration of the economical aspects.

## 1.1. Botany of MESQUITE

### 1.1.1. Taxonomy, patterns of variation

Among the legumes, the genus Prosopis (common name: MESQUITE) belongs to the subfamily of Mimosideae. There are 44 known species, but only one still exists in tropical Africa, where MESQUITE possibly originated. From there, the ancestors of present day Prosopis may have migrated to east and west during the continental drift at the end of the Mesozoic or the beginnings of tertiary times (1).

To identify the correct Prosopis species in the field can be an extremely difficult task, even for someone who thinks he knows MESQUITE, since Prosopis plants can be small shrubs or short trunked trees but can even develop into 20 m tall trees, all depending on the species and/or the availability of water (2).

There are not only differences in size or shape of the tree; even more astounding may be the differences of the pods. They may be 2 cm long curled pods with the characteristic name "screwbean" (P. pubescens) or up to 13 cm long brown pods of P. chilensis, which might almost be confused with the fruit of a carob tree (Ceratonia siliqua).

The thorns are yet another variation. Some species have nasty long thorns which led to proposals to use MESQUITE as a natural barbed wire fence around military installations. The thorns have even caused vicious infections (3). However, there are also species which produce no thorns at all.

On top of all this variability, Prosopis crossbreeds among species, and it is therefore often almost impossible to determine with which specie one is dealing.

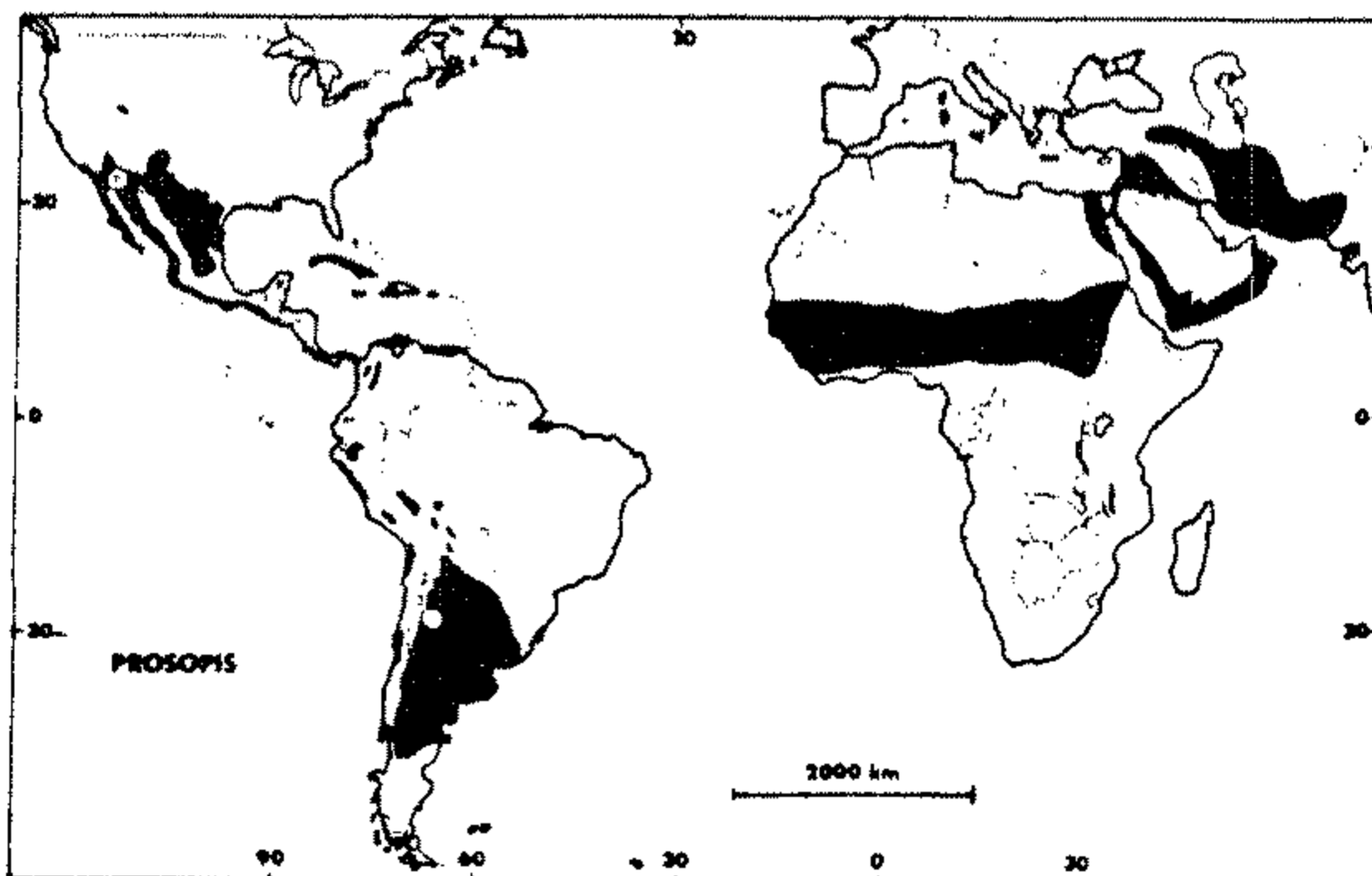
### 1.1.2. Adaptation to environmental conditions

MESQUITE covers 35 million hectares in the United States alone, and is found all around the world in arid and semi-arid zones (Figure 1).

Harsh conditions like extreme temperature, drought, poor soil quality and wind in arid and semi-arid zones pose severe constraints on the growth of a plant. To overcome these problems, MESQUITE possesses special features in the morphology and physiology of its roots, conducting system and leaves.



Figure 1: Worldwide distribution of *Prosopis* species (14)



The potential water reservoir available to MESQUITE is large compared to other desert shrubs. The trees develop two different rooting systems. Tap roots which use ground water (if there is any) have been reported to reach 80 m deep (4). There is also a lateral rooting system, which can extend to 20 m from the tree (5).

Some species can even absorb moisture (dew) through their leaves and translocate it to the roots (6). On the other hand the water losses are minimized by the ability of *Prosopis* spp. to fold their leaflets together at midday (7).

Some *Prosopis* species have been found to perform crassulacean acid metabolism (CAM), where the plant closes its stomata during the day to prevent moisture loss and fixes nitrogen at night (60). In addition, *Prosopis* is capable to absorb water held with high matrix forces and to carry on photosynthesis at xylem water potentials of less than -40 bars (8). The reported figures for water use efficiency differ from 250 water/kg dry matter (9) to 19 700 kg water/kg dry matter (10). The range points out the enormous genetic potential that exists in MESQUITE.

MESQUITE also has the ability to tolerate highly saline conditions. Certain species can grow through a salt crust of several feet (11), and others tolerate a pH value of 9.5-10.0 and a soluble salt content of 0.54-1.0 % which is even better than *Acacia arabica* (12).

It has been shown that Prosopis spp. are capable to fix nitrogen and are therefore able to grow even in nitrogen-free soil (13).

Not surprisingly, MESQUITE prefers hot temperatures. Optimum shoot growth occurs at 29°C (15), whereas most species do not survive frost at -5.6°C (13).

### 1.1.3. Pods

As much as the appearance of the tree from different species varies, as astounding is the diversity in size and shape of the pods.

To demonstrate the range of the differences, four species shall be looked at more closely (Figure 2):

P.velutina: The pods are about 10-15 cm long, slightly bent and of a light brown to yellow colour.

P.chilensis: Pods are up to 20 cm long, quite fleshy and light to dark brown. They resemble the pods of the carob tree.

P.tamarugo : Length of the pods about 3-5 cm, slightly brown color.

P.pubescens: Twisted pods, about 5 cm long pod. Their common name "screwbean" is descriptive of the bean, which is screw shaped.

Inspite of these obvious differences, all the pods have certain identical characteristics as well. They are indehiscent and have a similar botanical structure (pericarp/seed; see chapter 2.2.)

### 1.1.4. Fruit growth and dispersal

MESQUITE trees usually start to carry pods at the age of three to five years and reach a maximal production from year eight to fifteen (16).

Figures 3-6 show the pod-development from flower to the ripe pod of Prosopis velutina. The pictures were taken in the Imperial Valley in Southern California.

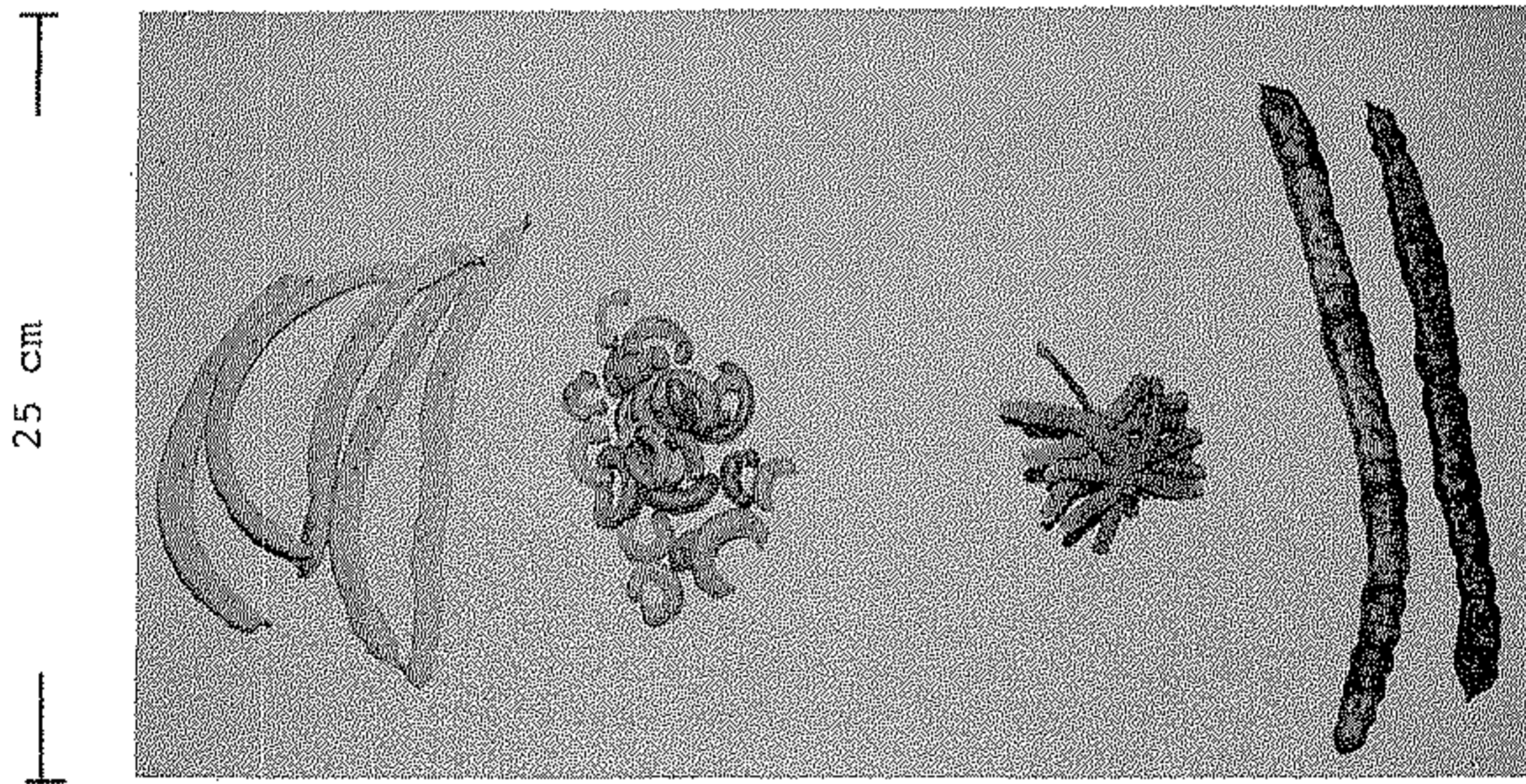
Like all members of the Leguminosae, species of MESQUITE produce their seeds in pods, though unlike many other legumes, the MESQUITE pods do not split open at maturity (indehiscent).

In nature the seeds would never be able to germinate lying on the dry ground. The reproduction cycle requires either mechanical scarification or the involvement of animals. The pods are avidly eaten by coyotes, rabbits, sheep and other mammals, which seem to like it because of its sweetness. Examination of scats of wild animals and feces of domesticated cows and goats reveal that up to 91 % of the seeds pass through the digestive tract of these animals unharmed (20).

This system serves multiple functions in that the seeds are dispersed away from the parent tree (which avoids competition of new plants for the limited water in arid regions); the digestive fluid kills the internal seed parasites and partially hydrolyses the seed coat. Excreted with the moist and mineral rich manure, the seeds are then in a ideal fertilizer. Under these conditions, seeds can then germinate after only six hours at 34 C (17,18).

It could be shown (19), that this natural system provides a much higher germination rate than any other mechanical or chemical treatment of the seeds.

Figure 2: Pods of different MESQUITE species



Figures 3-6: The development of MESQUITE pods from the flower to the ripe pods

3



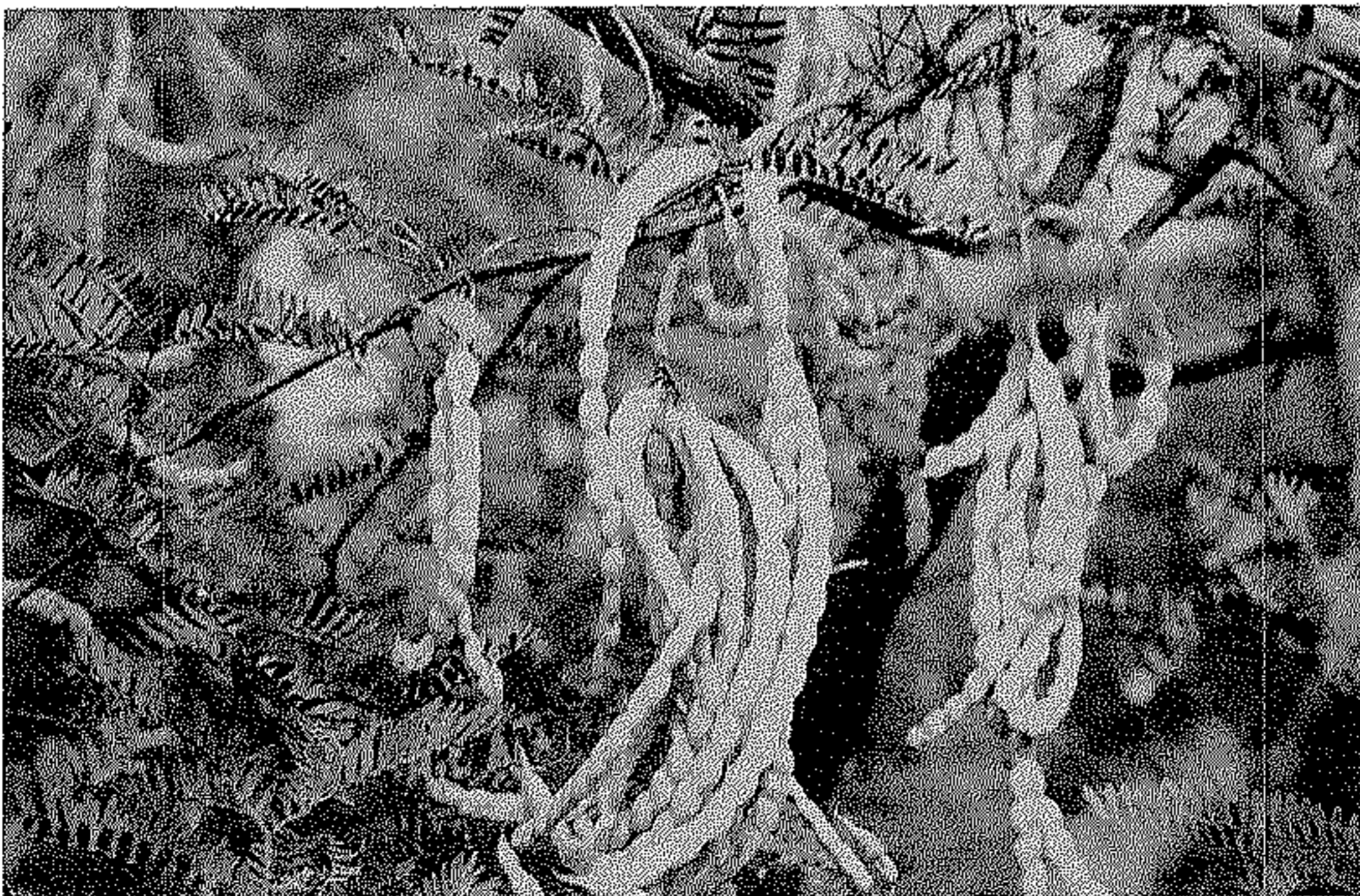
4



5



6



## 1.2. MESQUITE in the ecosystem

### 1.2.1. From weed to blessing

The image of MESQUITE varies widely: from a profit robbing nuisance to a valuable asset to mankind, depending upon who is asked, and where it grows.

In the United States, especially in Texas, where MESQUITE grows on an estimated 22.7 million hectares (20), most ranchers desire to eliminate it from their rangeland because it competes strongly with desirable forage. Nevertheless the attempts to get rid of MESQUITE have not been very successful. All methods i.e. fire, herbicides or bulldozing destroy most of the desired vegetation as well, and since MESQUITE seems to be one of the toughest of all plants, it is the first that reoccurs. As a result, the surface coverage of MESQUITE increased dramatically in the last two centuries (21).

In other countries of the world, MESQUITE was and still is, a highly welcome plant. Therefore, plantations have been established (Saudi-Arabia, Chile) for the following different reasons:

- Trees stabilize sand dunes, stop desertification and provide shade
- The pods are used as feed for animals and the wood can be utilized by people in such regions as lumber

A typical example of the bias effects of MESQUITE has been reported from India. A row of MESQUITE had been planted along a jowar plantation. It was observed, that the growth of the field crop was reduced along the MESQUITE belt, but its function as a shelter belt against wind and sand increased the crop on the whole orchard by a factor of 1.5 to 2. Thus MESQUITE is now recommended as shelter belt on farms (22).

Figure 7 illustrates the general role of MESQUITE in the ecosystem, which is one that would fit almost exactly the requirements of a plant to be used in a concept of "Three dimensional forestry" (23). The following chapters explain certain aspects in more details.

### 1.2.2. Feed for animals

Many properties of Prosopis fruits and characteristics of their production make them an important resource for numerous animals. The pods being predictable, abundant, nontoxic, and highly nutritious, naturally attract numerous herbivores, many of which destroy the seeds, but the only invertebrates known to use the pods as a food source are insects.

Insects that feed on Prosopis can be divided into two groups, those that feed from the outside and those that feed inside the fruits (24). Mozena obtusa (the hemipteran leaf footed bug) is one of the most abundant external fruit feeders in North America (25). Its damage to the honey MESQUITE in Texas was estimated at 50% of the potential fruit production (26).

Long-horn beetles of the genus Lophopoeum are known to develop inside the pods in Argentina and to consume all of the seeds within the pods while developing. The same damage to MESQUITE pods is done by members of the bruchid family, which are by far the most numerous and best known insects that use Prosopis pods as a food resource (27).

Many wild and domesticated mammals, birds and reptiles are also known to feed on MESQUITE leaves and pods. The following list is not ment to be complete:

Desert cavy, leaf eared mice, hare, jackrabbit, coyote, deer, armadillo, fox, goat, sheep, cow

For many of these animals, MESQUITE pods can be a big part of their diet. It has been reported that jackrabbits can get more than 50% of their calories from them (28).

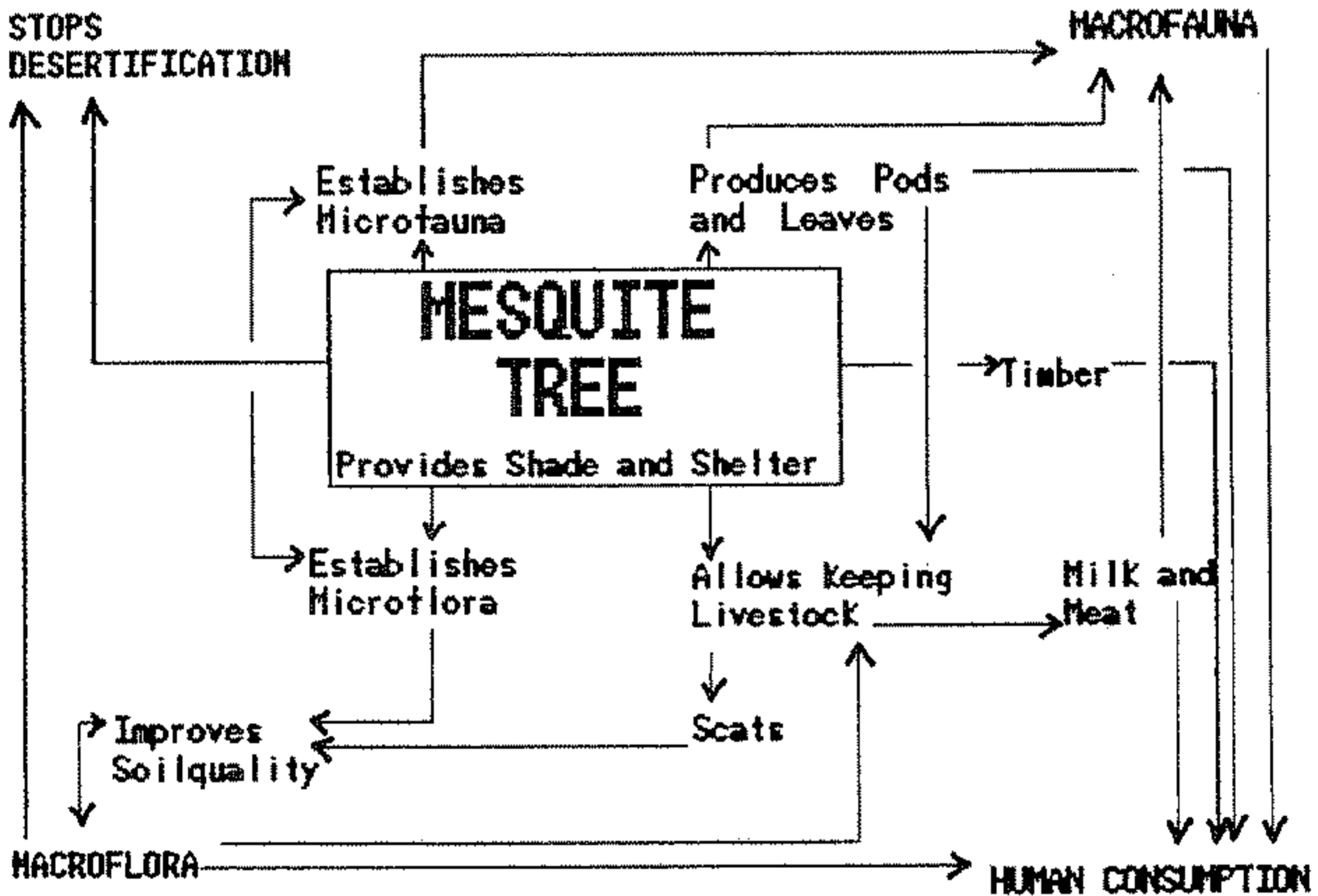
The elimination of MESQUITE can even be responsible for the abundance of animals in certain aeras, as it was observed for scaled squails in New Mexico (29).

Today, many farmers in Central and South America as well as in the Far East use MESQUITE pods in feed mixtures for their livestock. Results of feeding studies showed that up to 20% of the feed can be substituted economically with MESQUITE pods with no deleterious effect on growth of calves (30).

Even in Hawaii, the pods from Prosopis pallida (Kiawe) were of great value prior to the development of inexpensive bulk bin containers for trans-pacific shipment of feedstuff. The pods were often the only available feed during the dry season for dairy cows, cattle horses, donkeys, pigs and chicken (31).

The MESQUITE tree itself is perhaps even more important than the pods. Through its shade and shelter which it provides for animals in the desert and arid zones, the tree is a basic condition to actually establish some livestock.

Figure 7: The role of MESQUITE in the ecosystem



### 1.2.3. The role of MESQUITE in ancient and modern cultures

A great deal of information is available about the use of MESQUITE by ancient cultures in North and Central America.

The Sonoran Desert which stretches from Southern Arizona to North Western Mexico might be one of the location where MESQUITE played an extremely important role. MESQUITE may have been the second most important staple food to Indians like the Hohokam, who occupied Southern Arizona from about 300 B.C. to 1450 A.C.(32), the Pimas (33), the Mescalero-Apaches and the Seris.



The Seris had names for eight stages of growth of the fruit, from the youngest to the fallen, rotting pod. In the second youngest stage the pods were tied into small bundles and cooked with meat. Mature but still green pods were mashed in a bedrock mortar and cooked in clay pots (34). The most commonly utilized form of the fruit was the dry fallen pods, which have the highest carbohydrate content.

A single man could gather about 80 kilo of pods in a day. Most often the pods were first toasted, by lighting a fire on cleared ground, removing the charcoal and putting the pods on the hot ground. At the same time the pods were sprinkled with sand that had been heated by fires. The women then pounded the pods in mortars with pestels (often made from MESQUITE wood). After the pods were mashed, the flour which is actually only the exo- and mesocarp of the pods, was separated from the unbroken endocarp, which still contained the seeds. The Seris placed the flour in a large basket, mixed it with water, kneated the dough and formed round, 5 to 10 cm thick cakes. They then dried the cakes immediately in the sun, so that they could be stored for weeks (35).

Some tribes pounded the endocarp hulls until the seeds got free. The seeds were then separated and pounded to a fine flour to which water was added and the mixture drunk. Sometimes the different flour/water mixes were allowed to ferment for several days before they were consumed (36).

Father Barzana reported about the use of P.algaroba by South-American Indians (37) : "... they also prepared a very strong alcoholic beverage from the pods and there were never as many querrels and casualties as during the MESQUITE harvesting season."

MESQUITE had also been extensively used for a wide range of medicinal purposes (38). The gum exudate helped curing eyeinfections and sore throat (39). A tea prepared from young MESQUITE roots served against diarrhea (40), whereas a liquid prepared from the bark was used as a laxative (41).

Moreover, the MESQUITE wood served as fuel, as raw material for many "household" gadgets and building material and the Hohokam people of Snaketown cremated their dead on MESQUITE wood pyres (42).

From all this examples it becomes clear, that MESQUITE was not at all a weed for ancient cultures but a necessity for their daily live.

Currently, MESQUITE is of no more positive economical value or cultural importance in the United States. Today's people that inhabit the growing region of MESQUITE have no need for local food production (USA only) or produce cash-crops that require a tremendous input of irrigation and fertilizer (Imperial Valley, California).

There are attempts to use MESQUITE wood as lumber since the wood is of enormous hardness and can be compared to ironwood or white oak. Very appealing furniture and tile floors were manufactured in small quantities (43).

Trees are also chopped for fuel and some charcoal production.

All the current attempts in using MESQUITE are geared towards a utilization of the wood of existing trees which would be chopped anyhow, whereas the utilization of pods as an annual crop has hardly seriously been looked at.

Peter Felker, a researcher and outspoken advocate for MESQUITE, suggests to establish MESQUITE for biomass production, but the current "surplus" of traditional fuels does not favour such attempts. In the future the story might be different again.

In Mexico, MESQUITE charcoal is produced in considerable quantities. This charcoal is mainly exported to the United States where it is used in first class restaurants for barbecue. The charcoal is about three times more expensive than regular type but has a gourmet image due to its characteristics, like hot temperature and special flavor (44).

Pods can also be purchased from dealers in Mexico who buy them from people that collect the pods for a small income. The pods are used in feedstuff mixtures. It is said that some people or even tribes still prepare some food from the pods. This is certainly the case for a region in India, where the custom of eating P.cineraria pods seems to be the major factor in the prevention of protein malnutrition. These people chew the ripe pods and discard the seed (45). By this way of eating the pods, the high protein content of the seeds is wasted.

In South America (especially in Argentina and Chile) the wood is also used as fuel and for tilefloors, and a sirup is produced from the pods as beverage. In Hawaii pods and leaves are harvested from P.pallida for livestock.

Today, MESQUITE is worldwide a under-utilized plant because of its "weed" image, the lack of processing techniques and application of the pods.

### 1.3. Objectives of this work

It has been outlined in the preceeding chapters that a considerable amount of MESQUITE is growing wild in the United States and other countries around the world. The pods of these trees are hardly used as feedstuff and practically not at all for human consumption.

A look at the growing regions of MESQUITE reveals the following situation:

- Most of these regions do not permit an economically justifiable cultivation with a traditional crop due to their geographical isolation and lack of water.
- Many of these countries (with the exception of the United States) can not produce sufficient amounts of food for their rapidly growing population and have to import big amounts of cereals and legume flour.
- Most of these regions lack infrastructural developement.
- On millions of hectares in these countries, no plants are grown, even though MESQUITE would withstand the harsh conditions.

The single most important reason why MESQUITE pods are currently not being used for human consumption is that no modern technology has been developed to process the pods to a usable raw material.

The problem starts with the morphologically very complex structure of the pods with soft and extreme hard layers as described in Chapter 1.1.4.

By just running the pods through a hammermill a product of unspecific morphological and functional characteristics is obtained, which is only usable as feedstuff for ruminants.

The requirements for a raw material that serves as a basis for more or less sophisticated foodproducts are more specific:

The product has to have a uniform mesh size, texture, color and odor. It has to have a known composition with desirable functional characteristics, such as:

- A cereal flour (starch/gluten: structure giving)
- A soy concentrate (protein: emulsifier, foam)
- Guar gum (Galactomannan: thickening and stabilizing agent)

These requirements were already valid for the Indians. They had a basic but efficient technology to separate the exo- and mesocarp from the seeds (Chapter 1.2.3.). Their ideas and methods were the starting point for the process that will be described here. Some suggestions about milling MESQUITE-pods have been published in 1969 (46) and 1979 (47), but were directed towards obtaining seeds for reforestation purposes. Therefore only very small quantities were processed.

Several authors studied the composition of the pods or some of its morphological fractions (48;49;50;51;52;53;54;55;107) but its applications in food products have never seriously been investigated, even though no toxic components have been found (56), except of very small amount of cyanide in some species (106).

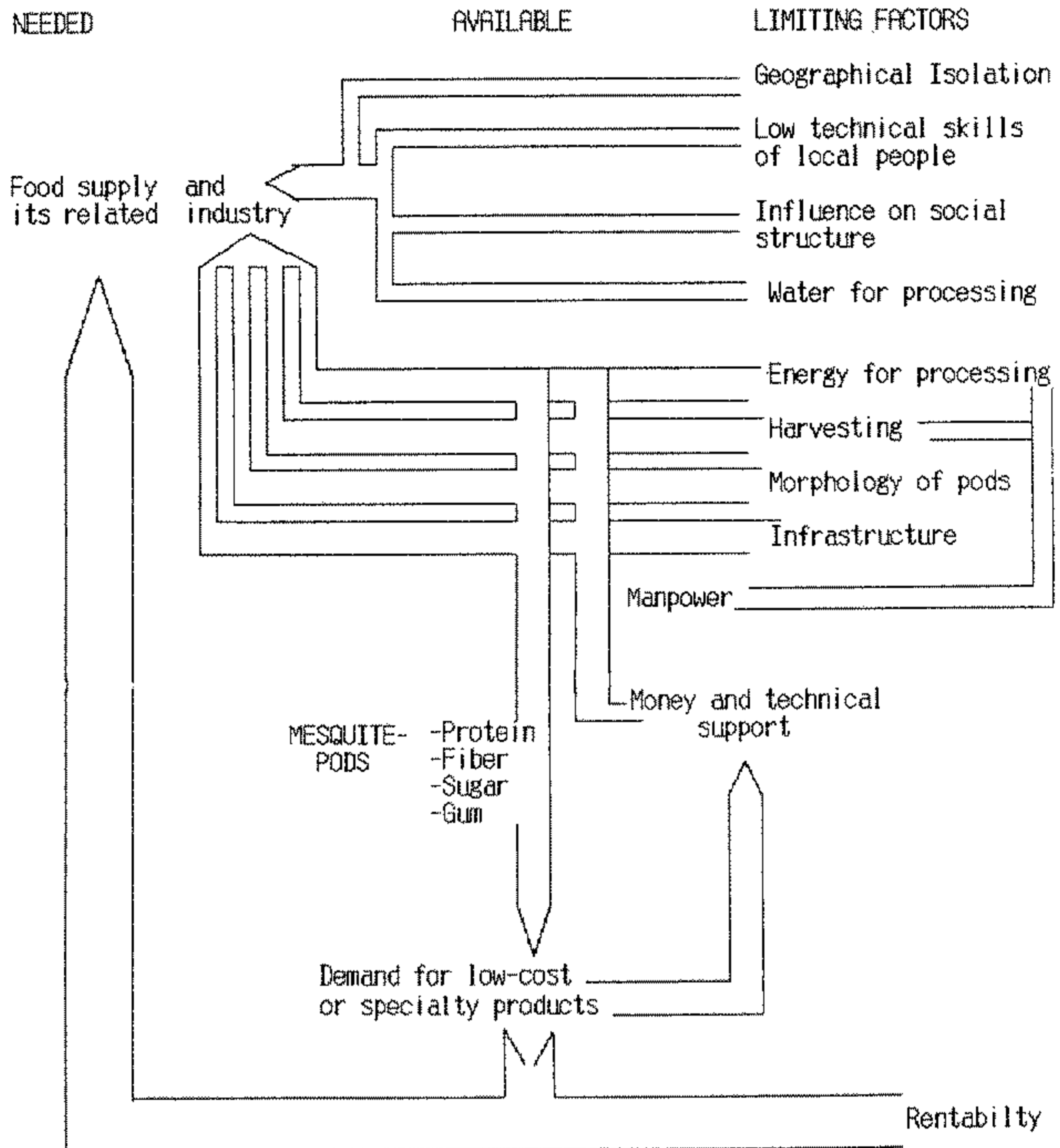
It is the purpose of this study to fill these gaps. Figure 8 illustrates the problems and possibilities that surround the potential utilization of MESQUITE pods as a food source, and serves as the framework and self-imposed task sheet for this work.

The verbal interpretation of Figure 8 leads to the following formulation:

**IT IS THE OBJECTIVE TO OUTLINE HOW MESQUITE PODS CAN BE HARVESTED, MILLED AND INCORPORATED INTO FOODSTUFF.**

**THE PROJECT HAS TO RESPECT THE SPECIAL CLIMATIC, GEOGRAPHICAL AND SOCIAL CIRCUMSTANCES OF THE ARID AND SEMI-ARID GROWING AREAS, AND HAS TO BE ECONOMICALLY FEASIBLE.**

Figure 8: Problems and possibilities surrounding the utilization of MESQUITE pods



## 2. EXPERIMENTAL PART AND RESULTS

### 2.1. Methods and materials

#### 2.1.1. General analytical methods

The following list covers only standard chemical methods that are frequently used for routine analyses. Methods that are specific for certain experiments are mentioned in the according chapters:

**Sucrose:**

AOAC Methods, 13th Ed. 1980, Method # 31.027-31.028

**Glucose:**

AOAC Methods, 13th Ed. 1980, Method # 31.032

**Protein (N):**

AOAC Methods, 13th Ed. 1980, Method # 7.021-7.024

**Moisture:**

AOAC Methods, 13th Ed. 1980, Method # 14.002-14.003

**Crude Fiber:**

AOAC Methods, 13th Ed. 1980, Method # 7.061-7.065

**Other Fibers:**

Forage Fiber, Agric.Handbook #379; Agric.Res.Service  
USDA 1970

**Fat:**

AOAC Methods, 13th Ed. 1980, Method # 7.055-7.056

**Ash:**

AOAC Methods, 13th Ed. 1980, Method # 7.009

**Metals:**

AOAC Methods, 13th Ed. 1980, Method # 3.006-3.058

**Carbon / Hydrogen:**

AOAC Methods, 13th Ed. 1980, Method # 47.009-47.012

**Phosphorus:**

Biochem.J. ; 34B; 858 (1940)

**Sulfur:**

J.Food Sci. 44 ,p.1772, (1979)

### 2.1.2. Specification of pods

As described in Chapter 1.1.1., there are 44 known species of MESQUITE which produce pods with considerable morphological variations.

For practical reasons the following studies have been restricted to one type of MESQUITE, unless otherwise mentioned. This one type is not necessarily one species, but rather pods that are morphologically similar. They are basically P.velutina, P.glandulosa and its hybrids. This type of pods represents the overwhelming amount of MESQUITE found in the United States and Central America. The pods that have been used for this work have been collected by the author in the Imperial Valley in Southern California and in the Yuma area in South-Western Arizona. The pods were gathered in July and August 1982 and 1983 under approximately 20 different wild growing trees with racks (Figure 9), stored in guny-bags and brought to the laboratory in Albany, CA where they were kept in freezers at minus 20°C until used for the experiments. Some tests have been performed with pods from Chile (referred to as such in the text).

Figure 9: Pod collecting in Southern California



## 2.2. Pod structure and terminology

The overall goal of processing the pods has been outlined in Chapter 1.3.2.:

To produce morphologically and functionally homogenous fractions.

A milling and separation process would evidentially have to be based on the general physiological structures of the pod. It is therefore necessary to describe the pod from this point of view:

The pod basically consists of the PERICARP which contains the SEEDS (Figure 10).

The PERICARP itself has three different layers:

- The EXO-CARP, or outer layer is approx. 1 mm thin, relatively soft and of a yellow color.
- The MESO-CARP, lying just beneath the exocarp is about 2-4 mm thick and rather soft.
- The ENDO-CARP (which is often thought to be the seed by people who see a pod for the first time) is a very hard and fibrous layer, enclosing the seed. This hull can hardly be opened by hand.

The small SEEDS inside the endocarp hull again are extremely hard and are composed of:

- The brown, very thin SEED COAT.
- The ENDOSPERM which lies directly beneath the seedcoat
- The COTYLEDON and a tiny GERM.

Table 1 gives the terminology of the four fractions according to their origin. These names have been created to simplify the description and will be used from here on through the whole study where applicable.



Figure 10: Pod structure

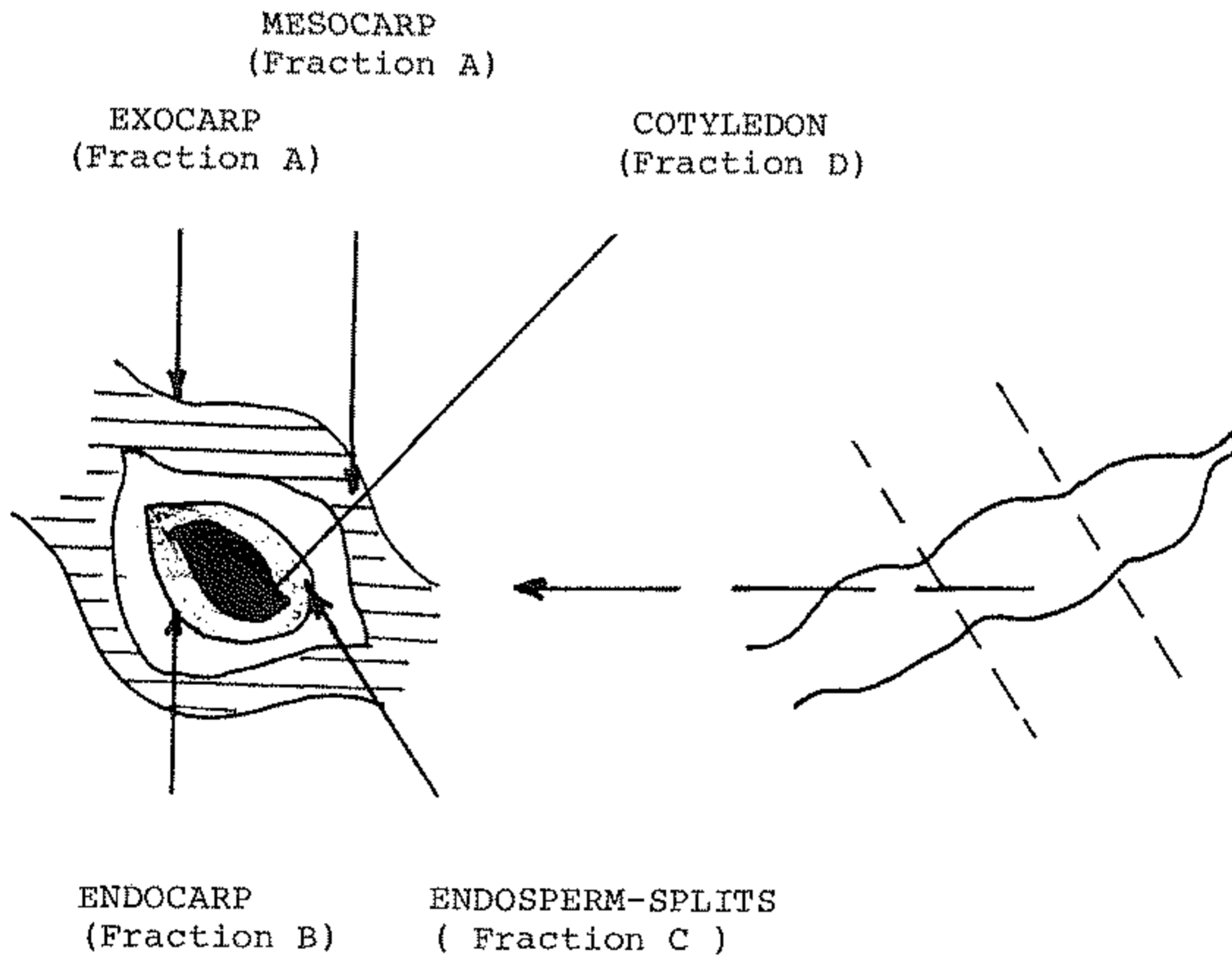


Table 1: Terminology of fractions

Botanical origin		TERM USED IN THIS WORK
=====		
Pericarp:		
EXO- and MESOCARP	(outer pericarp)	FRACTION A
ENDOCARP	(inner pericarp)	FRACTION B
Seed:		
ENDOSPERM with adhering SEED COAT	(seed splits)	FRACTION C
COTYLEDON with GERM		FRACTION D
=====		

### 2.3. Milling and separation process

In order to develop a milling and separation process the whole array of different type of mills had to be tested for MESQUITE pods, but only the combination of machinery which will be described, finally provided satisfying results.

It became clear during the evaluation procedure, that there is a need for unbroken seeds for reforestation purposes and the process therefore would not only have to produce raw material for further applications, but would also have to deliver unbroken seeds as an intermediate product. Also the unbroken seeds would be much easier to separate from the remaining pericarp material.

In order to be able to determine the effect and efficiency of different mills and separators that were to be used, some helpful standard numbers of the pods had to be determined. For this purpose, the pods were dried for 10 hours at 50°C, run through a laboratory disc-mill without breaking any seeds; still unopened endocarp hulls were opened with pliers. Fractions A, B and unbroken seeds were then manually carefully separated.

This preliminary investigation revealed the average size of product fractions as shown in Table 2. Table 3 shows standard figures of MESQUITE pods that had to be determined in order to evaluate and to control the milling process. Numbers in parentheses are the extremes that were found in this study.

Table 2: Percentages of pod fractions

Whole pod	100.00 %	
Fraction A (Exo-mesocarp) :	53.0 %	(49.0 -57.0%)
Fraction B (Endocarp ) :	22.0 %	(19.0 -24.0%)
Seeds :	25.0 %	(18.0 -27.0%)

Table 3: Standard figures for process control (averages)

Weight of 100 pods :	300.0 g	(155.0 -480.0g)
Number of pods / kg pods :	333	(645 -210 )
Seeds per pod :	12	( 7 - 15 )
Weight of 100 seeds or :	4.0 g	( 3.5 - 4.3 )
Number of seeds/kg seeds :	25000	(23200 -28300 )

### 2.3.1. Process description

#### 2.3.1.1. Drying

The MESQUITE pods reach a minimal moisture content by the time they mature and fall to the ground. Once they drop, they equilibrate with ambient moisture conditions, usually remaining quite dry in the desert unless rained upon. When transported to the more humid San Francisco Bay Area, they rapidly absorb ambient moisture. Therefore, the pods were either stored frozen or in a low humidity room. Special dry storage conditions were required for broken or milled pods because the mesocarp is very hygroscopic and would rapidly absorb moisture.

The natural moisture of the ripe pods, which has been determined to vary from 8 to 14%, make it impossible to run the pods through any milling process at all; the machinery clogs up almost immediately. It is therefore mandatory to dry the pods prior to any further processing.

Drying curves were determined with approximately 5 kg pods of three different varieties, which were laid as a 3 cm high layer on trays, and dried in a tunnel-drier (Taylor) at 70°C with an air velocity of 250 m/min (Figure 11)

Figure 11: Drying of pods in a tunnel-drier



The pods were weighed several times during the drying process and after 21 hours the remaining moisture was determined. The actual moisture at all intermediate drying times was then calculated.

The drying curves of the pods are shown in Figures 12 and 13.

Temperatures above 75°C have resulted in partial burning or at least browning of the pods. Bellow 65°C the drying times are increasing rapidly.

Figure 12: Drying curve of Prosopis velutina (70°C)

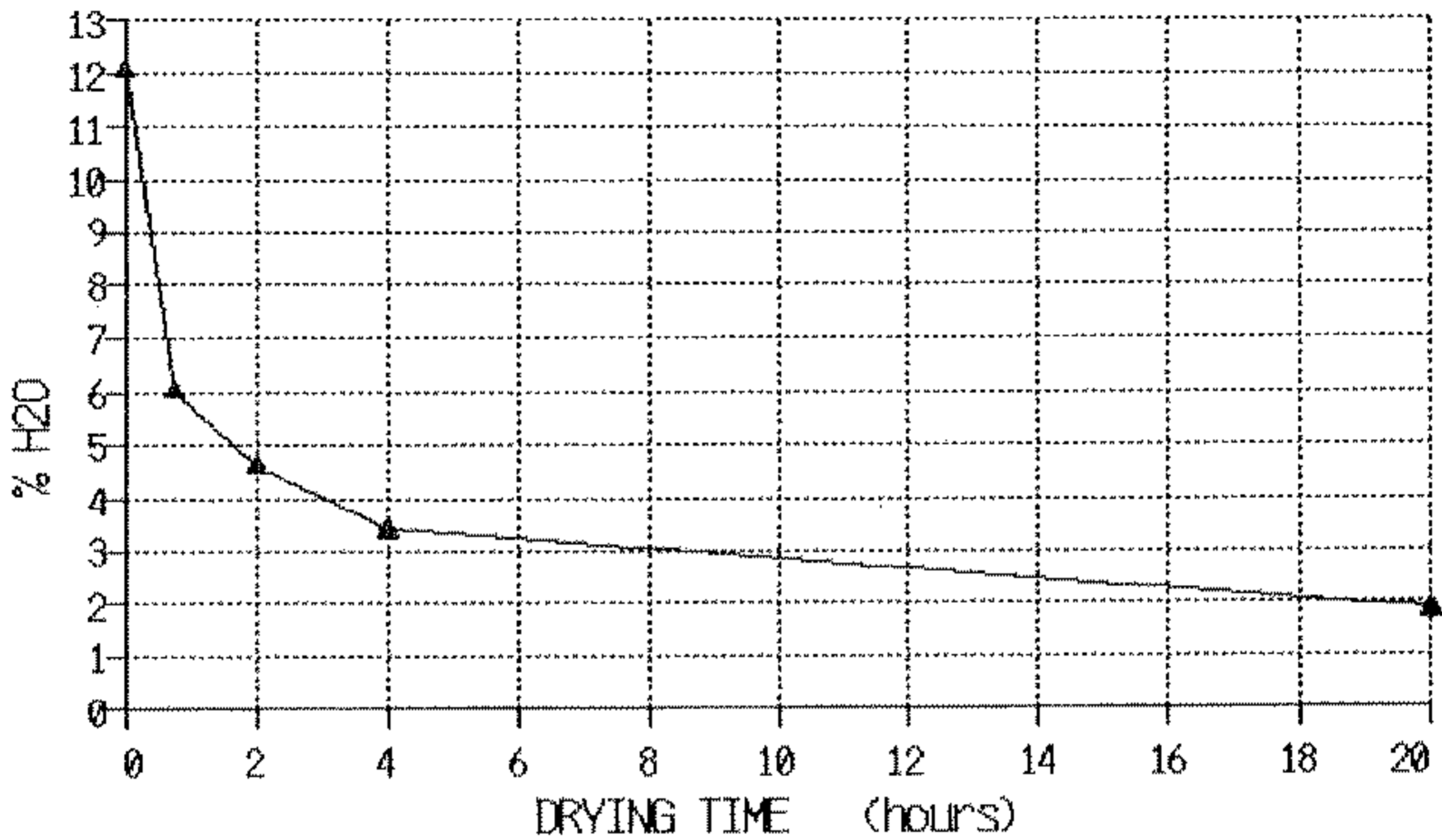
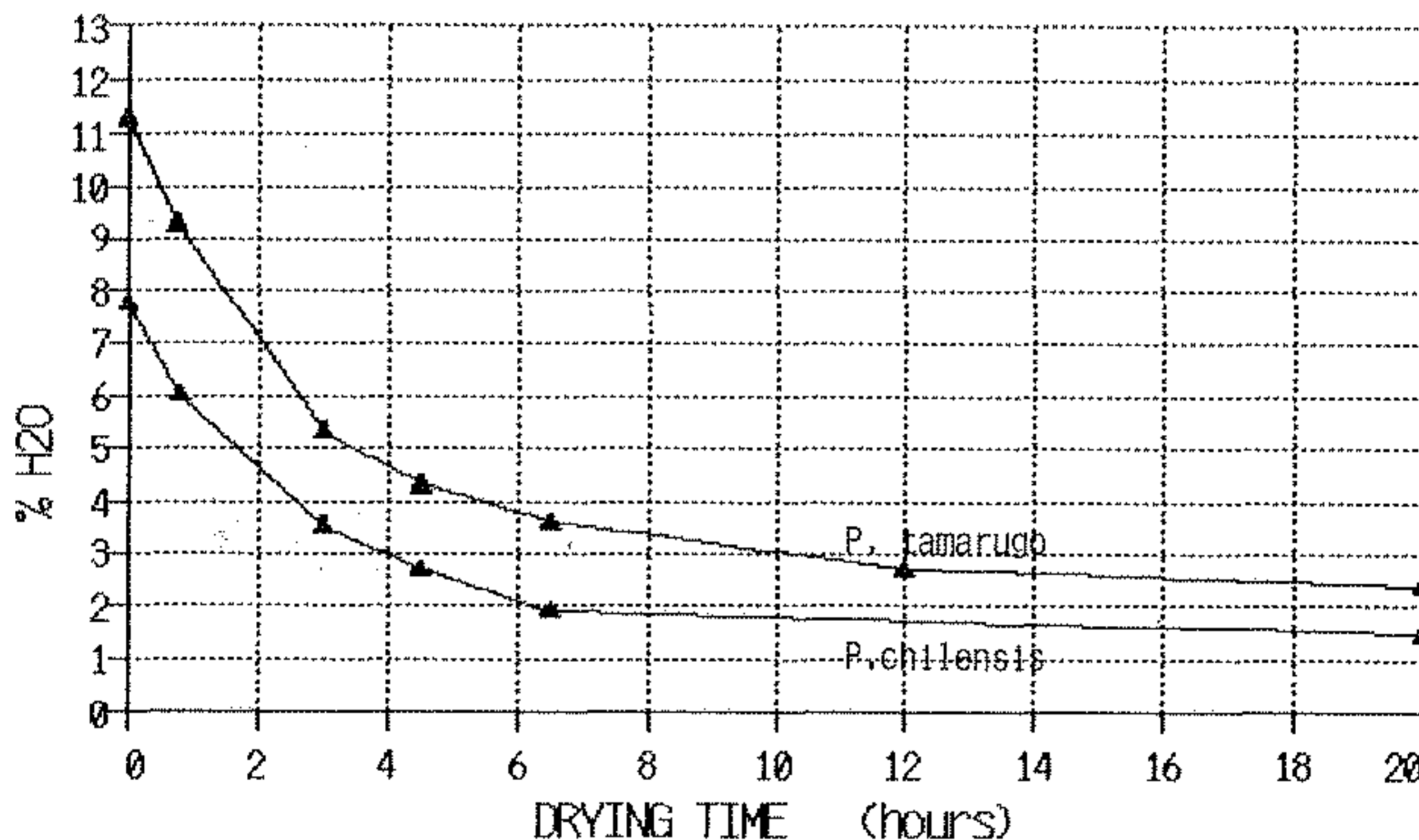


Figure 13: Drying curve of P.chilensis and P. tamarugo (70°C)



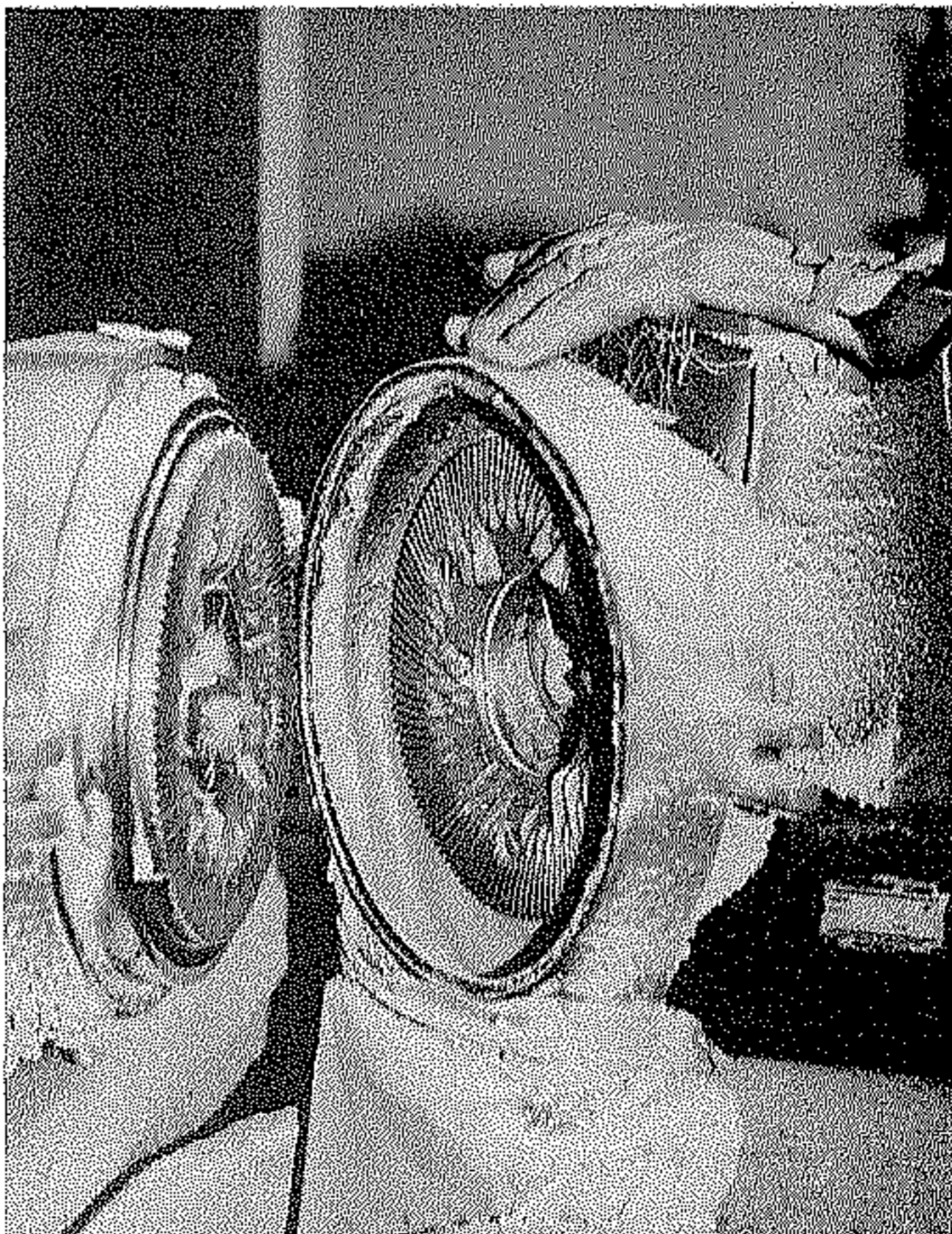
2.3.1.2. Breaking

In order to ensure a proper feed of pods to the subsequent milling operation (2.3.1.3.), the pods have to be broken into smaller pieces, about 3-4 cm long. These pieces are straight, whereas whole pods are slightly bowed. It is important, that this first breaking does not release seeds since they would otherwise be broken in the next step. Also no fine material should be produced in this step, since the dust formed disturbs feeding to the mill. All these conditions can generally be fulfilled with a slow turning disintegrator. (Rietz Disintegrator; speed 500 rpm; Figure 14).

Figure 14: Breaking



Figure 15: Milling



2.3.1.3. Milling

This is with no doubt the most critical step of the milling and separation process of the pods. Many attempts with a large variety of mills produced unspecific mixtures of different pod-fractions (Table 4).

Table 4: Milling characteristics of two unsuccessful mills

Equipment	Conditions	Result
Corrugated roller-mill	variable speeds and gaps	75% of endocarp hulls not opened; release of broken seeds
Hammermill	500-2500 rpm	Seeds are broken into small pieces

It became obvious, that only a disc-mill could eventually do the expected job. Horizontal discmills, highspeed discmills and squaretoothed discs were however not suitable. Eventually a vertical dicsmill with corrugated discs at relatively low speed proved successful in producing a maximal amount of released but unbroken seeds as well as a proper separation of endocarphulls from mesocarp (Figure 15).

Besides speed and the right type of disc it is even more critical to find the proper gap between the discs. It has to be just a little smaller than the endocarp hulls, but slightly larger than the thickness of the seeds. This gap has to be adjusted depending on the average thickness of the pods before a new different batch is milled. This can be done with a handful of pods and visually checking the output. In the mill, the exo- and mesocarp is cut off the endocarp hulls, which themselves are not powderized since they are much harder than Fraction A. The hulls are torn apart along the two sides, and the seeds released. The seeds are scarified, but most of them (min. 85%) not broken, since they are smaller than the gap between the discs and the centrifugal force which spins the seeds to the frame is insufficient to break them.

In a first suggestion for a milling process (61), the same machine was used but at a higher speed. Under these conditions the seeds are broken by crashing them to the frame, but the subsequent separation proved to be too unspecific.

Specification, Milling

Equipment : Bauer mill 148 (horizontal disc mill), Size 8  
 Disc : 8114 Gap-setting: 40 Speed : 3450 rpm

#### 2.3.1.4. Separation A

The milling by means of a horizontal discmill resulted in a mixture of pod fractions (Fraction A and B as well as complete seeds) , which now has to be separated. At this stage this can be done by a unit that allows separation according to mesh size only, with three outlets.

This was carried out by a vibrating screen sifter with two different screens. The milled pods are fed on top of screen 1 which retains Fraction B i.e. the endocarp hulls. The seeds and Fraction A pass this screen. The seeds along with some pericarp fragments are retained on screen 2, whereas Fraction A passes and is collected at the bottom. The steady vibration of the apparatus ensures a proper functioning and automatically ejects the material from the screen which can be collected externally.

It is important that this separation step is performed immediately after the milling, since Fraction A is subject to lumping due to its hygroscopicity. If this happens, separation is not possible anymore. Working in dry environment (dry room) eliminates these restrictions. Fraction A also has to be stored properly after separation, whereas Fraction B and the seeds pose no such problems.

The quantitative flow corresponds to the actual distribution of the fractions of the processed pod if the milling has been carried out properly.

Visual checking of the fractions for unopened endocarp hulls or excessive broken seed material in Fraction A would at this stage inform of necessary adjustment (gap, speed) at the milling level. For analytical purposes, Fraction B could be rerun through the mill if too many hulls were still unopened.

This processing step releases the two pure Fractions A and B which need no further separation except a size reduction for their specific application. The seeds along with pericarp fragments go to the next separation step (Separation B).

#### Specification, Separation A

Equipement : Sweco, Screen-separator  
Screen 1 : 4.8 mm round holes  
Screen 2 : 1.0 mm square holes  
Pods with extreme seed size might require other sieves, which are easily exchangeable in this unit.



2.3.1.5. Seed cleaning

The seeds along with some pericarp fragments are retained by sieve #2 in the preceding step. The pericarp fragments account for 20-50 % of this fraction, depending on a proper adjustment of the mill (see chapter 2.3.1.3.). The retained material consists of endocarp fragments and exocarp pieces that come from the tips of the pods. This material has to be regarded as "dirt" and must be separated from the seeds.

The seeds are smaller and heavier than the pericarp fragments. Therefore, a cyclone (Mc Gill, Houston TX, Laboratory aspirator 66-17721) with adjustable airspeed effectively separates the two fractions. The clean seeds pass the vertical tube and can be collected; the pericarp fragments are carried away in the airstream and can be discharged or added to Fraction B, since a visual check makes clear, that most of this material is part of endocarp hulls. To prove this observation, an analysis of the pericarp fragments was performed: Fat and protein of the pure fraction as well as of the pericarp fragments were determined (Table 5).

Table 5: Composition of pericarp fragments versus clean fractions

Fat/ Protein	Fraction A (pure)	Fraction B (pure)	Pericarp fragments
Protein ( N x 6.25)	8.9	6.3	6.9
Fat	2.7	1.2	1.7

The calculated composition of the pericarp fragments reveals that one can expect it to be 70-75 % Fraction B and 20-25 % Fraction A.

### 2.3.1.6. Seed splitting

The cleaned seeds represent an end product if used for reforestation, or can be further processed by splitting into endosperm and cotyledon if their utilization for food-purposes is anticipated.

Two pieces of equipment have proven to be successful for seed splitting. Both will be described here and basically perform the same function: The seeds are fed to a cyclone mill (Udy-cyclone mill with steel impeller and rough abrasive frame 2000 rpm; Figure 16) or to a graintester (Strong-scott 17810; Figure 17) in which they are thrown to the frame of the unit. The speed and force of the crash causes the seeds to break into three parts; two endosperm splits (=seed coat with endosperm, Fraction C) and the cotyledon with the tiny germ (Fraction D).

If the process works properly with the graintester, it is the one to choose because of its simplicity. The seeds are run in the unit for about 30 seconds (the endpoint can be determined accustically). This unit does not allow adjustments (rotor, frame or speed) and therefore some seeds just break without being splitted, and come out as small pieces or even a fine powder. Table 6 gives the result of a poor splitting experiment with a large percentage of fine material.

Table 6: Example of poor seed splitting

Seed input	:	120.0 g	100.0 %
Unbroken seeds	:	3.4 g	2.8 %
Splits (C)	:	48.0 g	40.0 %
Cotyledon (D)	:	26.6 g	22.0 %
Fine material	:	48.0 g	40.0 %

As will be shown, the seeds consist of approx. 55 % of Fraction C and 45 % of Fraction D. Table 6 therefore indicates that the fine material contains a substantial amount of Fraction D. This was confirmed by a comparison of the protein content of the fine material with Fraction D:

Fine material = 36.4% Protein  
Fraction D = 54.0% Protein  
Fraction C = 4.0% Protein

Fraction D accordingly accounted for 70 % of the fine material.

If the unspecifically broken seeds or the fine material are in excess of 25% of the input, it is recommended to use a cyclone mill instead of the graintester. The cyclone mill allows changing of the rotor size, form, material), the frame (coarse or fine surface), speed and air flow. In addition, the top of the unit is made from clear plexiglas which allows to observe exactly what happens with the help of a stroboscope.

The seeds are run through the unit for 90 seconds, then the small sieve in front of the outlet is removed to allow the splitted seeds to fall in the collector. The disadvantage of this unit is that it requires more attention and fine tuning from the operator.

An average of 85 % of the seeds can be recovered as splitted seeds with 15% of the input being collected as fine material which consists of 70% Fraction D and 30% Fraction C (see above).

#### 2.3.1.7. Separation B

The purpose of this step is to separate the endosperm splits (Fraction C) from the cotyledon (Fraction D). The process is the same whether the graintester or the Udy-cyclone-mill is used in the preceding step.

The inevitable fine material that forms during splitting of the seeds is first of all removed by running the material through a 10 mesh sieve. Fractions C and D can then be separated by air classification. Theoretically any air classifier such as the cyclon that is used in separation A (2.3.1.4.) could be used, but a unit that allows good finetuning is preferred, since the size/weight differences of the two fractions are not as pronounced as in separation A.

A simple clear plexiglass tube with the necessary collecting devices and an adjustable airflow performs a completely satisfying seperation. Fraction C is collected at the top and Fraction D stays at the bottom of the tube.

The average distribution of the two fractions is 55 % Fraction C (endosperm splits) and 45 % Fraction D (cotyledon).

Figure 16: Seed splitting  
with a cyclone-mill

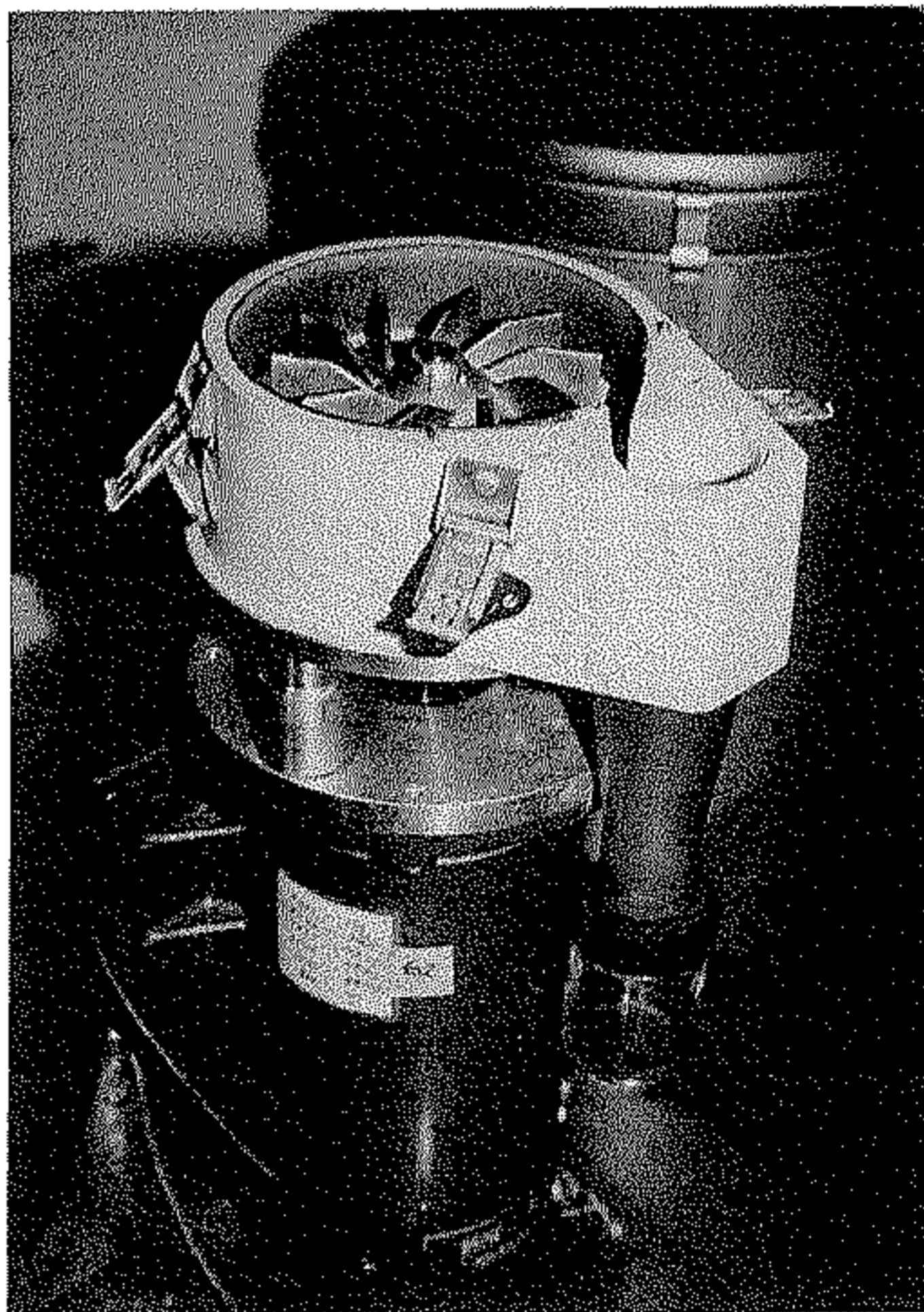
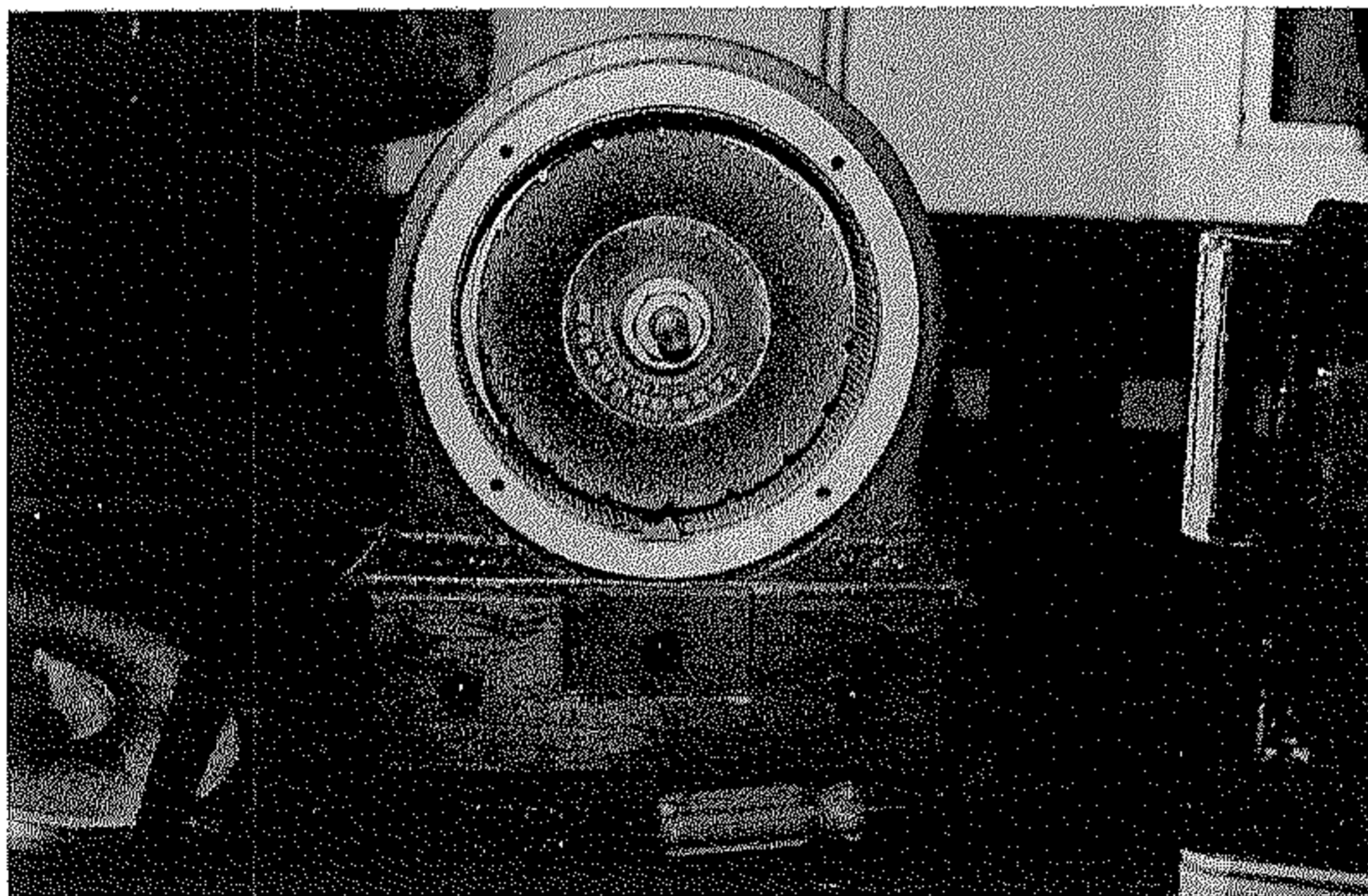


Figure 17: Seed splitting with a graintester



#### 2.3.1.8. Fine-milling

Each fraction that is obtained by the described process has its relatively uniform mesh-size at this stage, and needs only to be reduced in size depending on what further application is intended.

Fraction A: The flour has already a partical size of  $< 1\text{mm}$ , which corresponds to  $< 20$  mesh. All proposed applications except sucrose-extraction (2.5.2.1.) require a size reduction to at least  $< 60$  mesh. This can be achieved by milling the flour with a Wiley-mill, using a 60 mesh outlet-screen. Bigger quantities were produced with a disc-mill (Alpina, Augsburg 160 Z).

Size reduction of the other fractions will be discussed along with their specific application (2.5.2.), since no standard procedures are applicable.

#### 2.3.2. Flow sheet and process yield

Figure 18 shows the flow sheet for the complete milling and separation process, whereas Figure 19 illustrates the yield of each fraction obtained through this process.

Figure 18: Flow sheet for the milling and separation process

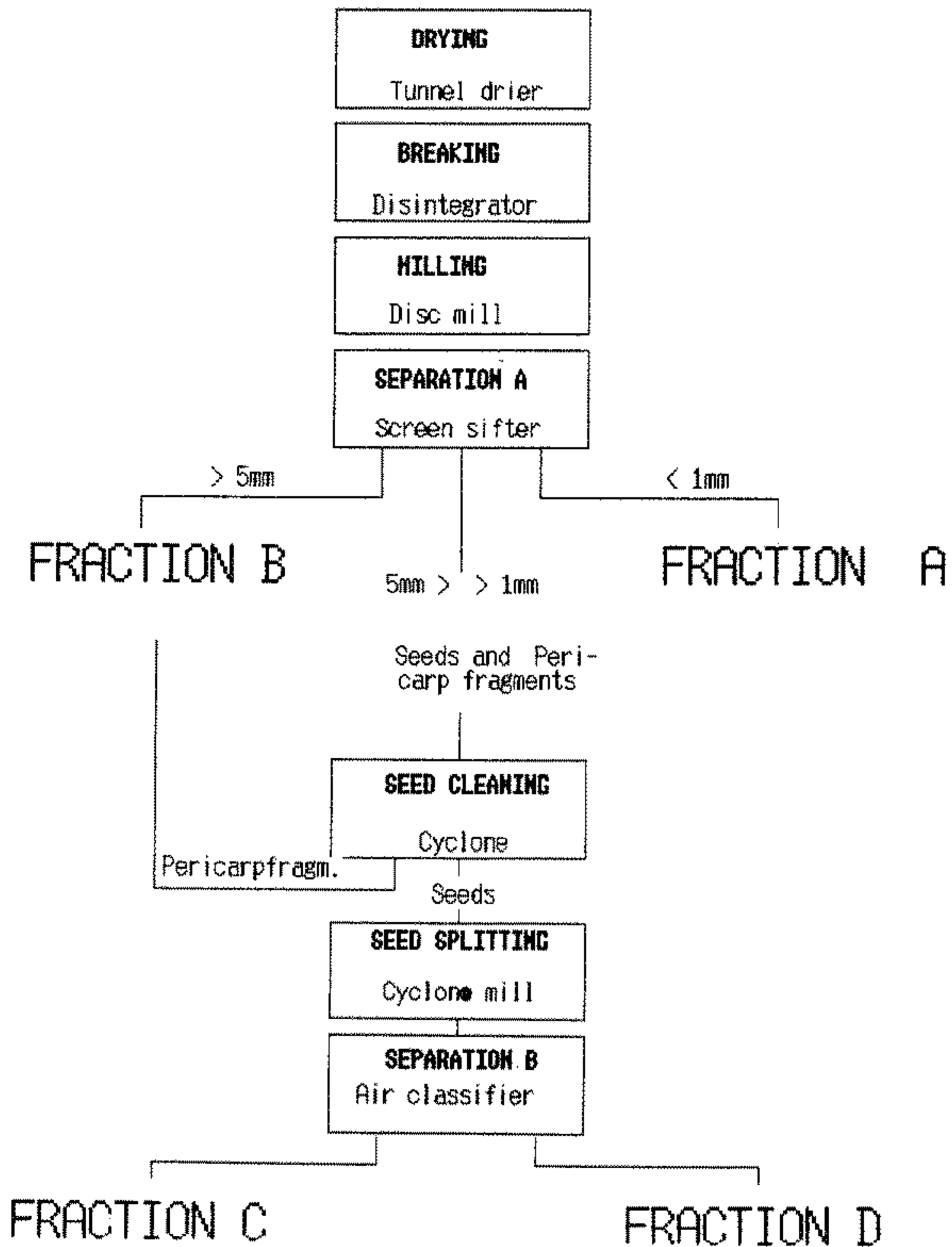
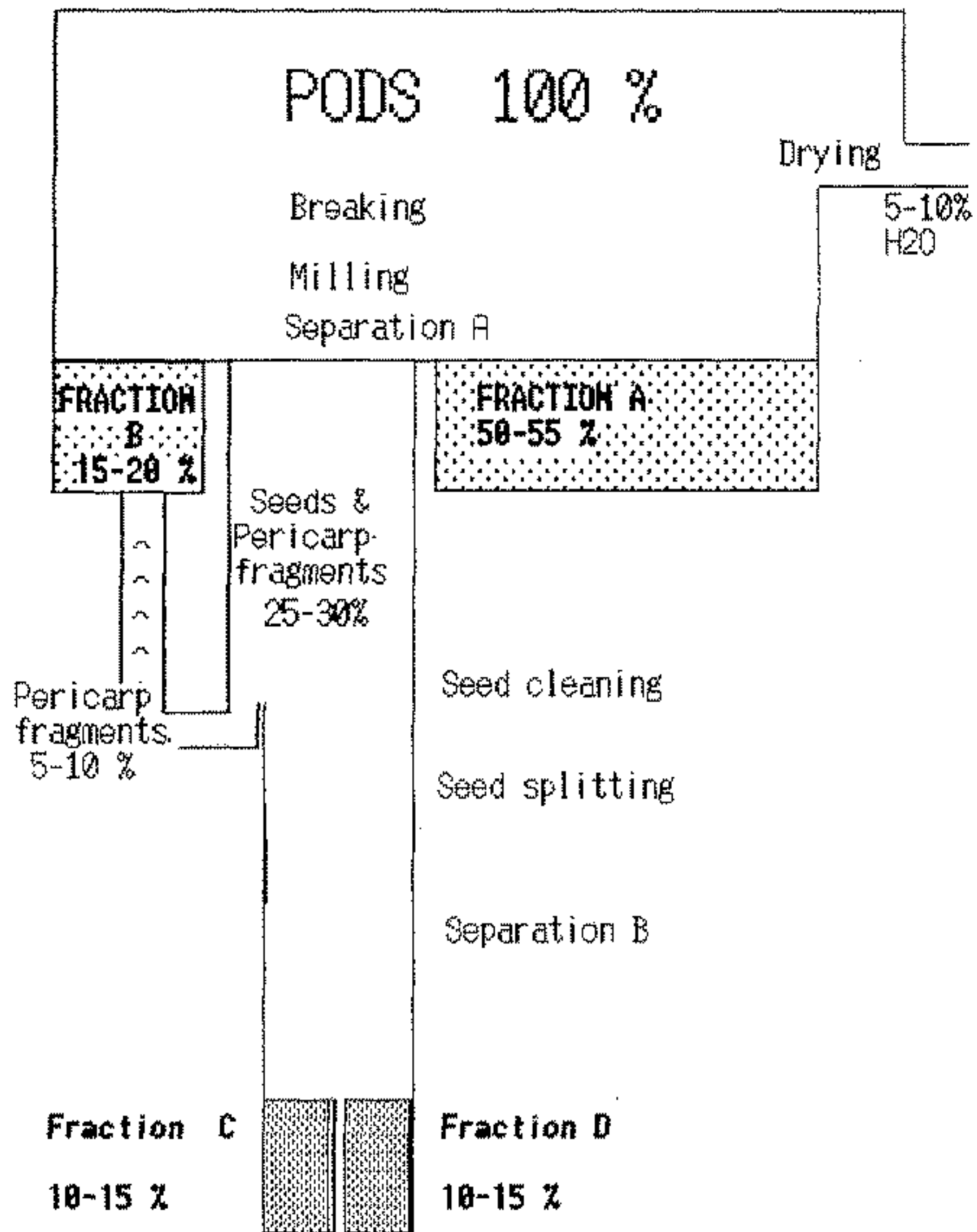


Figure 19: Process yield of the milling and separation process



2.4. Chemical composition of the pods

2.4.1. Detailed analysis of the fractions

Work by Becker (49), Figuereido (50) and Del Valle (58) concentrated on the chemical composition of either the whole pod or differentiated only between seeds and pericarp. The following chapters study the fractions as obtained by the described milling and separation process with regard to their possible application.

The results present a representative sample of all pods which were used and analyzed during the time of this study. They are based on a rounded average of samples of 25 different trees (P.velutina type), as well as extremes.

It was not attempted to investigate the minor compounds, but each chapter will mention other interesting substances found by other researchers (if applicable).

2.4.1.1. Fraction A

Tables 7-11 show the overall chemical composition of Fraction A (exo-and mesocarp) as well as the analysis of individual components (all results on a moisture-free basis).

Table 7: Chemical composition of Fraction A

Compound	Average %	Extremes %
Total sugars	48.0	25 ; 58
Protein (N x 6,25)	9.5	6 ; 11
Fat	2.0	0.8 ; 4
Crude Fiber	16.0	10 ; 23
Ash	4.5	3.7 ; 4.9

It is not surprising that almost all the sweetness of the pod is caused by the very high sugar content of Fraction A. Nevertheless, its percentage (close to half of the drymatter) is unique for a leguminous plant, only carob pods being comparable.

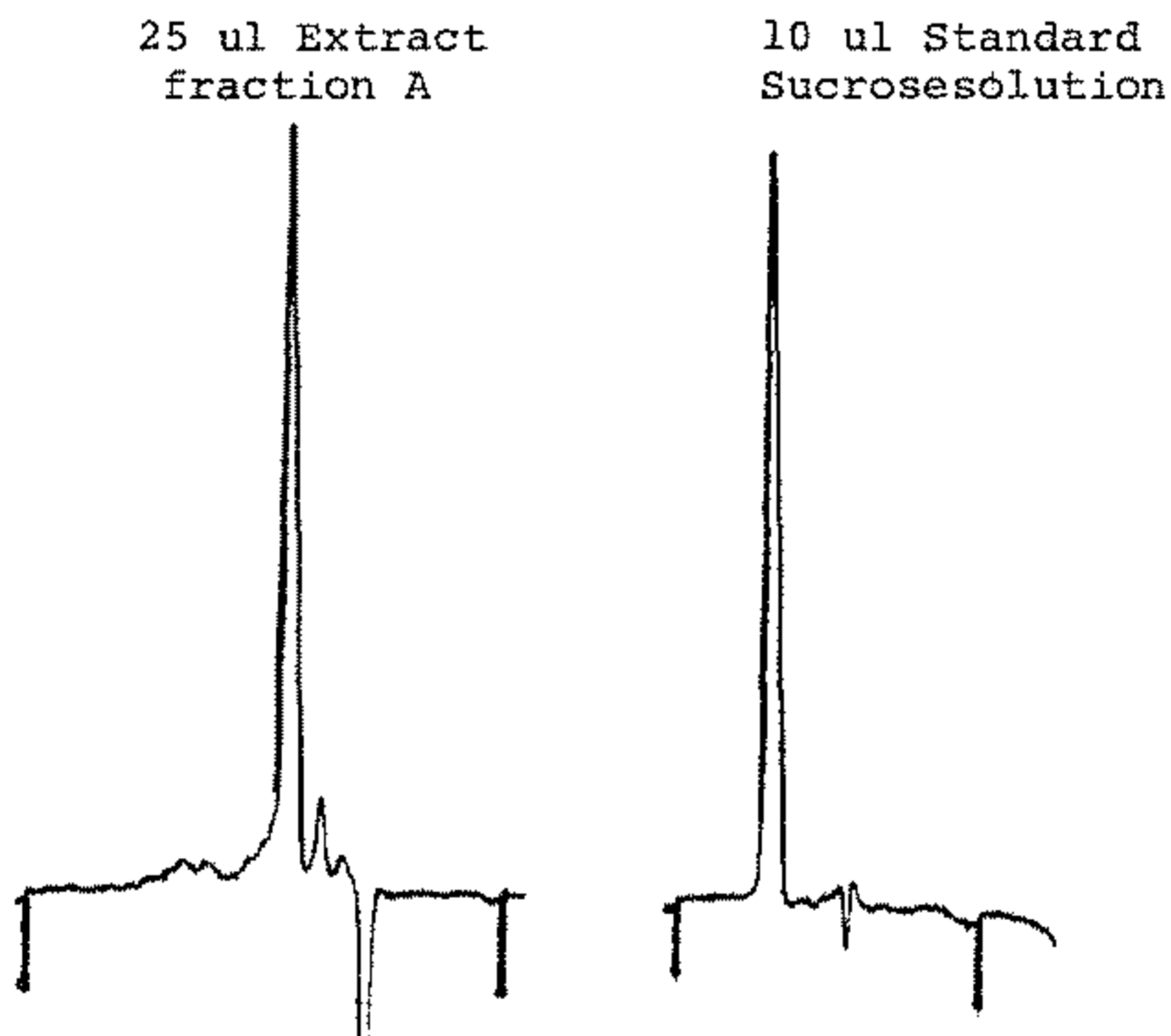


Sugars:

A considerable sweetness is the dominant organoleptic impression when tasting the flour of Fraction A. The question was, whether sucrose would be the only compound, or whether other sugars would also be detectable in large quantities. Samples that were analyzed by HPLC for sucrose/ glucose/ fructose resulted in a respective content of 92 % / 3 % / 5 % (Figure 20). Therefore, the ratio of sucrose versus reducing sugars is approximately 9:1 .

Figure 20: HPLC-analysis of a water extract of Fraction A

Solvent : Aldonitrilacetat:H2O = 80:20  
Flow : 2.0ml /min Refractiveindex : 8x  
Column : Water Associate Carbohydrate Column  
Printer : Atten. 8x; 10 mv AUFS Reference : Conrad (101)



---

Sugar components found by other researchers:

Malhotra (55) reports ellagic acid 4-O-rutinoside, to be present in pods of P. juliflora.

Becker (49) found small amounts of raffinose and inositol in the pericarp of P. velutina.

Shalaby (59) reports traces of rhamnose, galactose and glucuronic acid in the pericarp of P. stephaniana.

Protein:

The protein content of Fraction A is relatively high (close to 10%). In an attempt to determine its quality, the amino acid composition was investigated (Table 8).

Table 8: Amino acid composition of Fraction A

Analyzed with a Durram amino acid analyzer, Model D-500 (110)

Amino acid	Grams per 100g of Fraction A	mg per gram nitrogen	Provisional score (FAO) mg/g N (102)
ASPARTIC ACID	2.026	866	
THREONINE	0.461	197	250
SERINE	0.553	236	
GLUTAMIC ACID	1.784	762	
PROLINE	1.126	481	
GLYCINE	0.615	263	
ALANINE	0.561	240	
CYSTEINE	0.193	83	
VALINE	0.699	299	310
METHIONINE	0.125	54	(MET+CYS) 220
ISOLEUCINE	0.387	165	250
LEUCINE	0.933	399	440
TYROSINE	0.377	161	
PHENYLALANINE	0.385	165	(PHE+TYR) 380
HYSTIDINE	0.317	135	
LYSINE	0.506	216	340
ARGININE	0.975	533	

Fatty acids:

The small amount of fat (<3%) would definitely not justify to use this fraction as a source for oil. For reasons of completeness however, the fat which had been extracted with hexan from Fraction A had been analyzed by GLC for its fatty acid composition (Table 9).

Some technologically important characteristics are discussed in chapter 2.5.2.1.

Table 9: Fatty acid composition of Fraction A

Conditions:

Carriergas : N2 , pressure 4 bar, flow 30ml/min  
Detector : FID, H2 1.86 bar, Air 1.8 bar  
Oven temp. : 175°C isotherm Attenuation : 5

Fatty acid	Retention time	Area	Percentage
Myristic acid	1.47	1.1362	1.1
Palmitic acid	2.55	14.2899	13.7
Stearic acid	4.52	4.8313	4.6
Oleic acid	5.24	25.5500	24.5
Linoleic acid	6.65	48.6912	46.7
Linolenic acid	8.94	4.8374	4.6

-----  
Fat components found by other researchers:

Figueredo (50) found beta-sitosterin in the ether extract of the pericarp of P.juliflora.

Fiber:

Several different types of fibers of Fraction A were determined, in order to receive a most complete overview over this compound (Table 10).

Table 10: Types of fiber of Fraction A

Type of fiber	% of Fraction A
a) Dietary fiber	35.3
b) Crude fiber	16.0
-----	
c) Neutral detergent fiber	23.3
Standard deviation	0.7
d) Acid detergent fiber	24.7
Standard deviation	1.0
e) Lignin	5.7
Standard deviation	0.8
f) Cellulose	14.6
Standard deviation	1.0
=====	

a-b, respectively c-f, were determined on different batches

2.4.1.2. Fraction B

The endocarp hulls (Fraction B), which make up an average of 20-25 % of the pod, appear to be the least interesting part of the MESQUITE-pod. They are extremely hard and fibrous. Nevertheless, they deserve a closer look at their chemical constituents (Table 11)

In an attempt to obtain a better quality of Fraction B, the endocarphulls were milled in a pin-mill and separated into two fractions with a cut at 40 mesh. This separates quantitatively 1:1. Differences in their composition are listed in Tables 12 and 13.

Table 11: Chemical composition of Fraction B  
(on moisture-free basis)

Compound	Average % of Fraction B	Extremes	Fraction B	
			>40mesh	<40mesh
Total sugars	6.0	3; 11	-	-
Protein (N x 6,25)	6.5	4; 9	4.3	15.5
Fat	1.3	0.8; 1.8	-	-
Crude Fiber	45.0	39; 55	51.5	25.3
Ash	3.5	3.3; 3.9	3.0	3.5

Sugars:

The sugars found in Fraction B are most likely to be residues of Fraction A, since its percentage varies quiet widely.

Samples that were analyzed for sucrose and reducing sugars respectively, showed 97.5% sucrose versus 2.5% reducing sugars.

Protein:

The protein content of Fraction B averages around 6 % and is therefore considerably lower than in Fraction A . Its amino acid composition is shown in Table 12 (the analytical conditions are the same as shown in Table 8)

Table 12: Amino acid composition of Fraction B

Amino acid	Grams per 100g of Fraction A	mg per gram nitrogen	Provisional score (FAO) mg/g N (102)
ASPARTIC ACID	1.897	666	
THREONINE	0.541	190	250
SERINE	0.808	284	
GLUTAMIC ACID	2.929	1.029	
PROLINE	0.997	350	
GLYCINE	0.856	301	
ALANINE	0.710	249	
CYSTEINE	0.259	91	
VALINE	0.769	270	310
METHIONINE	0.054	19	MET+CYS 220
ISOLEUCINE	0.590	207	250
LEUCINE	1.186	416	440
TYROSINE	0.497	175	
PHENYLALANINE	0.664	233	PHE+TYR 380
HYSTIDINE	0.465	163	
LYSINE	0.812	285	340
ARGININE	1.516	533	

It is apparent, that the amino acid composition of Fraction B is very similar to the one of Fraction A, or even slightly more valuable, except for aspartic acid, proline and especially methionine, for which the percentage in Fraction B is significantly below Fraction A and only about 15% of the FAO-score.

Fiber:

For the analysis of the fiber content of Fraction B (Table 13), the same methods were used as for Fraction A. It is evident that this fraction has a very high fiber content.

Table 13: Types of fiber of Fraction B

Fiber	% of Fraction B	Fraction B	
		>40mesh	<40mesh
a) Dietary fiber	61.6	-	-
b) Crude fiber	45.0	51.5	25.3
c) Neutral detergent fiber	69.0	85.0	52.9
Standard deviation	3.5	2.3	4.8
d) Acid detergent fiber	53.7	69.5	37.8
Standard deviation	2.8	2.4	3.2
e) Lignin	9.8	11.3	8.2
Standard deviation	0.8	0.6	1.1
f) Cellulose	41.0	54.8	27.2
Standard deviation	2.2	1.6	2.7

a-b, respectively c-f, were determined on different batches

2.4.1.3. Fraction C

Fraction C in its form after the milling and separation process consists of two different morphological parts, namely the seed coat and the endosperm; the combination is called **endosperm split**. The seed coat is a very thin, brown and fibrous layer, which adheres to the transparent endosperm.

A complete separation of the seed coat from the endosperm can only be achieved manually. The endosperm split has to be soaked in water and can then be peeled off carefully.

Analysis of these two parts reveals differences in their composition. These results as well as the composition of the complete Fraction C is shown in Table 14.

Table 14: Composition of Fraction C

Compound	Fraction C %	Seed coat %	Endosperm %
H2O	6.0	-	-
Protein (Nx6.25)	4.0	6.2	3.1
Crude Fiber	7.6	18.1	0.6
Fat	0.0	0.0	0.0
Gum content (by diff.)	<b>82.5</b>	75.7	96.3

The most interesting constituent of Fraction C as far as its commercial utilization is concerned, is the carbohydrate fraction of the endosperm.

GLC-analysis reveals that it consists predominantly of a galactomannan (a polysaccharide similiar to locust bean and guar gum. Galactomannans form highly viscous solutions at low concentrations. This interesting characteristic is well known. Galactomannans are therefore used extensively for thickening purposes (61;62;63;64).

The carbohydrate of MESQUITE Fraction C contains also traces of other sugars. Table 15 shows their quantitativ distribution.

Table 15: GLC-analysis of the hydrolysate of MESQUITE endosperm

Monosaccharide	Retention time	Concentration (%)
Rhamnose	99	0.225
Fucose	123	0.100
Arabinose	139	4.182
Xylose	156	1.957
Xylit	177	0.222
<b>Mannose</b>	<b>221</b>	<b>56.470</b>
Glucose	248	0.596
<b>Galactose</b>	<b>269</b>	<b>36.240</b>



According to Table 15, the mannose : galactose ratio is 1:1.6, which is similar to guar gum. This ratio is important for some of the functional properties of the galactomannan (Chapter 2.5.2.3.).

It is known from other galactomannans that this ratio can vary widely among different species, place of origin or even seasonally (61). As an example, for Prosopis juliflora, a mannose : galactose ratio of 1:4.2 has been reported (108). Another variable is the actual amount of galactomannan in Fraction C. This will be discussed in Chapter 2.4.2.

In chapter 2.5.2.3., methods are described how the purity of Fraction C can be increased. Purity means a higher percentage of endosperm or a reduction of the seed coat.

#### 2.4.1.4. Fraction D

The cotyledons and the tiny germ make up Fraction D, which is yellow and of a relatively soft structure.

The germ itself is so small that it is almost impossible to visually or physically separate it from the cotyledons. The whole Fraction consist basically of protein and fat, as shown in Table 16.

Table 16: Chemical composition of Fraction D

Compound	Average %	Extremes %
Moisture	4.5	2.0 ; 6.0
Protein (N x 6,25)	61.0	56.0 ; 63.0
Fat	8.0	5.0 ; 11.0
Crude Fiber	4.0	3.0 ; 6.0
Ash	4.7	4.1 ; 5.1

Protein:

The amino acid composition of Fraction D is shown in Table 17.

Table 17: Amino acid composition of Fraction D

Amino acid	Grams per 100g of Fraction D	mg per gram nitrogen	Provisional score (FAO) mg/g N (102)
ASPARTIC ACID	4.583	505	
THREONINE	1.321	146	250
SERINE	2.291	253	
GLUTAMIC ACID	11.214	1236	
PROLINE	4.093	445	
GLYCINE	2.508	276	
ALANINE	2.290	252	
CYSTEINE	0.961	106	
VALINE	2.198	242	310
METHIONINE	0.550	61	MET+CYS 220
ISOLEUCINE	1.777	196	250
LEUCINE	4.148	457	440
TYROSINE	1.500	165	
PHENYLALANINE	2.134	235	PHE+TYR 380
HYSTIDINE	1.696	187	
LYSINE	2.292	253	340
ARGININE	7.552	832	

-----

Components in the seeds reported by other researchers:

Beri et al. (65) reports 3.92 % starch in the defatted seeds of Prosopis cineraria.

Bhardwaj et al. (52 and 53) found some polyphenolics in the seeds of Prosopis spiciqera: gallic acid, patuletin, luteolin, patulitrin, rutin, prosogerin E and D.

Pant et al. (54) reports two polystyrenes in the seeds of Prosopis juliflora.

Chellamuthu et al. (67) reports a percentage of 17.25 % fat in Prosopis juliflora seeds with a saponification value of 179.1 mg, iodine number of 69.75 and acid value of 8.55 .

Figueiredo (50) checked seeds of Prosopis juliflora for free amino acids and found arginin, glutamic acid, leucin and alanin. He found two major proteins with molecular weights of 77 000 and 96 500.

2.4.2. Chemical variation in the main constituents of different pods

It is known, that pods from the same species but different trees vary widely in their apparent sweetness. This had been observed by simply chewing the pods. It therefore seemed to be interesting to determine, whether the compositional differences are limited only to the sucrose content or if they are found in other dominant constituents as well. For that purpose, pods from 16 different trees were collected at random, milled and separated as described in Chapter 2.3.. The fractions obtained were then analyzed chemically (Table 18).

Table 18: Compositional variation, Fraction A

Pod #	Total Sugars Sucrose +Glucose	Protein Nx 6.25	Fat	Crude Fiber
FN 1	45.6	10.4	2.2	12.6
FN 2	54.2	9.9	1.6	11.6
FN 5	43.2	8.4	1.7	14.2
FN 12m	43.4	9.1	1.8	19.3
FN 15	50.2	7.7	2.8	14.6
FN 15/30	47.0	8.9	2.25	13.2
FN 16	39.9	7.4	1.3	14.9
FN 17	41.9	10.2	1.7	16.5
FN 23	52.3	5.7	1.6	13.0
12 A	48.2	9.1	1.6	12.9
12 B	46.2	8.9	2.7	10.1
12/8	50.0	7.1	2.1	14.3
3/38	49.6	7.7	1.3	13.6
18/19m	56.4	7.8	1.4	11.1
X	39.0	8.7	2.9	16.3
X 2	46.8	9.0	1.7	17.0
-----				
Average	47.1	8.6	1.92	14.1
-----				
Standard- deviation	4.9 =10.4%	1.5 =17.4%	0.5 =26.0%	2.4 =17.0%
=====				

The analysis shows that the composition does not only vary in the total sugar content, but even more significantly in the other constituents of Fraction A. Nevertheless, the sugars are the absolute dominant ingredients of this fraction, accounting for almost half of it.

Fraction B consists mainly of crude fiber. The other components however vary more significantly (Table 19).

Table 19: Compositional variation, Fraction B

Pod #	Total Sugars Sucrose + Glucose	Protein N* 6.25	Fat	Crude Fiber
FN 1	9.4	5.0	1.4	46.2
FN 2	10.6	6.9	1.0	45.6
FN 5	4.4	4.3	1.3	54.8
FN 12m	4.3	9.1	1.7	40.4
FN 15	6.5	5.7	1.4	41.6
FN 15/30	8.8	6.5	1.8	41.4
FN 16	5.7	5.9	1.2	45.7
FN 17	7.6	6.8	1.1	48.8
FN 23	5.3	4.6	0.8	51.7
12 A	7.3	5.7	1.2	41.1
12 B	5.7	6.3	1.1	46.6
12/8	5.9	4.9	1.0	47.1
3/38	11.0	7.5	1.1	39.4
18/19m	5.8	6.9	0.9	46.2
X	7.0	5.8	1.2	44.0
X 2	4.2	6.1	1.7	39.0
-----				
<b>Average</b>	<b>6.8</b>	<b>6.2</b>	<b>1.3</b>	<b>45.0</b>
-----				
<b>Standard- deviation</b>	<b>2.2</b>	<b>1.2</b>	<b>0.45</b>	<b>4.5</b>
	<b>=32.4%</b>	<b>=19.4%</b>	<b>=34.6%</b>	<b>=10.0%</b>
=====				

As already mentioned in Chapter 2.4.1.3, the interesting question regarding the compositional variation of Fraction C is its ratio of galactose : mannose. Table 20 shows the results.

Table 20: Compositional variation, Fraction C

Pod#	Mannose:Galactose	Pod#	Mannose: Galactose
FN 2	1.14	FN 23	1.22
FN 5	1.22	12 A	1.40
FN 12m	1.99	12 B	1.43
FN 15	1.26	12/8	1.24
FN 15/30	1.14	3/38	1.31
FN 16	1.38	18/19m	1.36
FN 17	1.37	X	1.04
X-2	1.52		
<b>Average</b>			<b>1.314</b>
<b>Standard-deviation</b>			<b>0.228</b>

It can be seen that the galactomannan composition of all samples is within a relatively narrow range, even though the deviation within each sample was above satisfaction, probably due to impurities. The result satisfies insofar as the variation is too small to cause measurable functional differences.

The ratio of Fraction C to Fraction D of a seed is also of importance. A small seed with a high percentage of Fraction C could eventually give a higher yield of galactomannan than a large seed which consists primarily of Fraction D.

The ratio was determined by splitting the seeds with the graintester (see chapter 2.3.1.6.), sieving out the fine material that is being produced, and weighing the two fractions. The protein content of the fine material was analyzed and compared to the protein content of the pure Fraction C and D respectively. This allowed to determine the percentage of each Fraction lost in this fine material, and led to the correction factor in determining the ratio of Fraction C to D (Table 21).

Example for the determination of correction factor:

Composition of fine material= 75% Fraction D + 25% Fraction C  
 % fine material = 40%

Fraction C = 2.95g  
 Fraction D = 2.61g      Fine material = 3.71g  
 Effective C = 2.95g + 0.25 x 3.71g = 3.88g  
 Effective D = 2.61g + 0.75 x 3.71g = 5.39g

Uncorrected ratio of C:D = 2.95 / 2.61 = 1.13  
 Corrected ratio of C:D = 3.88 / 5.39 = 0.72  
 Correction factor = 0.62

The results of this study with the correction factor are shown in Table 21

Table 21: Compositional variation, Ratio of Fration C:D

Pod #	C:D	Pod#	C:D
FN 1	0.71	FN 23	1.10
FN 2	1.12	12 A	0.50
FN 5	0.71	12 B	0.69
FN 12m	0.56	12-8	0.69
FN 15	0.71	3-38	0.74
FN 15/30	0.60	18/19m	0.80
FN 16	0.66	X	0.74
FN 17	1.00	X-2	0.60
<b>Average</b>		<b>0.75</b>	
<b>Standard-deviation</b>		<b>0.18</b>	

The average ratio of Fraction C:D translates into a morphological seed composition of 43% endosperm splits and 57% cotyledons.

In contrast to Fractions A and B (Tables 18,19), Fraction D does not show a significant variations in the amounts of its main constituents. Protein, which accounts for more than half of this fractions, is found in very similiar percentages in all pods analyzed, whereas the fat content deviates to a somewhat greater extend (Table 22).

Table 22: Compositional variation, Fraction D

Pod #	Protein (N * 6.25)	Fat
FN 1	56.1	9.6
FN 2	52.0	9.4
FN 5	60.4	7.6
FN 12m	56.3	8.0
FN 15	56.9	7.5
FN 15/30	56.2	9.0
FN 16	57.7	7.7
FN 17	57.1	7.2
FN 23	59.2	7.5
12 A	56.3	6.2
12 B	55.6	8.0
12/8	55.6	9.3
3/38	59.1	7.0
18/19m	60.7	7.3
X	57.9	7.4
X 2	56.6	6.9
<b>Average</b>	<b>57.1</b>	<b>7.85</b>
<b>Standard-</b>	<b>2.1</b>	<b>1.0</b>
<b>deviation</b>	<b>=3.7 %</b>	<b>=12.7 %</b>





## 2.5. Uses and applications of pod fractions

### 2.5.1. Objectives

The overall objective concerning the use of the MESQUITE-pods is to find the optimal application for each fraction in or as a food product.

"Optimal" is defined as the application which takes maximal advantage of the functional characteristics, leaves a minimal amount of unusable residue and provides the highest economical value.

The following applications fulfill these criterias to varying degrees. Such applications are nevertheless described with regard to the use of MESQUITE in lesser developed countries, where the most important criteria is to produce foodstuff for survival.

Some products might also be unfamiliar to the reader since they are specific to certain areas where MESQUITE grows or had traditionally been consumed. All applications are based on the fractions as received by the milling and separation processes described in Chapter 2.3. .

### 2.5.2. Applications of the various fractions

#### 2.5.2.1. Fraction A

Fraction A is quantitatively the most important fraction, since it represents almost 60% of the whole pod. The chemical analyses in Chapter 2.4.2.1. revealed, that sucrose is the major compound of the flour (45%), followed by fiber and protein. Therefore, the use of Fraction A as a raw material for sucrose extraction is the first and most obvious application.

The use of Fraction A in composite-flours for cereal-based products will also be described. However, its major disadvantage, i.e. the complete lack of starch or a structure-building protein, such as gluten, will be shown to restrict this type of application to either low percentage of incorporation of Fraction A, or to products where structure is not the dominant characteristic.

#### 2.5.2.1.1. Sucrose extraction

In many areas where MESQUITE grows wild, such as the Imperial-valley in Southern California or Hawaai, sugarcane or sugarbeets are grown and processed nearby.

MESQUITE compares favorable to the two traditional sucrose-sources on "as is" sucrose-percentage (sugarbeet 10-15%; sugarcane 14-26%; MESQUITE 30-~~50~~%).

The following list provides some thoughts why or why not, MESQUITE could be an interesting alternative to the traditional sugar crops.

#### Advantages:

- Sugarbeet processing starts in october, so MESQUITE would fit in off season of sugar production.
- Sucrose plants show currently low profitability, partly because of the short season.
- Sucrose is the main compound of MESQUITE Fraction A.
- Infrastructure already available.

#### Disadvantages:

- High soluble protein and mineral content of MESQUITE Fraction A interferences with the crystallisation and purification of sucrose.
- Existing surplus of sucrose in many countries except Mexico which has to import 300 000 tons of sugar in 1984 (103).
- Extremely high energy and water input.

#### Conclusions:

MESQUITE Fraction A should be processed using the already existing machinery and process steps of a conventional sugar-plant. No major changes should be required, the product should not compete head-on with regular sugar, but be sold as a "special" MESQUITE sugar.

Another possibility would be to stop the process before crystallization, or to invert some of the sucrose in order to produce a liquid sweetener or syrup, such as a maple syrup.

Therefore, the following experiments were based on the known methods of sucrose extraction as known from sugar beet processing, without attempting to produce a high purity sucrose identical to a conventional sugar.

a) Preparation of small batches of sucrose syrup for analytical purposes

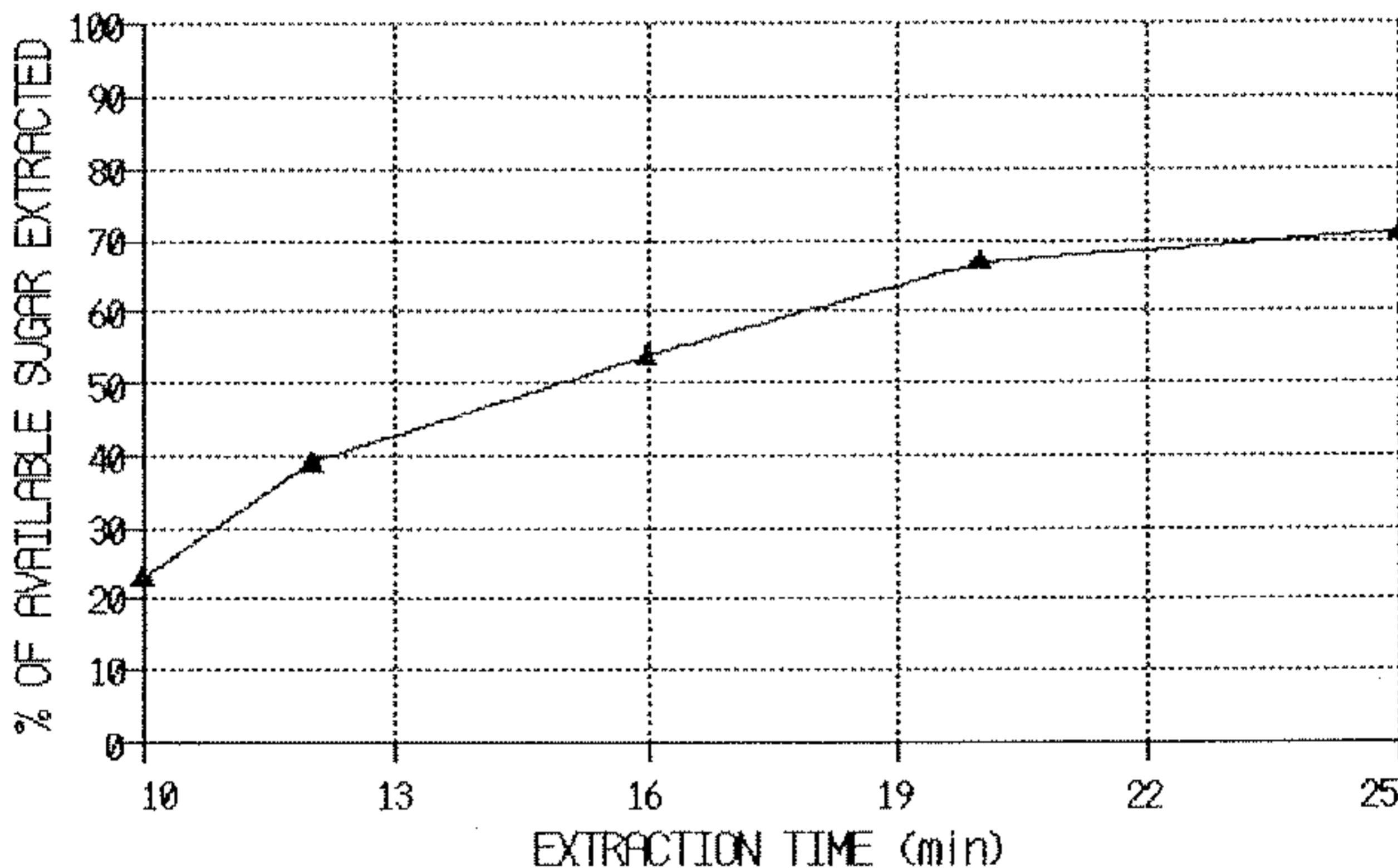
---

- Give 20g MESQUITE-Fraction A to 200ml H<sub>2</sub>O
- Heat solution to 80 °C for up to 20 min
- Filter solution through cheesecloth
- Run filtrate through roundfilter
- Heat filtrate to 80 °C, add 2% CaO then keep at the temperature for 20-25 min
- Cool filtrate to 25 °C
- Centrifuge for 20 min at 12 000 rpm
- Decant supernatant , set aside the sediment for analysis
- Inject CO<sub>2</sub> to supernatant for 5 minutes
- Second centrifugation for 20 minutes at 12 000 rpm
- Add 2 % activated charcoal and stir solution for 5 minutes
- Centrifugation for 20 min at 12 000 rpm
- Decant supernatant and concentrate in evaporator to 12.5 % sucrose (refractive index= 1.3515 )
- Analyze supernatant by HPLC to determine sugar purity (see Chapter 2.4.2.)

Samples were kept at 80 °C for different length of times in order to determine the necessary extraction time (Figure 21). Heating for 20 minutes at 80 °C proved to be sufficient to extract around 70% of the theoretically available sugar.

Protein (N x 6.25) in the extract was also determined; the ratio of sucrose:protein in the extract varied from 7.2 after 10 minutes extraction, to 8.2 after 20 minutes extraction.

Figure 21: Extraction curve for sucrose from Fraction A at 80°C

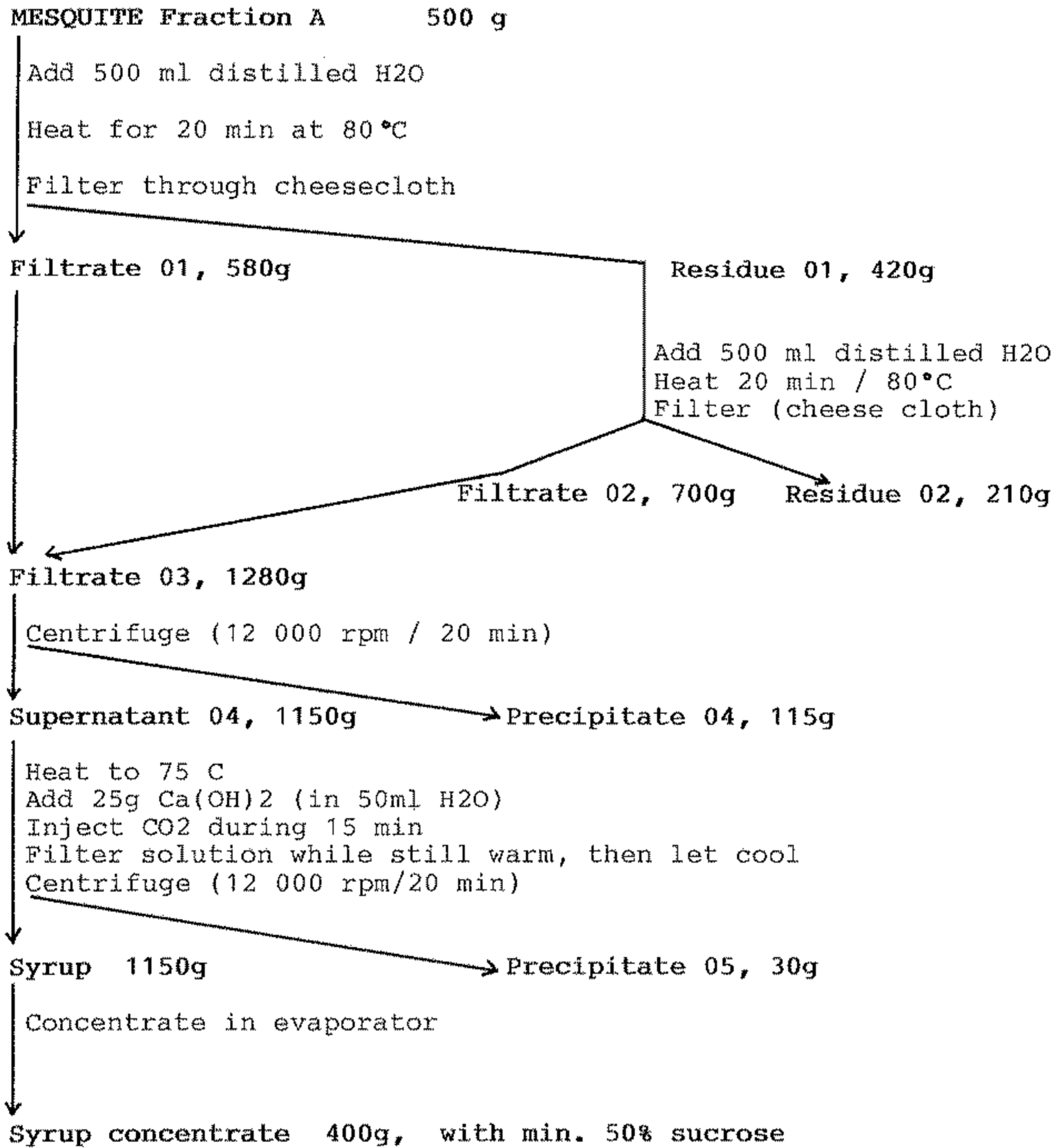


b) Procedure to obtain pilot plant scale batches of sucrose syrup

---

The procedure follows basically the same system as described for small batches, but more data could be collected on a larger scale. The method is based on the industrial procedure for sugar beet processing (68), except for the first few steps that are not necessary for MESQUITE and for the final crystallization. Attention was given to minimize the amount of water and energy to be used (Figure 22).

Figure 22: Sucrose extraction process for MESQUITE Fraction A



The intermediate and end products of the process described in Figure 22 were analyzed in order to determine the accuracy and efficiency of the system. The raw material that was used had relatively low percentage of sucrose of 42%.

Table 23 shows the results. The values also correspond to the preceding page. Figures 23-25 show the extraction at different stages as well as intermediate products of the extraction process.

Table 23: Chemical analysis of intermediate and end products of the sucrose-extraction from MESQUITE Fraction A

Product	g (* )	Sucrose % of product	% yield	Protein % of product	%
MESQUITE Fraction A	500	42		10	
<u>1.Extraction</u>					
Filtrate 01	580	21	58	4.2	49
Residue 01	420	21	42	6.1	51
<u>2.Extraction (of residue 01)</u>					
Filtrate 02	700	7.4	25	1.5	21
Residue 02	210	12.2	12	6.9	29
Filtrate 03 (=F 01+02)	1280	13.6	83	2.7	70
<u>1.Centrifugation (of filtrate 03)</u>					
Super- natent 04	1150	13.5	74	1.8	32
Pre cipitate 04	115	12.1	6.5	12.0	28
<u>2.Centrifugation (of supernatent 04)</u>					
SYRUP	1145	13.1	71	1.2	28
Pre- cipitate 05	30	13.0	2	7.0	4

(\*) added water included

It is certainly no surprise, that the pilot plant scale process does not achieve the same extraction rate as the one in the laboratory experiment. Nevertheless, 70% of all available sucrose can be found in the end product after a two step extraction and multiple purification procedures, which effectively separate most of the protein, but also reduce the yield of sucrose slightly. The figures could certainly be improved by enforced stirring of the flour in the solution, or by an increase in the amount of extraction liquid, which in turn would increase costs significantly.

Table 24 illustrates the output of usable product. The table also shows the mineral content of the syrup, which serves as a quality standard in the sugar industry.

Table 24: Input / output of sucrose extraction

	Sucrose g	Protein g	Crude fiber,g	Zn	Mg	Fe	Cu	Ca	Na
				ppm			g/100g		
=====									
Input:									
500g MESQUITE									
Fraction A	210	50	90						
-----									
Output:									
400 ml MESQUITE									
Syrup	150	14	0	17	4	20	2	0.4	0.1
160g usable									
Residue	26	14	85						
=====									

The numbers do not necessarily add up to 100% due to material losses and percentages of compounds which are precipitated through centrifugation, and do not present reusable material.

The syrup represents a good tasting end product, which can be compared to a maple syrup even though its aroma is more pronounced. It could be used as a raw material for softdrinks such as rootbeer, pancake syrup or as a general purpose liquid sweetener.

Crystallization is possible, however in this study could not be carried out due to unavailability of equipment.

The residue represents a fibrous by-product with hardly any value except for feeding purposes.

#### Fermentation:

The syrup might also serve as a raw material for alcoholic beverages after fermentation. A small experiment has been performed to investigate this possibility:

-1 g *Saccharomyces cerevisiae* was given to 200 ml MESQUITE syrup with 14.2 °Brix (pH value 5.3) and fermented at 25°C. After 48 hours no more CO<sub>2</sub>-production could be observed and the pH value had reached 6.5 .

-The solution was centrifuged during 20 min at 10 000 rpm, the supernatant still measured 6.5 °Brix.

-Evaporation under vacuum resulted in 50 ml destillate with 9.1 % alcohol (v/v) or 7.3 % (w/v) (was determined with an ebulliometer; boiling point : 92.9°C).

-An additional 1g of yeast was added and the fermentation continued for 24 hours. 2.2 % alcohol (v/v) could again be recovered. Therefore, with an input of 28.4 g sucrose, which would theoretically result in 14.2 g alcohol, and an actual yield of 6.95 g, the efficiency of the fermentation was 49%.

The low yield is probably due to sub-optimal fermentation conditions.

The obtained destillat had a very pleasant taste.

For the production of alcohol, it might be more reasonable to ferment the complete Fraction A, rather than to extract the sugars, since the residue of the extraction does not represent a valuable material.

Some research has been published on the successful fermentation of whole MESQUITE pods to alcohol for energy production (69). This however represents a completely different approach in the utilization of MESQUITE pods. Nevertheless, it might be an interesting possibility in a mixed-use concept. .



Figure 23: Sucrose extraction:  
first stage

---

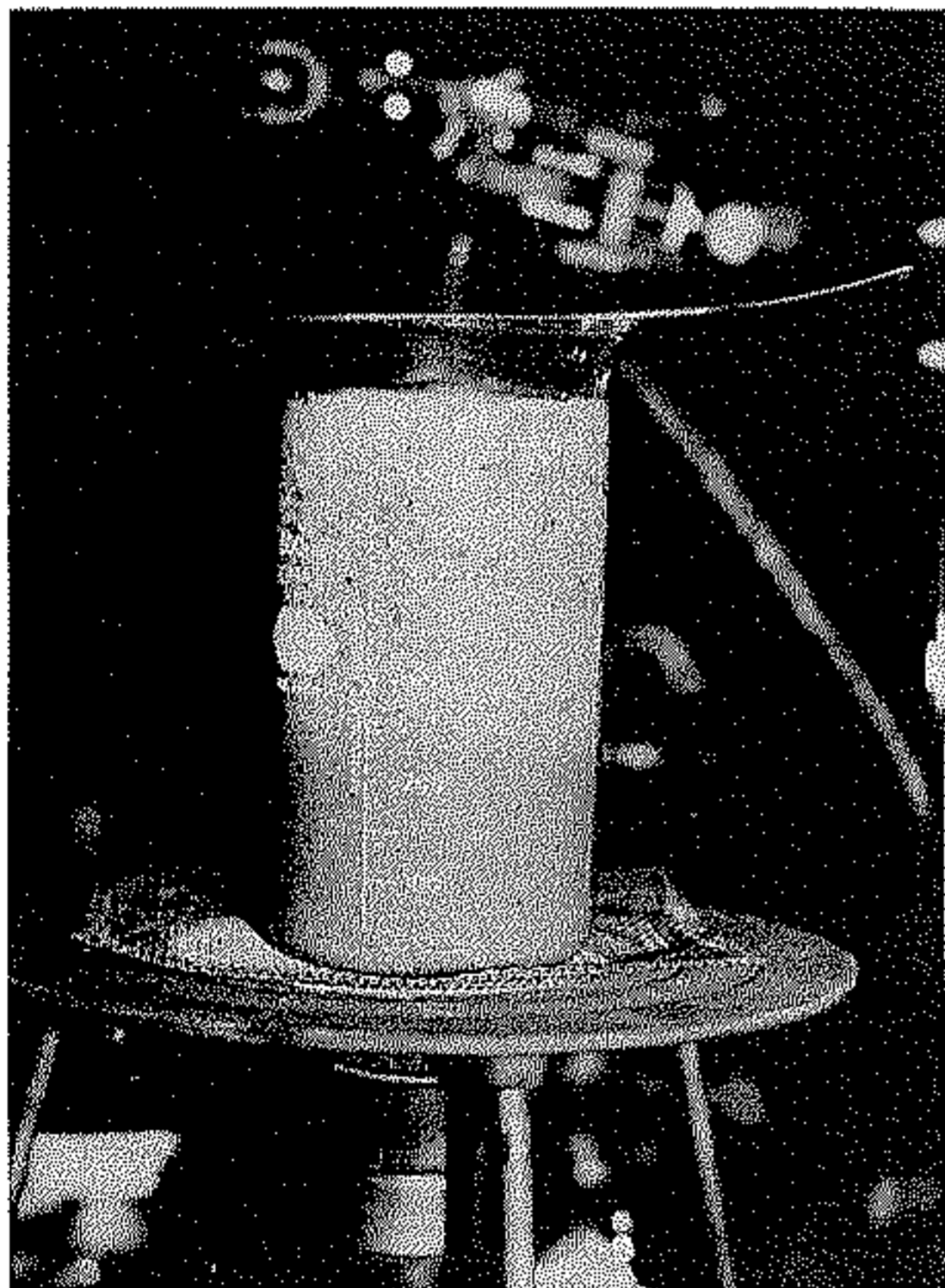
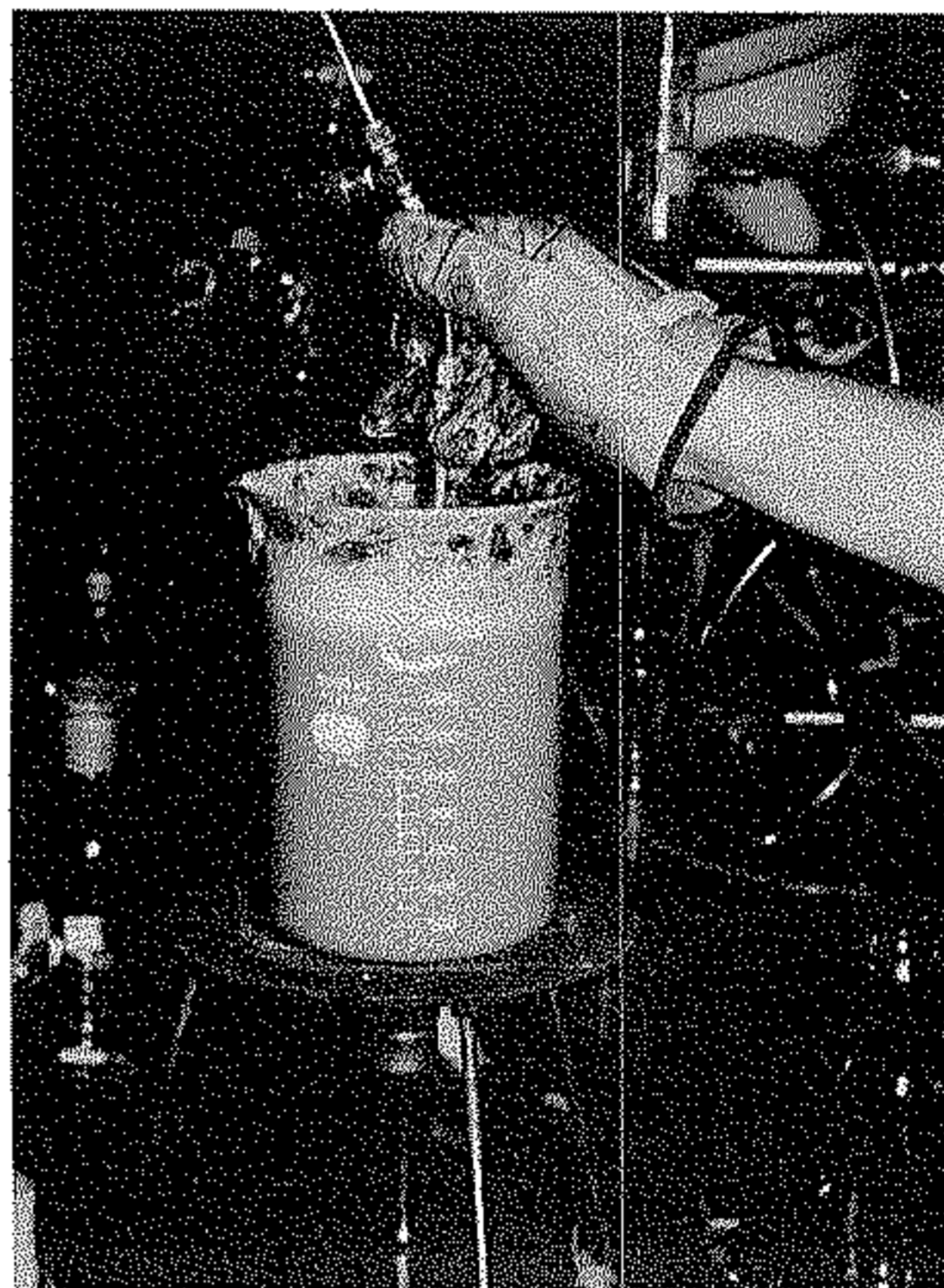


Figure 24: Sucrose extraction:  
CO<sub>2</sub>-injektion

---



#### 2.5.2.1.2. Composite flours

The use of legumes in composite flours is not new. Soy flour, pea flour and other similar raw materials have been suggested as a partial substitute for cereal flours. Some mixtures are currently used, whereas others have never found wide acceptance.

In order to justify the use of MESQUITE Fraction A in products such as bread, its baking qualities would have to bring some advantages over a product without MESQUITE or at least provide a special taste. In lesser developed countries (LDC) with under-supply of food, the situation is different. It would already be promising to find ways to incorporate MESQUITE at levels where the taste of a product would be acceptable. Incorporation in existing products would not require major changes at production level. A nutritional improvement of already existing products through addition of MESQUITE would definitely be helpful in establishing its use.

Therefore, the application of MESQUITE Fraction A in composite flours has to be concentrated on the following possibilities, where each end product has to fulfill different criterias:

US market:

- Use in regular American leavened bread.
- Use in other cereal-based products such as drum dried flakes, crackers, biscuits and deep-fried snacks.

LDC market:

- Use in unleavened breads, which are produced in most lesser developed countries (chapati).
- Use in other cereal-based and widely used products such as corn tortillas.

This chapter discusses the possibilities and limits of the use of MESQUITE Fraction A, with emphasis on the feasibility rather than on recipe optimization.

#### 2.5.2.1.2.1. Leavened Bread

The procedure to investigate a possible incorporation of MESQUITE Fraction A in regular leavened bread was as follows:

Breads were prepared according to standard recipes with different percentages of MESQUITE Fraction A. An internal panel tasted the products and determined the level at which the incorporation of Mesquite Fraction A was detectable, and the level at which the bread is judged negatively due to its taste.

Judged for taste only (not for volume nor color) an addition above 10% MESQUITE Fraction A could be detected, but was still acceptable.

However, at concentrations above 25% the taste of the bread became increasingly adstringent and was no longer acceptable. Therefore, the dough and baking characteristics of breads were investigated with additions of 10% to 25% MESQUITE Fraction A (some results also refer to breads with higher percentages)

The major variable in the recipes besides the flour itself, is sucrose, since MESQUITE Fraction A already consist of roughly 40% sucrose. Therefore, with the CONTROL containing 4 parts sucrose (based on 100 parts flour), a bread with 12 parts MESQUITE Fraction A requires no additional sucrose. At all other levels, the recipes were adjusted accordingly.

The percentage of water is also depending on the amount of MESQUITE Fraction A, since the water holding capacity of MESQUITE Fraction A is very low. In order to obtain a dough similar to one without MESQUITE, added water has to be reduced by 0.5% for each percent of MESQUITE (example: 10% MESQUITE - 95% H<sub>2</sub>O). Breads were also prepared using MESQUITE syrup (see Chapter 2.5.2.1.1.) instead of the complete MESQUITE Fraction A, and using no additional sucrose.

Composition of leavend bread with MESQUITE Fraction A:  
-----

100 parts	Flour (100%- 75% whole wheat Peavey; 0% - 25% MESQUITE Fraction A)
3 parts	Shortening (Crisco)
2 parts	NaCl
4 parts	Sucrose ( - correction)
3 parts	Yeast
59 parts	H <sub>2</sub> O (- correction )

Procedure:

- Add ingredients to water
- Mix for 5 minutes in laboratory-mixer
- Fermentation: 105 minutes at 29°C / 90% rh
- 1st punch, fold dough
- Fermentation 20 minutes
- 2nd punch, roll dough and make 2 loafes
- Fermentation 55 minutes
- Baking 25 minutes / 220°C

The following results show data collected from doughs with different percentages of MESQUITE Fraction A.

Dough developement (Figure 25): Due to the lack of starch and gluten in MESQUITE Fraction A, the dough development suffers with increasing percentage of MESQUITE. The dough development takes a relatively long time and the strength is reduced, but it does not come to a radical breakdown.

The addition of 1% guar gum (or eventually MESQUITE gum) distinctly improves the dough characteristics. The dough improvement by the gum is also visible in the mixer. Dough without gum is very difficult to handle in comparison to one with 1% gum. Figure 25 shows the farinograms of doughs with 50% MESQUITE Fraction A with and without guar-gum. Locust bean gum and methyl cellulose do not lead to the same improvement.

Figure 25: Farinogram of a dough with 50% MESQUITE Fraction A

a) without gum

b) with 1% guar gum

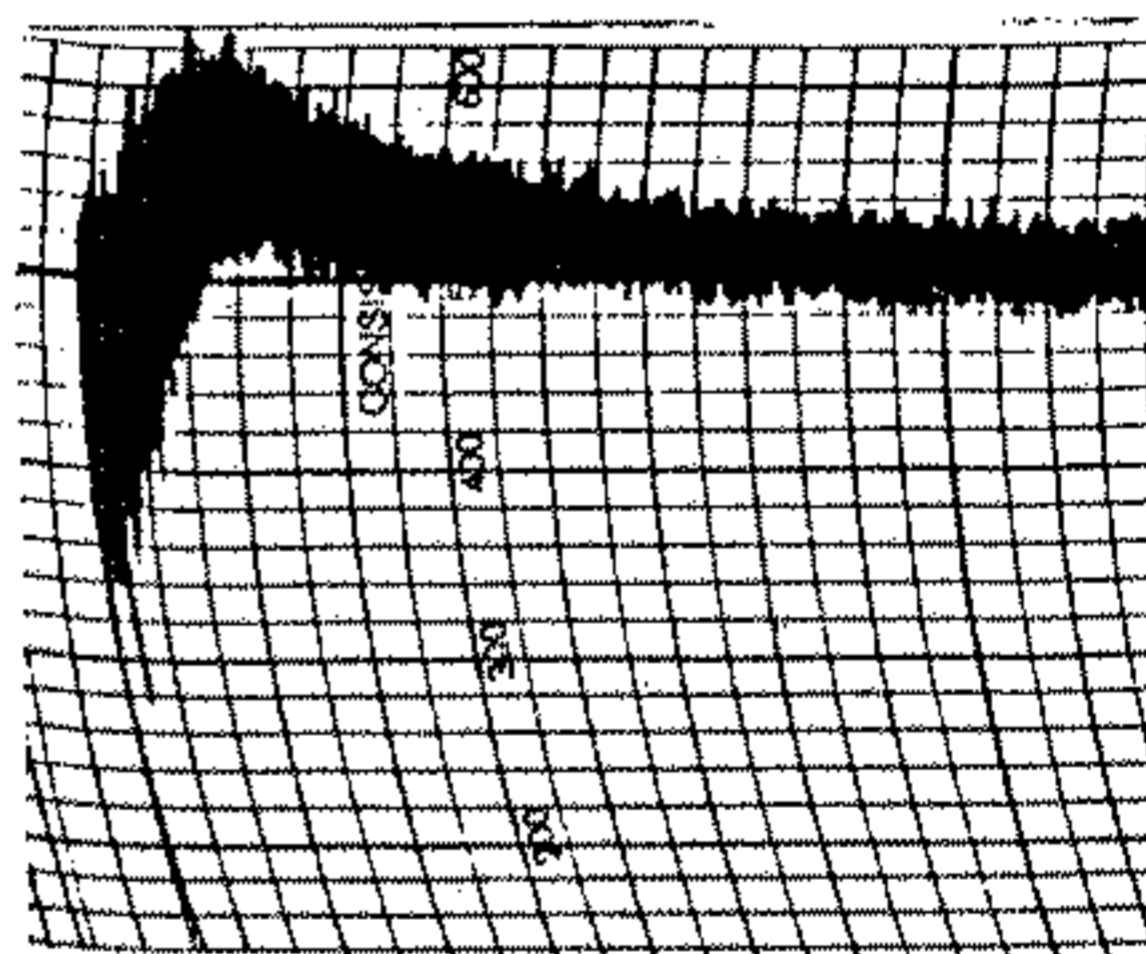
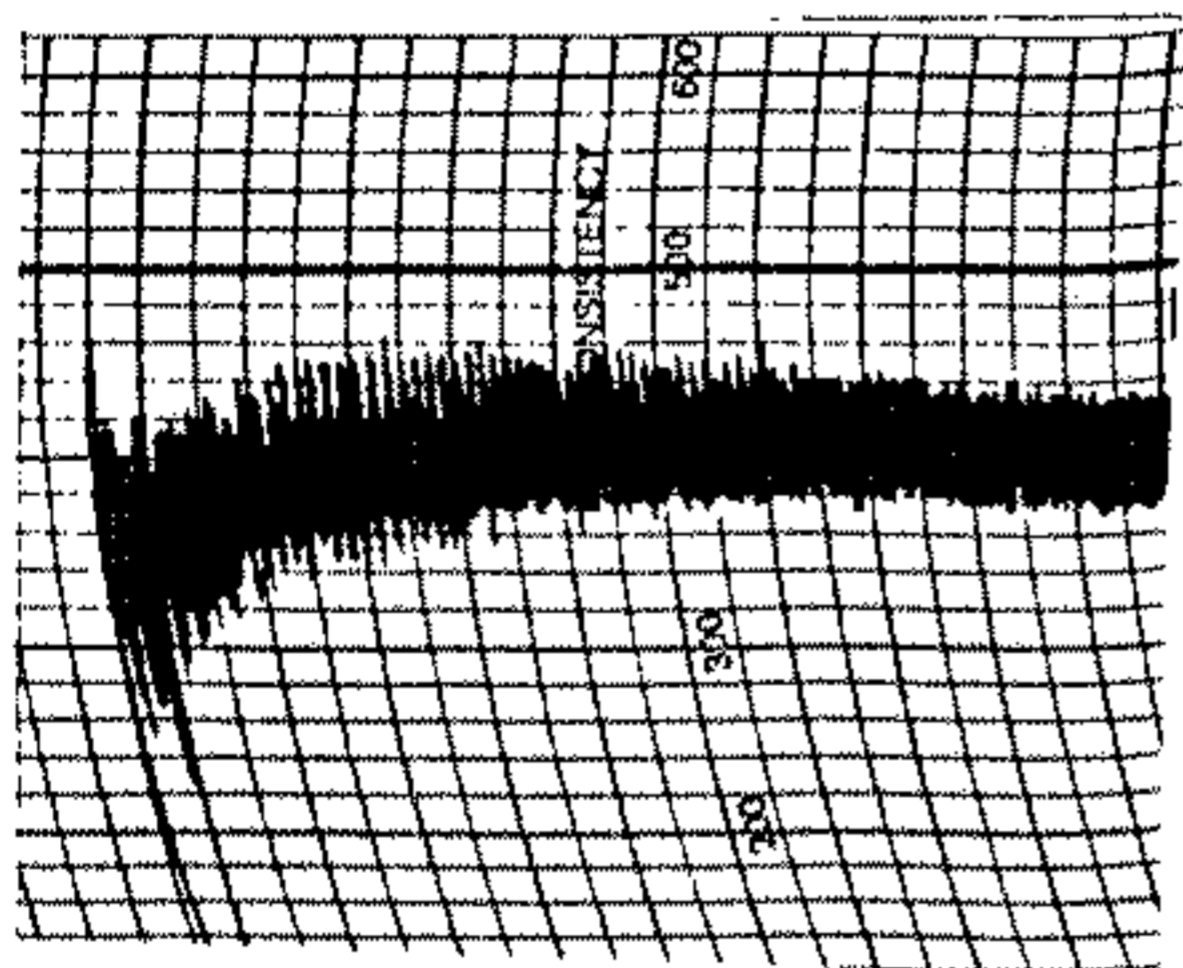


Table 25 shows additional dough and baking characteristics of breads with MESQUITE compared with the CONTROL sample. Tabulated are proof height of the loaves after fermentation, loaf volume, loaf weight and crumb firmness.

Breads were also prepared using MESQUITE Fraction B, the fibrous endocarphulls milled to a 40mesh size (see Chapter 2.5.2.2.), and MESQUITE syrup (2.5.2.1.1.) instead of Fraction A. The recipe and preparation was the same as described for Fraction A.

Table 25: Characteristics of breads with MESQUITE

Bread	Proof height (in 1/16 inch)	Loaf volume cm3 *	Loaf weight grams	Crumb ** firmness
CONTROL	15	680	123.5	335
10% MESQUITE- Fraction A	21.5	675	123.5	370
10% MESQUITE- syrup	15	640	123.3	410
25% MESQUITE- Fraction B	20.5	500	126	483

=====

\* determined with rapseeds

\*\*determined with Bloom gelometer

The bread containing 10% MESQUITE Fraction A developed the biggest proof height but resultet in an almost identical loaf volume and weight after baking. The crumb firmness after 24 hours however was slightly increased. Nevertheless, at this level of substitution with MESQUITE Fraction A, a good tasting bread can be produced with no major negative baking properties.

Incorporation of 10% MESQUITE syrup turned out to be not quite as successful. Loaf volume was almost 10% reduced, along with an increased crumb firmness. The taste was satisfactory.

A bread containing 25% MESQUITE Fraction B showed a clearly reduced loaf volume and increased crumb firmness. The bread was much darker than the CONTROL and the fiber was responsible for a sandy texture. However, it has to be taken in consideration that the comparision should be made with a bread much higher in fiber than CONTROL.

The actual appearance of the breads is shown in Figure 26.

#### 2.5.2.1.2.2. Chapatis and crackers

The incorporation of MESQUITE Fraction A in leavened bread proved to be possible, but did not provide any special advantages which would justify its use in regular bread, except in cases of undersupply of traditional flours.

Because of the limitations in leavened breads, it appeared to be more promising to investigate the possibility of using MESQUITE Fraction A in unleavened cereal products such as crackers or chapatis, which is the daily bread in most tropical countries. Volume and short time freshness are less crucial criterias for these products, and the taste expectations are not as specific. This widens the possible applications of MESQUITE Fraction A.

At the same time, the production of a cracker which could be marketed as a "MESQUITE cracker", would not have to try to copy an existing product. The requirements for a cracker are such attributes as crunchy, not subject to breaking in the package and resistance to oxidation. Also, the taste should not be too articulated.

The experiment conducted to study the use of MESQUITE Fraction A allowed basically the same procedure as for bread:

A standard recipe and procedure for crackers (or chapatis) was adapted to incorporate MESQUITE Fraction A at different percentages.

The dough composition is the same for both products, and was found to be optimal as follows:

#### Composition of doughs for chapatis and crackers:

-----  
100 g Wheat  
100 g MESQUITE Fraction A  
112 ml Water  
9 g Shortening  
2 g Guar gum

Procedure: -Dissolve guar gum in water  
-Mix the flours and the shortening  
-Add mix to water  
-Mix in a pin-mixer for 5 minutes and for an additional 10 minutes in a fork-mixer

### Crackers:

Roll dough in 3 mm thick sheet; cut dough in pieces (6x3 cm). At this stage three different methods are possible, where each produces a different type of cracker:

- 1) Bake for 15 minutes at 180°C .
- 2) Bake for 30 seconds on each side on griddle
- 3) Deep fry in vegetable oil, 20 seconds each side at 200°C.

### Chapatis:

They can even be produced using only the composite flour and water (this is the way they are actually made in most lesser developed countries). The addition of shortening and gum however provides a smoother texture which is similar to chapatis sold as specialities in Californian Supermarkets.

The dough is rolled in 3-5 mm thick sheets and cut to round pieces of 20 cm diameter (40g), which are baked on a griddle for 1 minute on each side.

### Results:

-----

#### Crackers:

Method 1) and 2) produce a visually similar product (Figure 27). The texture is indeed very crunchy. Baking on the griddle however is the better procedure since the slight off-flavor, which is detectable in the oven-baked cracker, is completely eliminated.

Method 3) provides even crunchier products similar to a "fortune-cookie" or chips. No off-flavor was registered. This product is not very stable due to the high oil content. Guar-gum (for dough structure and flavor masking, and shortening for texture), are extremely important additives in all described recipes. Addition of salt as it is usually done in crackers, does lead to an undesirable taste combination.

#### Chapatis:

An absolutely satisfying product is obtained. No disadvantages over the MESQUITE free product or off-flavors were detected.

Figure 26: Breads with MESQUITE Fraction A (product in the center is the CONTROL sample)

---

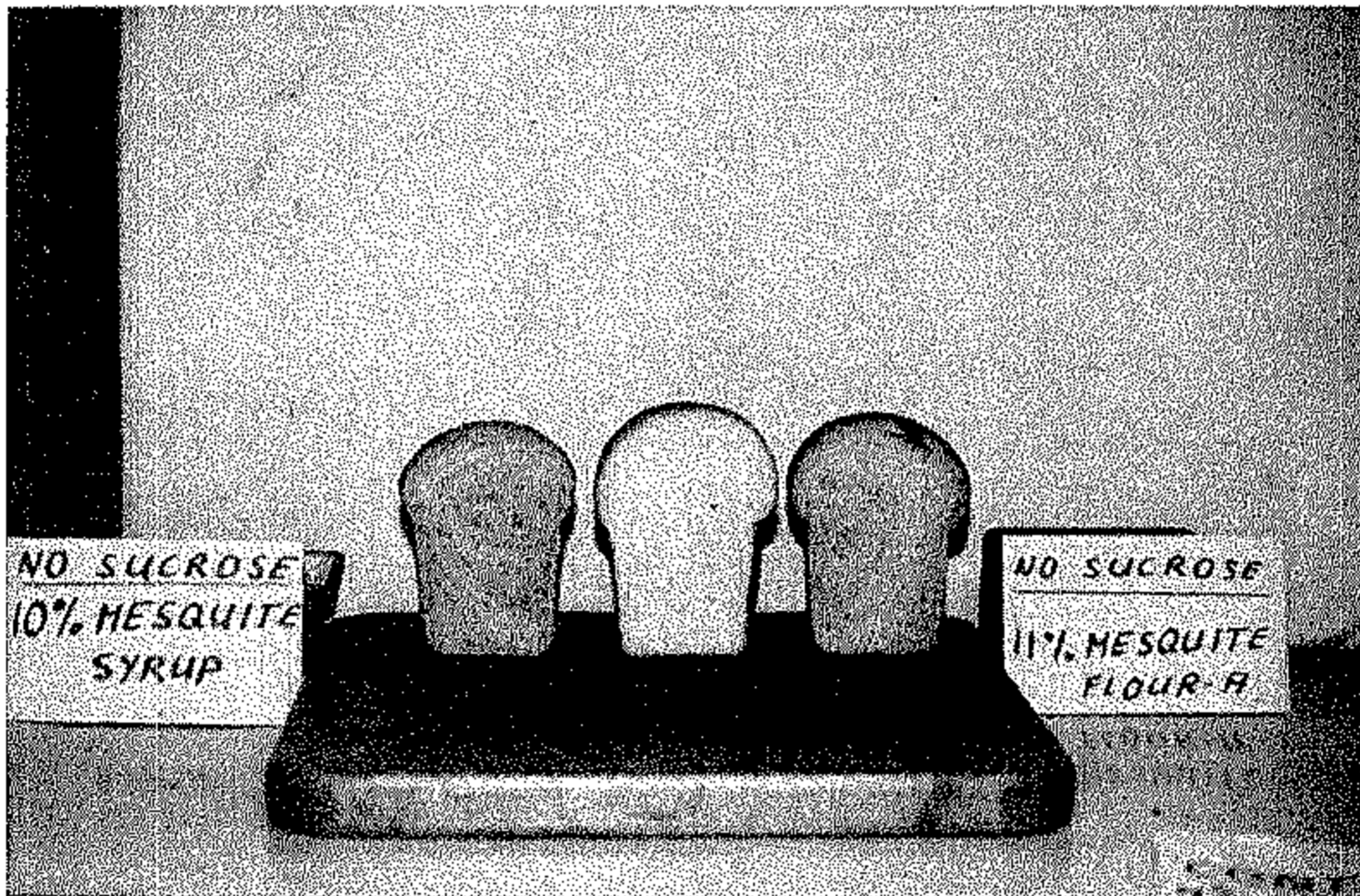
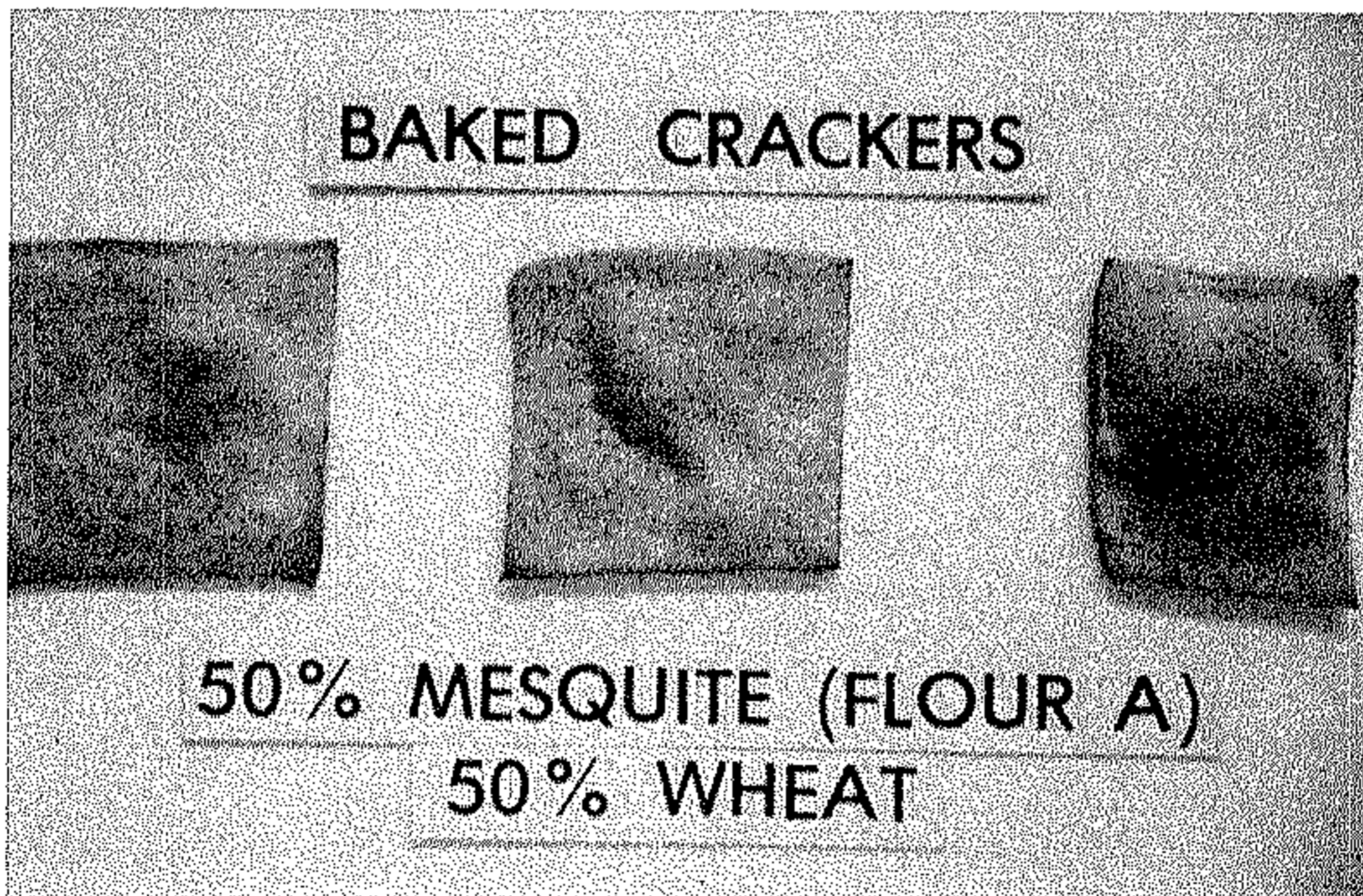


Figure 27: Crackers with MESQUITE Fraction A





Amino acid composition of a composite flour cracker:

Table 26 shows the amino acid composition of crackers, based on 50% wheat / 50% MESQUITE Fraction A.

For comparison the amino acid composition of a pure, untreated MESQUITE Fraction A is listed as well. All numbers are expressed as gram per 100 gram of sample.

Table 26: Amino acid composition of crackers with 50% MESQUITE Fraction A

Amino acid	50% Wheat+ 50% MESQUITE (g/100 g sample)	MESQUITE Fraction A (g/100 g sample)
ASPARTIC ACID	1.147	2.026
THREONINE	0.403	0.461
SERINE	0.650	0.553
GLUTAMIC ACID	3.827	1.784
PROLINE	1.501	1.126
GLYCINE	0.581	0.615
ALANINE	0.482	0.561
CYSTEINE	0.261	0.193
VALINE	0.655	0.699
METHIONINE	0.226	0.125
ISOLEUCINE	0.485	0.387
LEUCINE	0.995	0.933
TYROSINE	0.442	0.377
PHENYLALANINE	0.620	0.385
HYSTIDINE	0.345	0.317
LYSINE	0.398	0.506
ARGININE	0.764	0.975

Comparison with the amino acid composition of a standard wheat shows, that a 50/50 product has a better balance than either of the two flours alone. This comes as no surprise since it has been known from studies with other composite flours, that leguminous flour balances cereal flours in their overall amino acid composition. Chapter 2.5.2.1.2.2. supports these results by feeding studies with a MESQUITE Fraction A / wheat product.

### 2.5.2.1.2.3. Flakes

Drum dried flakes based on cereal or composite flours are widely used in the U.S. and also exported to lesser developed countries.

The technology is quite simple and the end products relatively stable and offer broad applications.

The intentions of the following experiments were:

- To find the limits of incorporation of MESQUITE Fraction A in an acceptable product.
- To compare the nutritional value of MESQUITE Fraction A / wheat product versus a wheat only product.
- To develop a product with a long shelf-life.

In a first attempt, flakes were produced with MESQUITE Fraction A and other flours but no other ingredients. The amount of MESQUITE Fraction A was varied, but not the drying parameters. The composite flour was either complemented with whole wheat flour (Peavy), Cassava or in one case MESQUITE Fraction D (MESQUITE cotyledon, see chapter 2.4.2.4.). The flakes were used for feeding studies to determine their nutritional qualities. They were also subjected to standard quality measurements.

In a second experiment, the quality of flakes with a given percentage of MESQUITE was optimized by addition of some ingredients and optimization of the operating variables.

Flakes with different levels of MESQUITE Fraction A:  
-----

Procedure:

- Mill MESQUITE Fraction A through a Wiley-mill using a 1 mm screen.
- Prepare composite flours with MESQUITE Fraction A incorporated at levels from 0-100% .
- Add the flour to water (20°C) and mix in a laboratory mixer at medium speed for 5 minutes.
- Feed slurry on a double drum drier; gap 0.75mm ; speed 0.8 rpm
- Allow flakes to cool at ambient temperatur, then run through the Wiley-mill with a 5 mm screen and take samples for further investigations.

Characterisation of flakes:  
-----

The following tests were performed (where applicable):

Sheeting:

Visual description (0= worst; 10= best)

Flake firmness:

Flakes are given in a 300 ml aluminium can (6.5 cm diameter; 9.5 cm long); the can is placed in an Instron apparatus and the 5.5 cm diameter compression-cell is driven four times 1.2 cm deep in sample (speed 12.5cm/min). The resistance is measured with a multiplication factor of 50x; The last drive was the measured value.

Specific volume:

Flakes were filled in a 500ml cylinder and the weight recorded as ml/100 g.

Viscosity:

60 g flakes and 440 ml H<sub>2</sub>O were given in an Amylograph bowl. Temperature procedure: 10 minutes at 25°C (value A), heated to 85 C and cooled back to 25°C (value B). The difference between A and B is a measure for the degree of cold water swelling and gelatinization during drum drying respectively. The absolute value is relative to the percentage of starch in the product. (All values in Brabender units = BU)

Chemical analysis:

Composition of the flakes (i.e. carbohydrates, sugar, protein, fat, fiber)

Feeding tests :

Flakes with different levels of MESQUITE were fed to male Sprague-Dawley rats ( initial age: 21 days, initial weight: 54g, 5 rats per group) for 28 days. The following data were collected:

- Final body weight;
- Total feed consumption;
- Protein efficiency ratio, PER = weight gain / protein intake
- Digestibility of total diet = (feed intake- fecal weight)/ (feed intake x 100)
- Digestibility of total nitrogen = (N intake- fecal N)/ (N intake x100)

## Results

### Functional properties (Interpretation of Table 27)

The specific volume (also shown in Figure 29) reaches a maximum when 25% MESQUITE Fraction A is incorporated, higher percentages cause a slight reduction. 100 % MESQUITE Fraction A gives the lowest value which can be increased with the addition of gum. The combination with cassava flour shows similar results as with wheat flour.

The reduction of the starch containing composite flour causes a decrease of the absolute viscosity. The percentage of cold water viscosity is significantly higher with MESQUITE. The incorporation of MESQUITE Fraction A evidentially reduces the need for extensive pre-gelatinization. A surprising exception occurs when MESQUITE Fraction D is incorporated: the percentage of cold water viscosity is even below the value of a 100% wheat flake. It suggests that MESQUITE Fraction D retards the gelatinization during drum drying.

The resistance of the flakes against breaking (strength) shows values that correspond with their specific volume: Higher specific volume (or lower density), causes reduced flake firmness.

The water activity value is slightly reduced with increased percentage of MESQUITE Fraction A, but the moisture content of the flakes is also lower with higher percentages of MESQUITE. The fact that the moisture content is lower with MESQUITE, suggests a reduced water holding capacity which has been observed in other experiments as well.

The most critical factor in the production of drum-dried flakes with MESQUITE is their sheeting-performance. Under the described production parameters, a mixture of 50% wheat / 50% MESQUITE Fraction A produced an excellent film (Figure 28). It was practically impossible to obtain an acceptable film with 100% MESQUITE only. Addition of guar gum improved the sheeting dramatically. Adjustment of process parameter would certainly allow to improve the sheeting characteristics of the other mixtures as well; the here described results have only comparative character.

In summary: It could be seen that the quantitative incorporation of MESQUITE Fraction A as well as Fraction D in composite flours is almost unlimited from the technological point of view.

The taste of all samples was very pleasant. The increase of MESQUITE Fraction A leads to a stronger flavor, but no after-taste or off-flavor could be detected.

Figure 28: Production of drum dried flakes with 50% MESQUITE Fraction A and 50% wheat

---

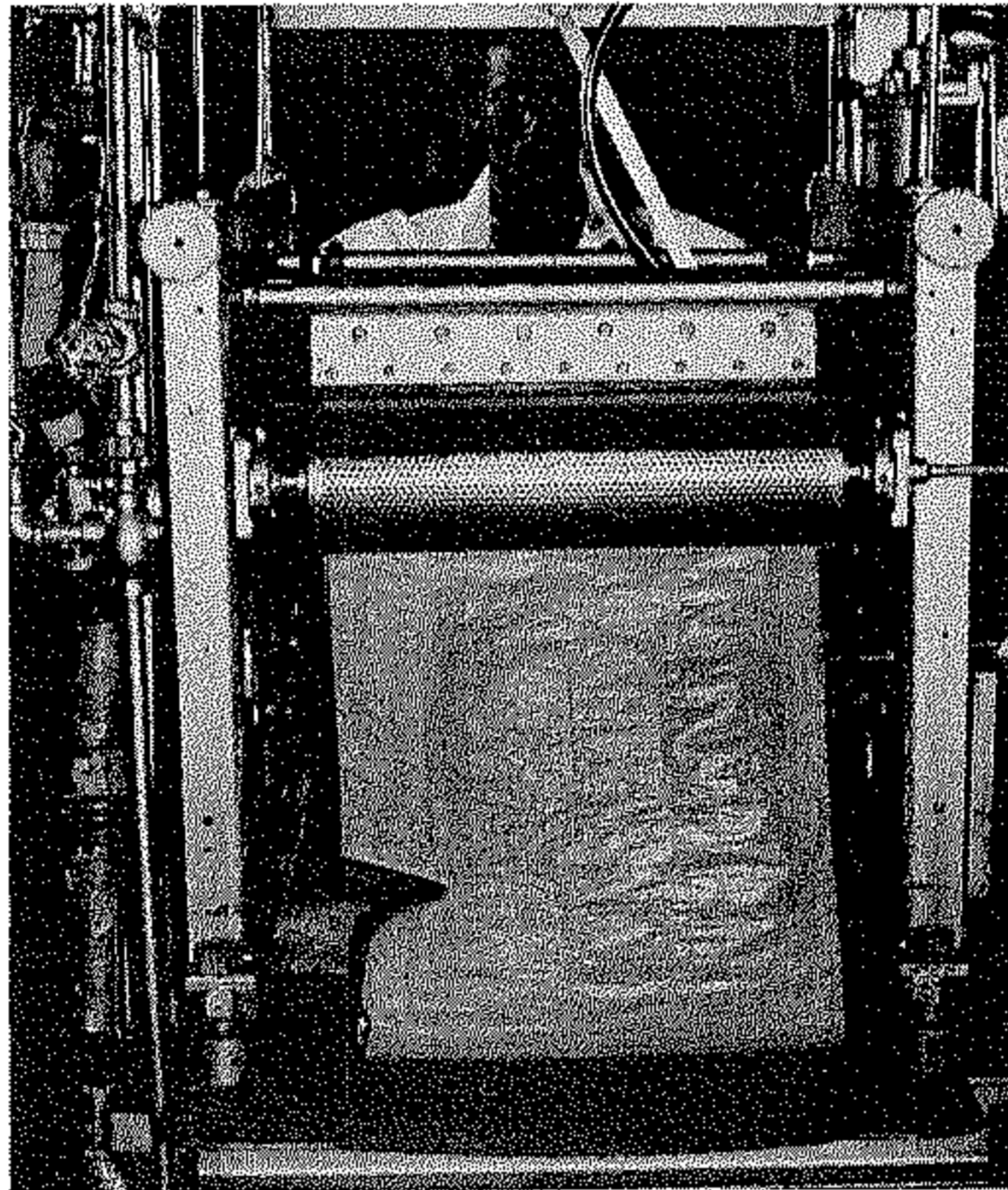


Figure 29: Specific volume of different drum dried flakes (numbers see Table 27)

---

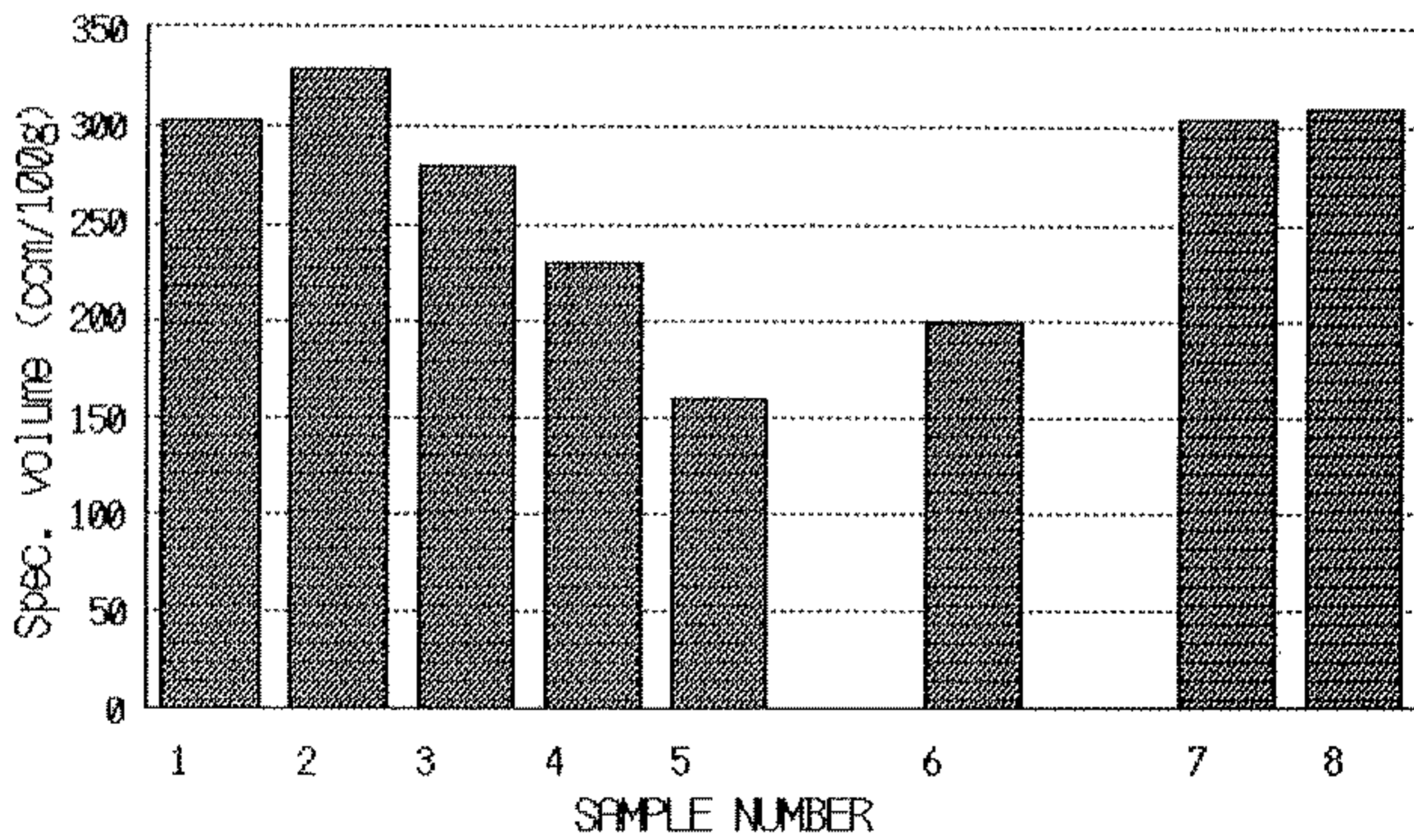


Table 27: Drum dried flakes: Functional properties (methods see page 75)

Composition	Specific volume (ccm/100g)	Viscosity A/B Ax100:B (BU)	Flake-firmness	aw	Sheeting quality	Sample# in Fig. 29
100% Wheat	303	1360/3200	42.5%	0.5	2	1
75% Wheat						
25% MESQUITE A	330	1200/1560	77.0%	0.48	5	2
50% Wheat						
50% MESQUITE A	280	380/ 520	73.1%	0.45	10	3
25% Wheat						
75% MESQUITE A	230	65/ 85	76.5%	0.38	5	4
100% MESQUITE A	160	unmeasurable			0	5
100% MESQUITE A (+1.5% Guar)	200	unmeasurable	69	0.42	7	6
40% Wheat						
20% Cassava						
20% MESQUITE A	304	430/1080	39.8%	0.55	5	7
20% MESQUITE D						
75% Cassava						
25% MESQUITE A	310	2000/2700	74.1%	0.62	5	8

Flour:H2O = 40:60, Gap: 0.75 mm, Speed: 0.8 rpm Productionrate: 10-12kg/h

### Chemical Analysis (Interpretation of Table 28)

As can be expected, the chemical composition of the flakes represents basically the arithmetic sum of the combination of the composite flour.

The protein content of the flakes is reduced with increased percentage of MESQUITE Fraction A, since MESQUITE has a lower protein content to start with. This however is partially compensated by its improved amino acid balance (Table 26). The flakes with 20% MESQUITE Fraction D have over 20% more protein and a improved amino acid balance than the product made out of wheat only. Flakes with cassava contain very little protein, since cassava itself is almost protein free. Addition of MESQUITE Fraction A or D would therefore be a positive improvement for the cassava flour.

The percentage of fat is almost on the same level in all the flakes.

As could be expected, the most significant changes in the chemical composition of the investigated flakes are found in their fiber content and the amount of sugars; both ingredients are found at much higher levels with increased MESQUITE incorporation.

### Feeding studies (Interpretation of Table 29)

Three types of flakes were used for feeding studies, along with a control sample containing casein:

- 1) 100% Wheat
- 2) 50% Wheat / 50% MESQUITE Fraction A
- 3) 40% Wheat / 20% Cassava / 20% MESQUITE A / 20% MESQUITE D

The results showed, that the products 1) and 2) were overall identical. No statistically significant differences were measurable, except for digestability of 2), which is lower for the whole diet as well as for nitrogen. Since this did not cause a lower PER, the protein-quality of the flakes containing 50% MESQUITE Fraction A must be better, due to an improved amino acid balance.

Flakes 3) showed better values than the two other flakes in all measured value. The PER as an example, is 50% higher. Since the digestibility is even lower than 1) and 2), the protein quality must again be significantly better. The improvement is definitely caused by the high-protein MESQUITE Fraction D.

This study also proves that MESQUITE shows no toxicity over the investigated period.

Table 28: Drum dried flakes: Chemical analysis

Composition	H2O %	Protein(1) %	Fat %	Fiber(2) %	Sugar(3) %	Carboh.(4) %
100% Wheat	7.8	13.9	0.9	0.3	3.3	73.4
75% Wheat						
25% MESQUITE A	5.5	12.7	1.1	3.0	14.5	76.7
50% Wheat						
50% MESQUITE A	3.3	12.1	1.0	5.4	23.4	79.6
25% Wheat						
75% MESQUITE A	2.1	10.6	1.1	9.7	35.2	82.2
100% MESQUITE A	5.0	9.8	1.6	9.9	41.1	79.6
40% Wheat						
20% Cassava						
20% MESQUITE A						
20% MESQUITE D	7.4	16.1	2.0	4.3	13.3	70.5
75% Cassava						
25% MESQUITE A	10.0	3.2	1.0	3.7	11.5	81.8

(1) N \* 6.25 (2) Crude fiber (3) Sucrose and glucose (4) By difference



Table 29: Drum dried flakes: Feeding studies.

Composition of feed	Final body weight, g	Total feed consumed, g	PER actual	adjusted	% digestibility diet	nitrogen
Casein CONTROL	174 +-7	349 +-20	3.43 +-0.06	2.5	93.3	92.3
100% Wheat	79 +-3(a)	215 +-10(b)	1.13 +-0.04(c)	0.82	91.4	87.8
50% Wheat 50% MESQUITE A	74 +-4(a)	186 +-14(b)	1.06 +-0.05(c)	0.77	84.7	75.2
40% Wheat 20% Cassava 20% MESQUITE A 20% MESQUITE D	100 +-2	278 +-5	1.64 +-0.04	1.2	83.9	71.4

=====  
 Mean +- S.E. Duncan's Multiple Range Test: Means with a common letter are not significantly different for p <sup>2</sup>.05

Optimization of flakes with a given percentage of MESQUITE Fraction A

After it could be shown that drum dried flakes can be produced at any level of MESQUITE incorporation, an attempt was made to optimize the flake quality at a given MESQUITE percentage by changing process parameters, or addition of specific ingredients.

The choosen product was based on 70% wheat and 30% MESQUITE Fraction A. A slurry with no addites served as CONTROL.

Experiments discussed in the preceeding chapter and performed with raw materials other than MESQUITE (72;73;74;75) suggested the use of guar gum (known to reduce cooking time (76)) and shortening for the functional improvement of the flakes.

Sucrose and NaCl are added for organoleptical reasons. In addition, the slurry would be pregelatinized.

The goal of the optimization was to obtain flakes with excellent sheeting characteristics, maximal strenght against breaking, and crispness.

The "ideal" flake at a given amount of MESQUITE percentage was therefore obtained as follows:

Composition: 65 parts unbleached Wheat flour  
35 parts MESQUITE Fraction A  
100 parts flour

+ 8 " Sucrose  
+ 5 " Shortening (veget.)  
+ 2 " NaCl  
+ 1 " Guar gum

+200 parts water

Procedure: -Prepare dry mix; dissolve guar in water  
-Add dry mix to water; mix for 5 minutes in lab mixer.  
-Pregelatinize slurry by heating for 4 minutes at 85 °C in steamkettle.  
-Feed slurry on drum drier; Drum gap = 0.16 mm  
Time on drum= 1'55" (=0.52 rpm);  
Temperature on drum surface = 145 °C (71)  
-Let flakes cool at room temperatur for 15 minutes; standardize flake size by running through Wyley-mill with 5 mm screen.

The characteristics of this "ideal" flake are described as follows:

Chemical composition: 80% total carbohydrates;  
20% sucrose;  
12.5% protein;  
2% fat;  
3.5% crude fiber;  
3.5% ash;  
2% moisture

Specific volume : 300 ccm/100 g  
Breaking : <3% (\*)

(\*) Standard procedure as described on page 75, but sifting through 10 mesh= % breakage

#### Oxidation stability of drum dried flakes

Samples of the flakes were studied for their stability against oxidation or rancidity, in order to get some ideas about their shelf life. A sample of plain MESQUITE Fraction A which had been stored for 6 month at room temperature (unprotected from light =A<sub>0</sub>) was also checked. The amount of oxidation was measured with the GLC as hexanal in the headspace above the flakes, known as the hexanal-value. This has been proven to be a good indicator for rancidity (70;71).

Method: 100 g of flakes were filled in gas tight jars and stored for 16 weeks at 38°C, protected from light. Another batch was stored for the same period of time at room temperature and not protected from light. After termination of the storage time, 5 g sample were given in 250 ml jars, 2 ml standard solution and 100 ml boiling water are added; the jar is immediately closed with a triple layer of aluminum foil; the sample is shaken for 45 seconds and then 1cc headspace-gas is drawn.

Standard 1 : 25 ul isobutyl methylketone,  
25 ul heptanone in 1l H<sub>2</sub>O  
Standard 2 : 2-Heptanon  
GC column : J+W fused silica capillary column;  
OV-351, 0.25IDx15M  
Carrier gas : He, flow rate 6cc/min  
Flame : H<sub>2</sub> , 32 psig  
Injection temp. : 260 °C splitless injection, 1cc  
Oven max. temp. : 400 °C  
Column pressure : 5 psig (0.33kg/cm<sup>2</sup>)

The results, shown in Table 30 and Figures 30-31, are quite impressive. The hexanal value decreases parallel to the increased amount of MESQUITE Fraction A. This could be caused by the presence of an anti-oxidative compound in MESQUITE, since untreated MESQUITE Fraction A also shows a very low value. A more likely explanation could a correlation with the moisture content, which is lower with higher percentages of MESQUITE (Table 28). This would also explain the high value of the flakes with MESQUITE Fraction D even though this product is certainly more subject to oxidation due to its high fat content. Storage at higher temperature results in an expected higher oxidation.

Table 30: Oxidation stability of drum dried flakes

Sample	HEXANAL-VALUE		Sample#
	stored at 38°C	stored at roomtemp.	
100% Wheat	24.7	21.4	1
75% Wheat 25% MESQUITE Fraction A	-	4.3	2
50% Wheat 50% MESQUITE Fraction A	3.0	3.0	3
100% MESQUITE Fraction A	0.0	2.5	4
40% Wheat; 20% Cassava 20% MESQUITE Fraction A 20% MESQUITE Fraction D	15.3	12.5	5
75% Cassava 25% MESQUITE Fraction A	0.9	1.3	6
MESQUITE Fraction A (Ao)		1.6	7

=====  
 Sample # refers to Figures 30 and 31  
 =====

Figure 30: Hexanal value of different flakes , stored at 38°C

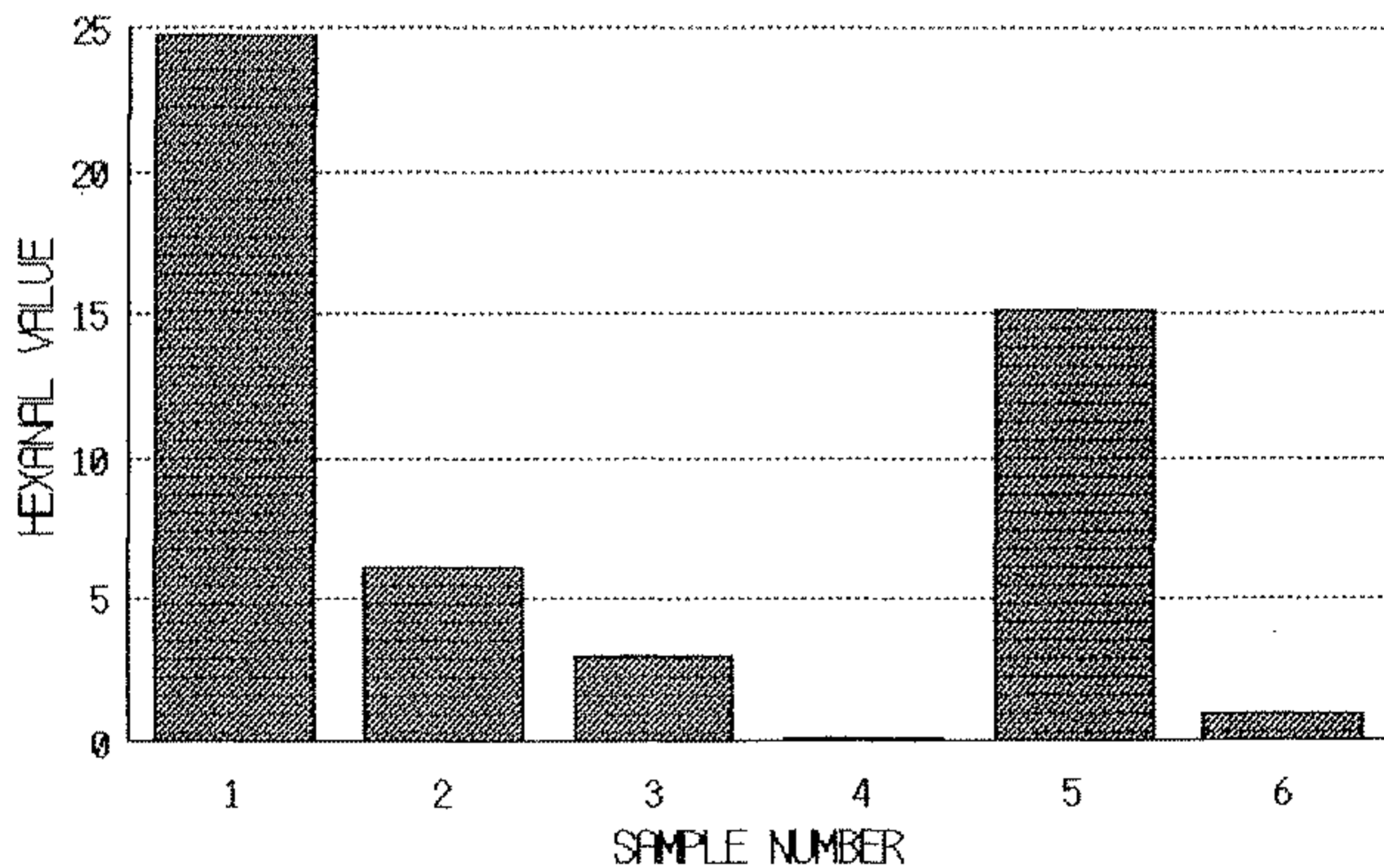
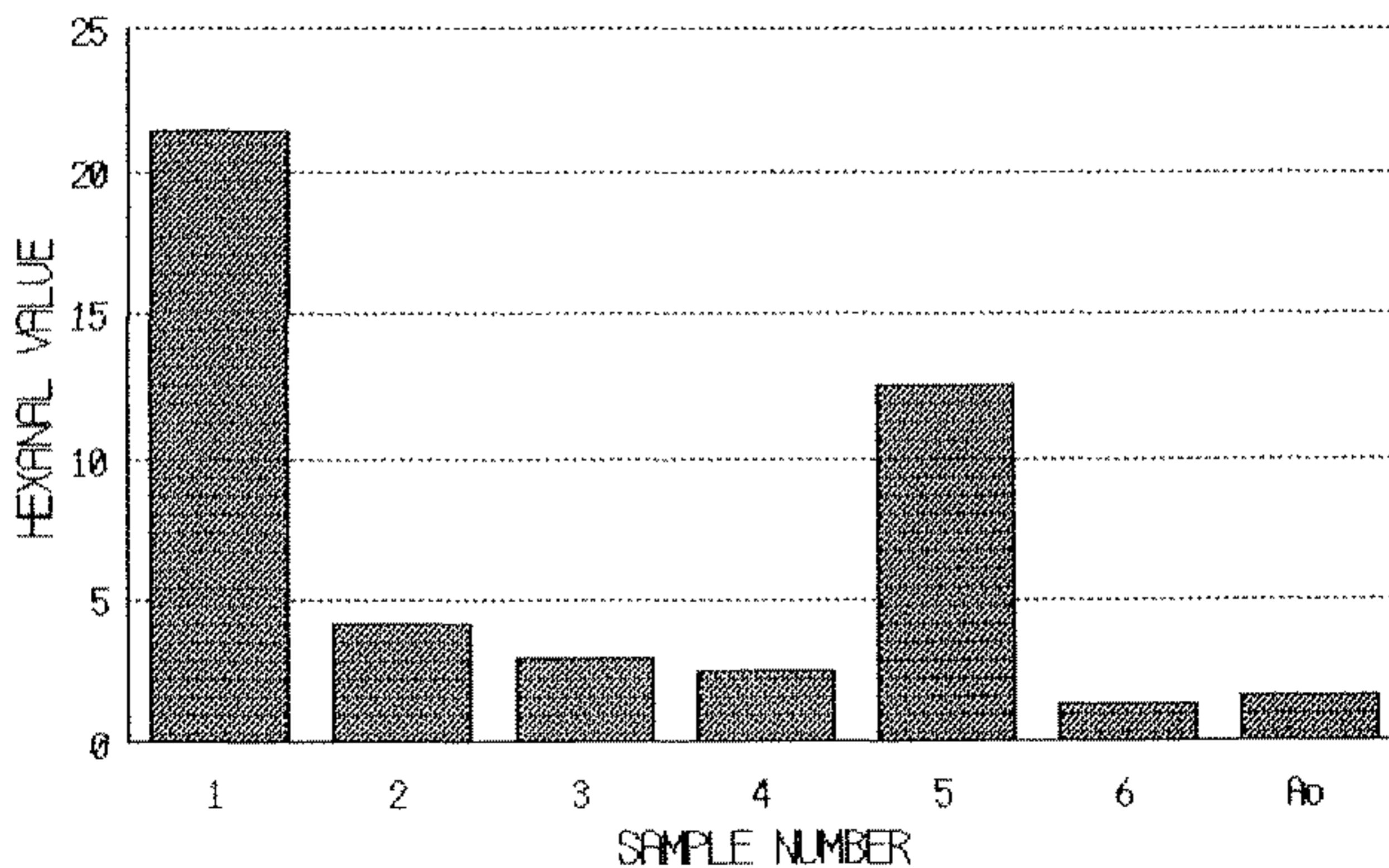


Figure 31: Hexanal value of different flakes, stored at roomtemperature



#### 2.5.2.1.2.4. Corn tortilla chips with MESQUITE Fraction A

Corn is the most important staple food in most lesser developed countries in arid and semi-arid zones. Corn is milled and processed to a product called "Masa", which serves as a rawmaterial for either unleavend flatbreads or deep-fried corn-chips.

The corn chips have also become a best-seller in the snack-food market the United States, mainly in the southern States and California.

Therefore, a corn tortilla chip with MESQUITE FractionA might well be a most promising application for MESQUITE in the U.S. as well as in LDC's. In addition, preliminary tests with wheat/MESQUITE composite-flours showed, that deep-frying destroys the slightly bitter after-taste of some MESQUITE pods most efficently.

There are many different procedures for the production of such corn chips, but this experiment is based on the most commonly used method which allows their production for private consumption as well as in an industrial scale.

#### Composition:

Standard corn chip: 100 parts processed corn flour (MASA)  
                          2 parts NaCl  
                          100 parts H<sub>2</sub>O

MESQUITE chip       : -Replace percentages of corn with MESQUITE Fraction A.  
                          -Reduce water by 5 parts for each 10 parts of MESQUITE Fraction A.

#### Procedure:

- Prepare dry mix
- Add warm water (50°C)
- Mix for 5 minutes in lab-mixer
- Roll dough between two pergament-papers into 1.5 mm thick sheets; cut sheets in 2 cm x 5 cm pieces and punch holes in each piece with a fork
- Immerse pieces in 210 °C oil (partially hydrogenated soybean oil, Crisco) and deep-fry for 25 seconds on each side.

Different time/temperature combinations of deep-frying were tested, in the range of 180°C to 220°C for oil temperature and 10 to 35 seconds deep-frying on each side.

A taste panel evaluated the products prepared under different conditions and determined the best combinations of flours and preparation parameters.

It was found, that samples deep-fried below 200°C or/and for less than 20 seconds were chewy (worse with higher MESQUITE percentage); samples deep-fried above 210°C or/and longer than 30 seconds were overcooked (worse with higher MESQUITE percentage). In both cases higher temperature/shorter time were better than lower temperature/long time.

Generally, increased MESQUITE percentages lead to a narrower range and slightly higher temperatur/time combinations for good chips.

#### Taste panel:

MESQUITE/corn tortilla chips with two different percentages of MESQUITE Fraction A were produced and used for a taste panel investigation. The intention was to determine whether such a chip would be accepted by people who are already consumers of regular corn-chips or whether they would even prefer a MESQUITE/corn tortilla chips over a plain corn tortilla chip. Therefore, the MESQUITE-percentage was kept below the theoretically possible level to make sure that corn was still the main ingredient.

Products: 1) Tortilla-chips made from 100% corn, based on the recipe described on the previous page.  
2) 90% corn +10% MESQUITE Fraction A  
3) 80% corn +20% MESQUITE Fraction A

Panel : 29 voluntary adults; all were trained and experienced taste panelists;

Test : The panelists did not know what type of product would have to be consumed; tests were performed between 10am and 11:30am;

Questionnaire:

Part 1:

- 
- a) Do you consider yourself a lover of Mexican food ? Y / N
  - b) Do you eat Corn-tortilla Chips ? Y, More than once a month;  
N, Less than once a month;
  - c) Please try these samples of Tortilla-chips and give them scores: (1=lowest; 10=highest)

	Sample 1	Sample 2	Sample 3
Color			
Texture			
Odor			
Taste			

Part 2:

(The following question and samples were given to the judges only after having turned in part 1)

- 
- d) This is a corn-tortilla Chips which contains MESQUITE!  
Please give scores! (1=lowest; 10=highest)

Score
Color
Texture
Odor
Taste

- e) What do you like best about the product? .....
  - f) What don't you like about the product ? .....
  - g) Do you detect an off-flavor ? Y / N  
If yes, describe it ! .....
- 

Objectives of each question:

Questions a) and b): To determine whether difference in judgement are based on the basic eating habits of consumer; one Y is referred to as "EATER" , two N is referred to as "Non EATER" in the resulting charts.

Question c): Actual score of product.



Question d): The product in part 2 was exactly the same as #2 in part 1 for the first 15 judges, and the same as #3 for the other 14 judges (in the resulting charts referred to as REPETITIVE SAMPLE), but the judges were unaware of this fact. The intention was to determine whether a subjective change in judgement occurs, knowing that the product contains an unfamiliar ingredient. A higher score would favor identification of a MESQUITE chips as such, instead of undeclared incorporation in a corn chips.

Questions e) and f): Additional information for possible improvements of the product.

Questions g) and h): Since off-flavor occurs in some pods, this question served to verify a possible but not dominant off-flavor.

### Results:

#### PART 1

##### Scores of each criteria (see Figure 32)

The product containing 10% MESQUITE Fraction A obtained the highest score for each criteria, followed by the product with 20% MESQUITE Fraction A (without separating between "EATERS / Non EATERS").

##### Total score (see Figure 33)

Presents the sum of the scores for all criterias of each product. The ranking is more significant ( $p < 0.001$ ).

##### Total score according to "EATERS/NonEATERS" (see Figure 34)

Shows the results from Figure 32, but according to eating habits of the panelists. It reveals, that people who do not eat regular corn-chips prefer a chips with increased MESQUITE Fraction A.

#### PART 2

##### Score of repetitive samples (see Figures 35-37)

Judges prefer the product once they know the ingredient in both percentages and for all criterias. The least obvious change occurs for color, since this characteristic is most unlikely subject to the attitude versus the ingredient.

List of statistical significance:

Numbers "1,2,3" refer to product specifications on page 87; NS = not significant; significance evaluated with standard F-test.

Color	"1;2;3; p<0.005"	"2;2rep; NS	"	"3;3rep; NS	"
Texture	"1;2;3; p<0.05 "	"2;2rep; NS	"	"3;3rep; NS	"
Odor	"1;2;3; NS	"2;2rep; NS	"	"3;3rep; NS	"
Taste	"1;2;3; NS	"2;2rep; NS	"	"3;3rep; NS	"
Sum of score	"1;2;3; p<0.001"	"2;2rep; NS	"	"3;3rep;p<0.05 "	"

Response to single questions:

What do you like best about the product ?

TASTE :32%  
 COLOR :25%  
 TEXTURE:25%  
 ODOR :10%

What don't you like about the product ?

TASTE :14%  
 COLOR :0  
 TEXTURE:27%  
 ODOR :0

Is there a off-flavor ? YES: 27% NO: 70%

If yes, describe it ! sweet 2x; astringent 3x;  
 single mentionings: chinese food,  
 garlic, oily, nutty  
 burned, cinnamon

Summary:

-Corn tortilla chips which contain up to 20% MESQUITE Fraction A, are judged as being better than pure corn tortilla chips for all organoleptical criterias, with statistical significanc when summarized to a overall score.

-10% MESQUITE Fraction A is prefered over 20% MESQUITE Fraction A by people who regularly consume pure corn chips, whereas people who usually do not eat pure corn chips prefer the highest percentage of MESQUITE incorporation.

-The MESQUITE/corn chips obtains a even higher score for all criterierias when the consumer is aware of the use of MESQUITE Fraction A.

-There is no off-flavor detected in MESQUITE/corn chips, as long as the question is not suggesttifely asked . Even then, only a fourth of the judges respond with yes, but give widelly varying descriptions.

Figure 32: Taste panel; scores of each criteria

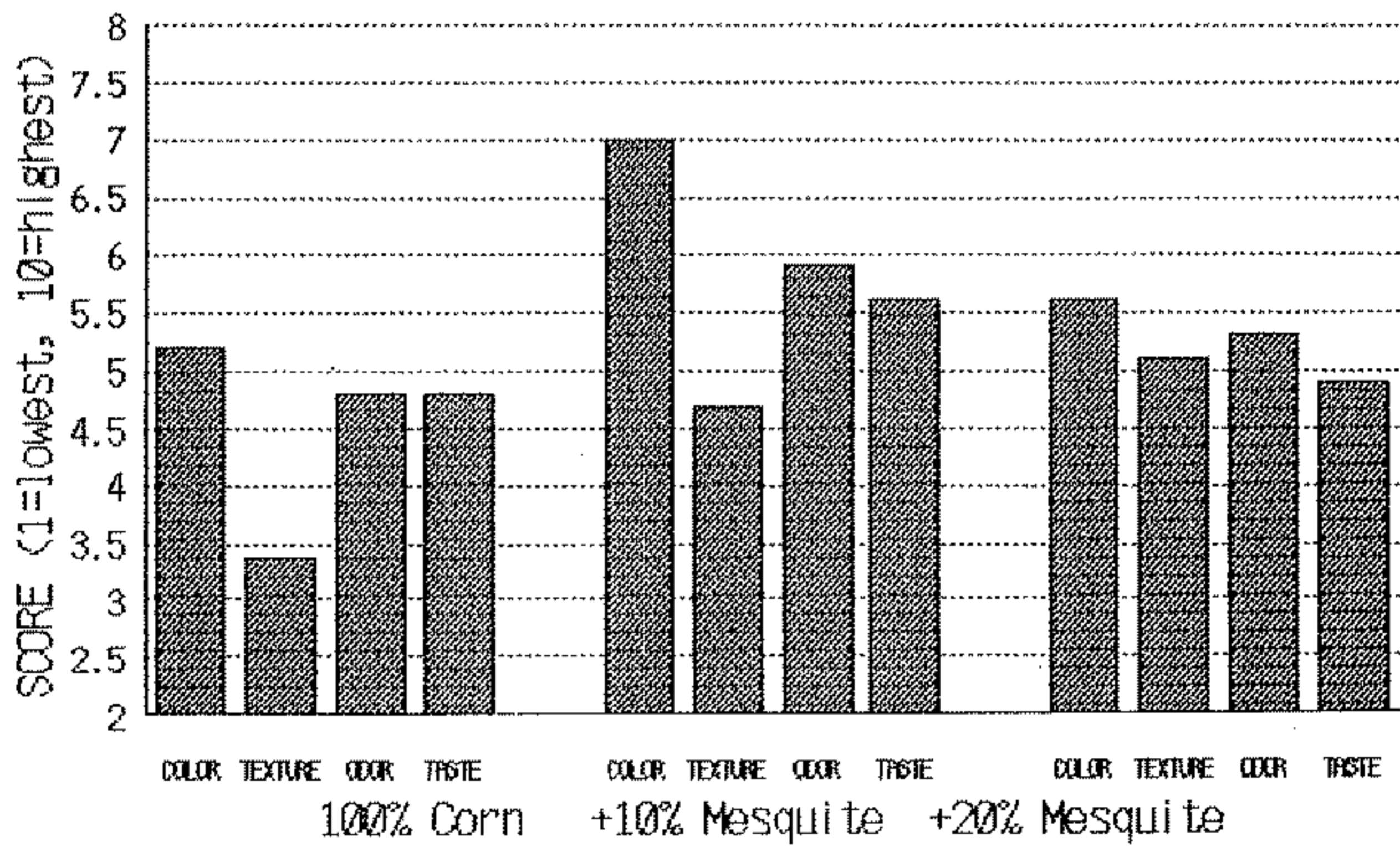


Figure 33: Taste panel; total score

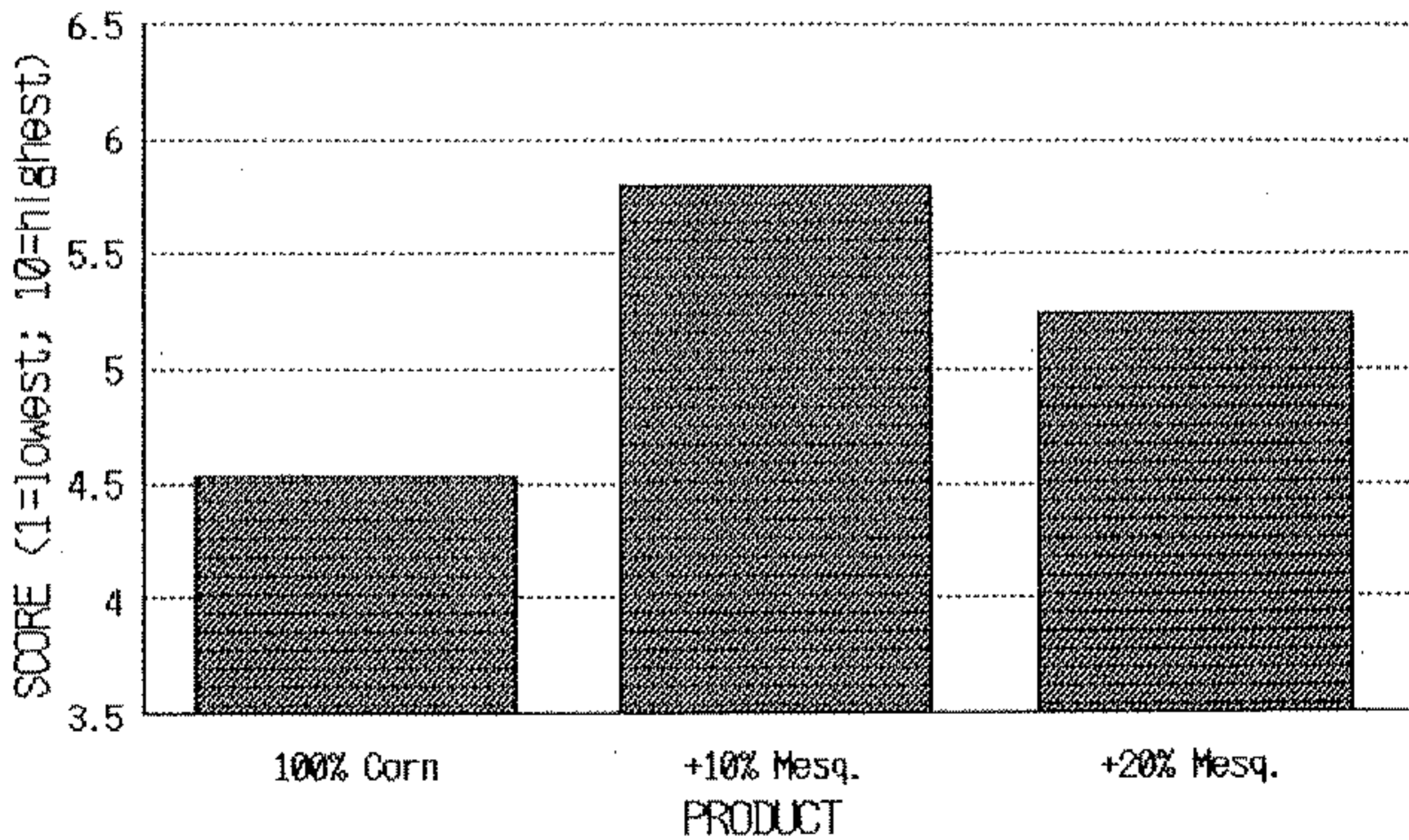


Figure 34: Taste panel; scores according to "EATERS/NON EATERS"

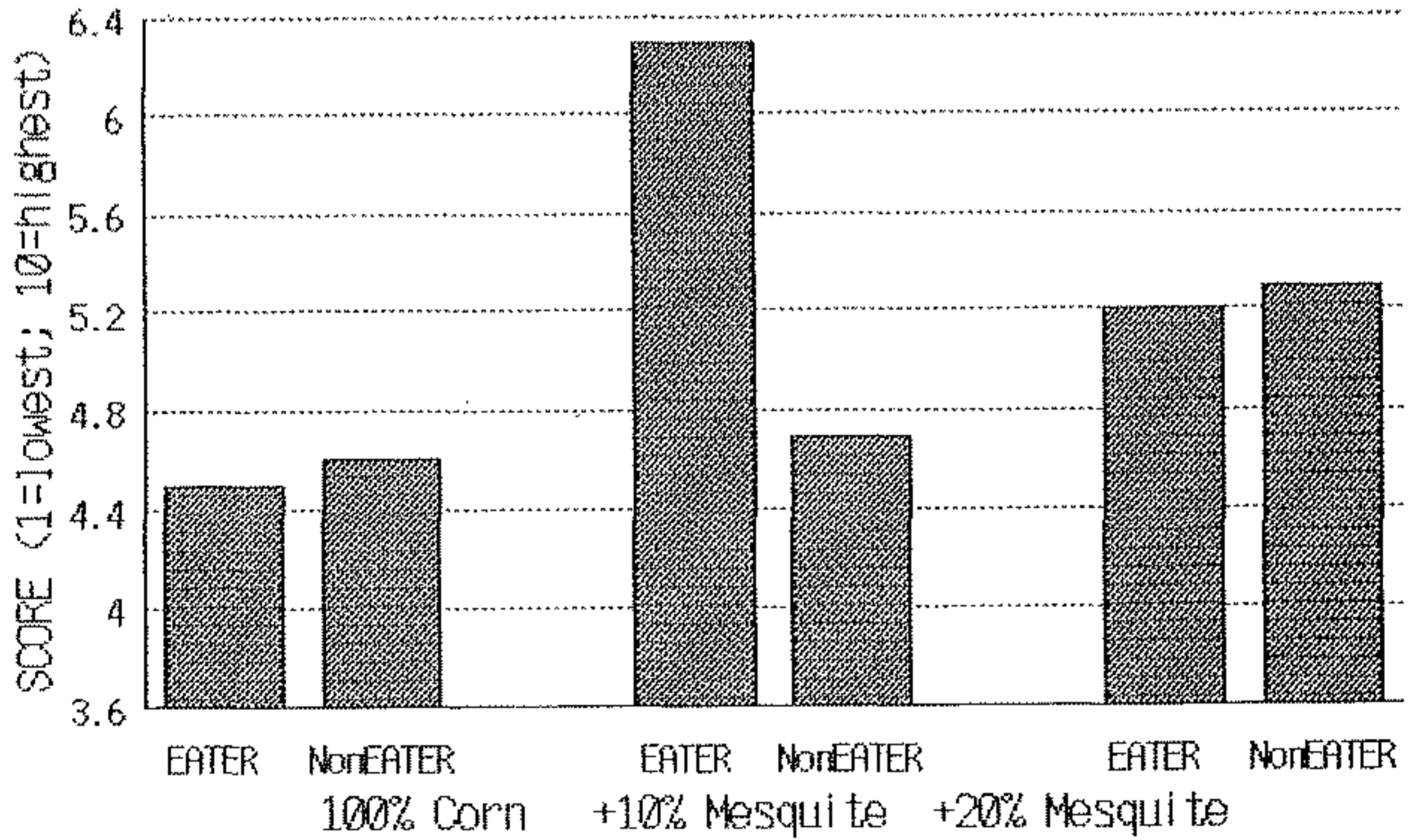


Figure 35: Taste panel; repetitive sample #2 (10% MESQUITE)

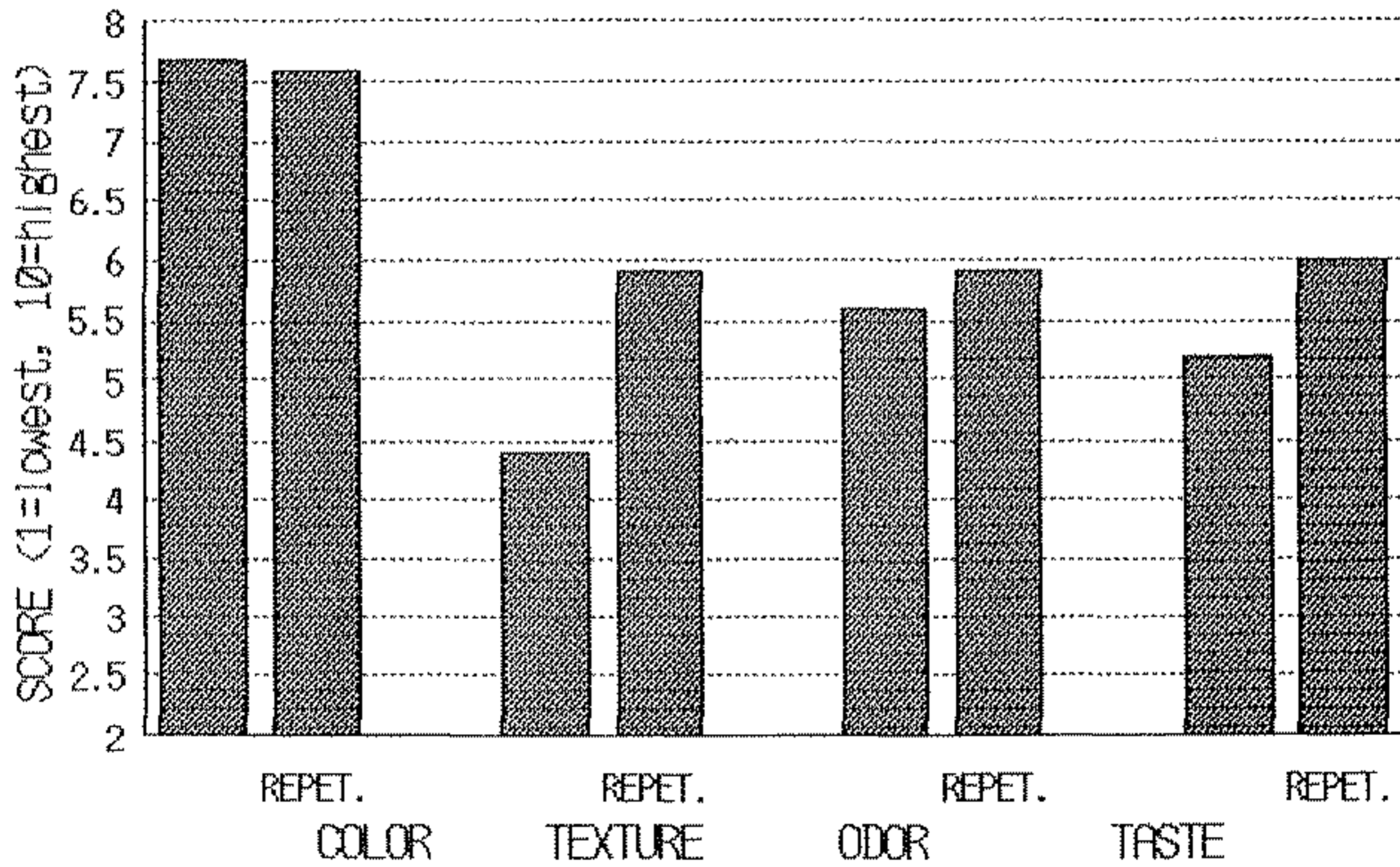


Figure 36: Taste panel; repetitive sample #3 (20% MESQUITE)

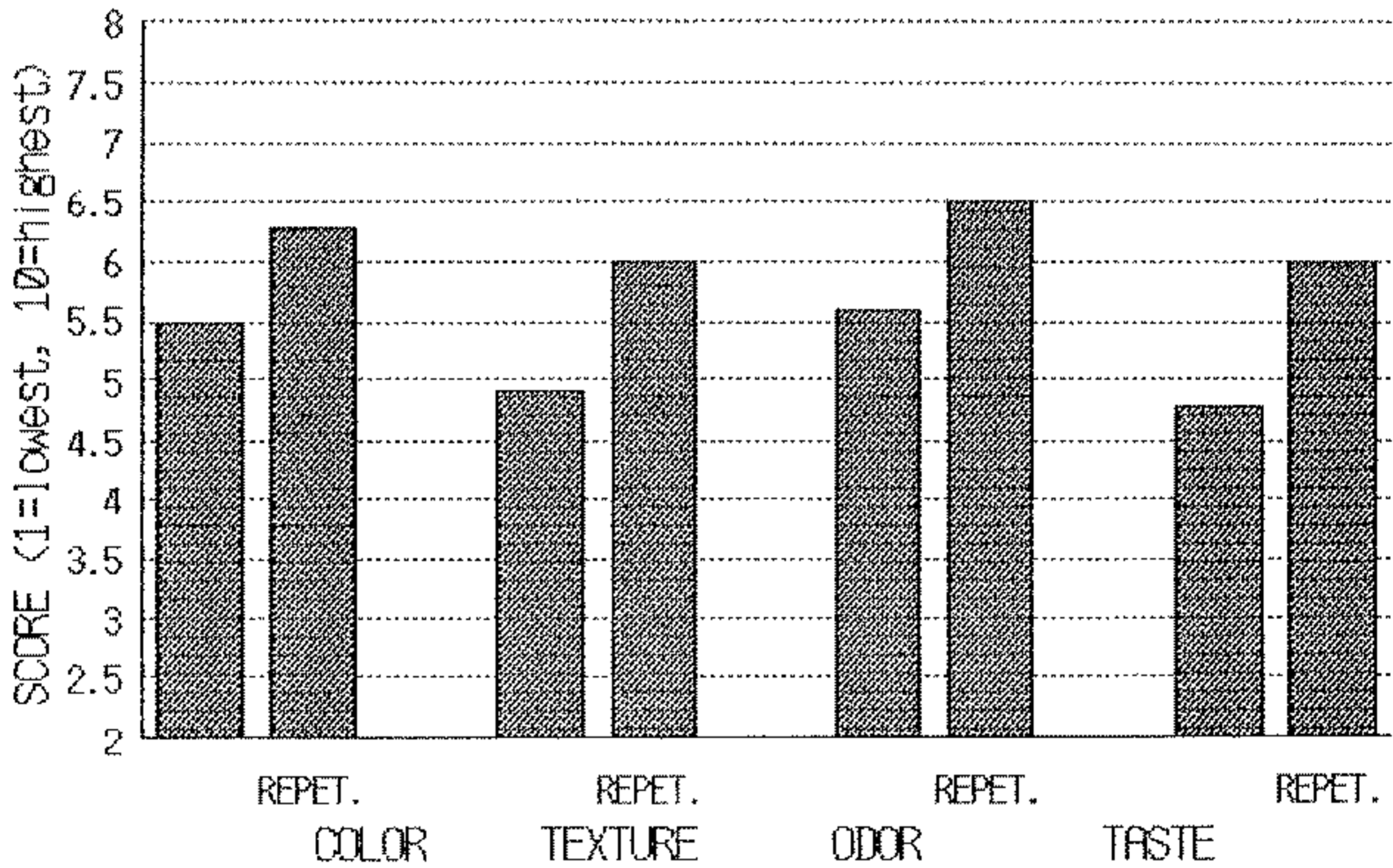
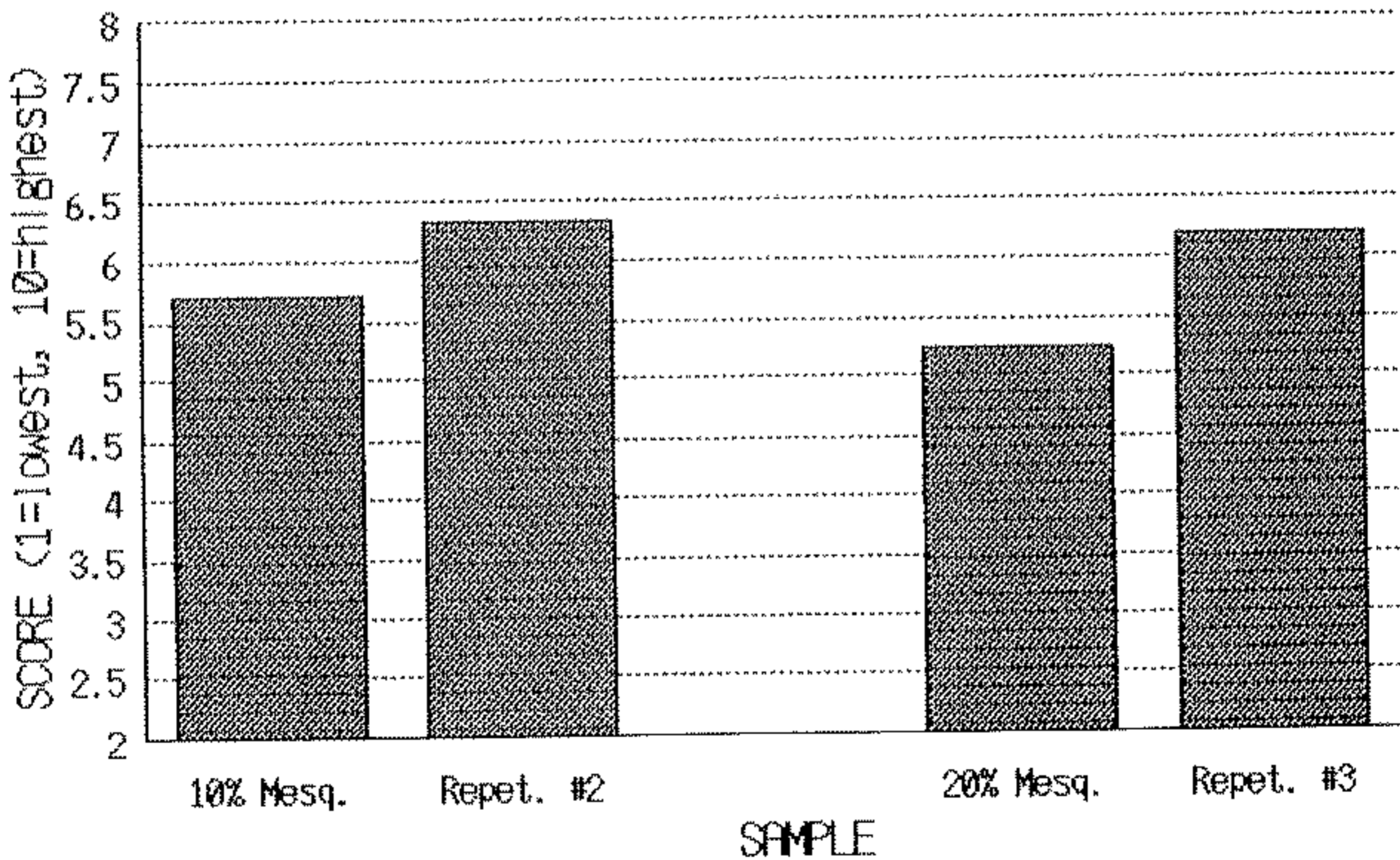


Figure 37: Taste panel; comparison total score with repetitive samples



#### 2.5.2.2. FRACTION B

Fraction B (or endocarp hull) represents quantitatively 20-25% of the whole MESQUITE pod.

The chemical analysis in Chapter 2.4.2.2. has revealed, that this fraction does not offer very interesting prospects as far as its use for human consumption is concerned.

This is due first of all to the very tough and fibrous structure of the endocarp which would require extensive milling and/or some heat treatment in order to be usable as a raw material of any kind .

Secondly, the nutritional value of the whole Fraction B is quite low, since fiber is its main compound (45%; Chapter 2.4.2.2.)

Nevertheless, if food or feedstuff in its ultimate extent shall be produced, it might still be feasible to separate the endocarp into two fractions (B1 >40mesh; B2 <40mesh), since B2 with its better nutritional value and finer texture might be used as a bland "filling" compound in bakery and other products. Its characteristic as an almost flavor- and odorless high fiber flour might justify such a separation.

A swiss chocolate company replaced defatted soyprotein with flour from MESQUITE Fraction B and found percentages up to 3% in the chocolate-mass acceptable. However, one has to be aware, that such an application would put MESQUITE Fraction B into a very competitive, low price market.

Therefore, with one of the basic goals of this work in mind, an **economically realistic utilization of MESQUITE pods**, alternatives which go beyond food- and feedstuff application had to be considered for Fraction B.

The simplest but nevertheless not useless application could be to plow the endocarp hulls back into the soil before a planting season, as it is most often done with residual crop materials (78). This organic material is an important soil conditioner because it improves the air- and water holding capacity of the soil and reduces wind and water erosion, which is a most urgent problem in MESQUITE-growing areas.

Another alternative would be to sell Fraction B for combustion to individuals, since such regions often obtain more than 40% of their energy needs through biomass (in comparison: worldwide only 14%) (78). However, since the milling and separation process of MESQUITE pods requires energy input itself, it would appear as a logical conclusion to utilize Fraction B as a energy resource in the processing of the pods.

Therefore, the characteristics of Fraction B for energy purposes and the options for its thermal conversion had to be studied at this stage.

A list of energy requirements during the milling and separation process revealed, that hot air, electricity and steam would be necessary along the line ( Chapter 3.3.).

Several possible ways of energy-production from biomass have been studied in the last ten years, such as fluid bed combustion (79) or fermentation to ethanol (80;81). Most of these options require an extensive know-how and sophisticated process-control. Direct combustion on the other hand is the simplest and cheapest thermal conversion to produce hot air, which in the case of MESQUITE processing is needed for drying of the pods.

MESQUITE Fraction B as the raw material for combustion has to be compared with the most commonly used biomass source, firewood and crop residues (sugar-cane bagasse (83) or wheat straw). The product which has been chosen to serve for comparison is sawdust, whose characteristics have been studied extensively by several authors (84).

#### Combustion-characteristics of MESQUITE Fraction B:

The most crucial factor determining the value of biomass for combustion is its moisture-content since drying as the first stage of burning is a highly endothermic reaction. Fraction B has a moisture content (after the milling and separation process) of only 4-6%. This is a value which is far better than most comparable products (Table 31).

Another important factor is the density of a product that should serve for combustion, since volume is quite a costfactor in the handling of such materials. MESQUITE Fraction B has a density of 0.4g/cm<sup>3</sup>. This is value comparable to sawdust. The density could be increased by a densification process (84), but would hardly pay off since the material does not have to be stored or transported in the proposed system. Another way of densification can be achieved by chopping the endocarp hulls with a pin-mill into two Fractions (B1<sub>></sub>40 mesh; B2<sub><</sub>40 mesh), which primarily serves other purposes (separation into two nutritionally different fractions; see above). The characteristics of Fraction B for combustion purposes are therefore being studied in two physical stages:

- a) As obtained during the milling and separation process (opened endocarp hulls, but not further reduced in size)
- b) Further reduction in size and separation into the above described two fractions ( 40<sub>></sub>mesh; 40<sub><</sub>mesh)

Burning value:

The burning value stands for the actual energy which is being released by a given material through combustion and is therefore the most important number besides burning residues. The figures shown in Table 31 (Method ASTM d3286).

Table 31: Burning value of MESQUITE Fraction B

Material	Burning value	Burning value	
	(as is) BTU/kg	(dry weight) BTU/kg	KJ/kg
Fraction B, complete	15277	16082	16999
Fraction B1, >40 mesh	15675	16500	17441
Fraction B2, <40 mesh	16101	16949	17916
-----			
For comparison:			
Sawdust (80)	16414	18238	19300
Sugarcane bagasse	8300	16600	17563
Rice straw	10480	13100	13860
Average of cereal crop residues (81)	13090	15400	16300

Chemical composition; residues

The chemical quality of a raw material for combustion is not only of importance regarding pollution but also because the efficiency and the operating-costs are affected by residues.

Nitrogen and sulfur are two of the compounds which are responsible for possible pollution which is generated upon combustion. Sulfur, phosphorus and ash are to be as low as possible since they also negatively affect the thermal conversion process.

In addition, the distribution of C,H, and O is of importance for the energy efficiency of the process (81).

The figures evaluated for MESQUITE Fraction B are listed in Table 32.



Table 32: Chemical composition of MESQUITE Fraction B for combustion purposes

Material	%C	%H	%O	% S	% P	% Ash
Fraction B, complete	44	6.5	44	none	0.13	3.25
Fraction B1, >40mesh	44	6.3	46	none	0.05	3.0
Fraction B2, <40mesh	45	6.6	42	none	0.23	3.5
-----						
For comparison:						
Dry sawdust (80)	50	6.4	42	0.06	-	0.86

Additional chemical information of importance for the combustion process is available in Chapter 2.4.2.2.

In conclusion it can be said, that MESQUITE Fraction B, whether used on a "as is" basis or densified, provides a very good source for direct combustion or other thermal conversion processes. The quality matches dried sawdust easily and is superior to most all other crop residues.

For an application of this information see Chapter 3.3.3.

### 2.5.2.3. FRACTION C

#### 2.5.2.3.1. Gum preparation

Fraction C represents the two endosperm splits of the seeds, which are obtained by the milling and separation process.

It has been found, that these splits consist of approximately 40% seed coat and 60% endosperm. The seed coats have no functional or nutritional value, whereas the endosperm (containing the galactomannan) could be of considerable economical value. However, the separation of the endosperm from the seed coat is the main obstacle for a utilization of the galactomannan. For analytical purposes this can be done by soaking the endosperm splits in water, peeling off the seed coat and drying the endosperm under vacuum. The endosperm splits contain accordingly 65% pure galactomannan on the average, with a range of 55-75%. For all subsequent studies, 65% gum in Fraction C is regarded as 100% yield of gum.

Since all impurities in the galactomannan such as remaining seed coat material negatively affect its functional properties as a thickening agent and subsequently its economical value, several methods were evaluated to separate seed coat from the endosperm:

- a) Wet process: The splits are allowed to soak in water for various times at different temperatures, the endosperm can then be separated from the seed coat in a juice mixer.
- b) Dry milling: The splits are dehulled in a Udy-cyclon mill with a rubber rotor and an abressive surface.
- c) Combination of a) and b): The splits are first dehulled, ground into a fine powder, which is then soaked in water, to dissolve the gum, separated by centrifugation and the supernatent gum freeze-dried.
- d) Enzymes : The splits are soaked in solutions of pectinase or/and cellulase to hydrolize the seed coat.
- e) Liquid Nitrogen :The splits are soaked in H<sub>2</sub>O for one hour and then frozen in liquid N<sub>2</sub>, to break the endosperm off the seed coat (86).

Of all the described methods only a) and b) were promising enough for further investigation, whereas the other procedures failed completely or resulted in a degradation of the gum.

Method a) and b) were therefore improved with the following results.

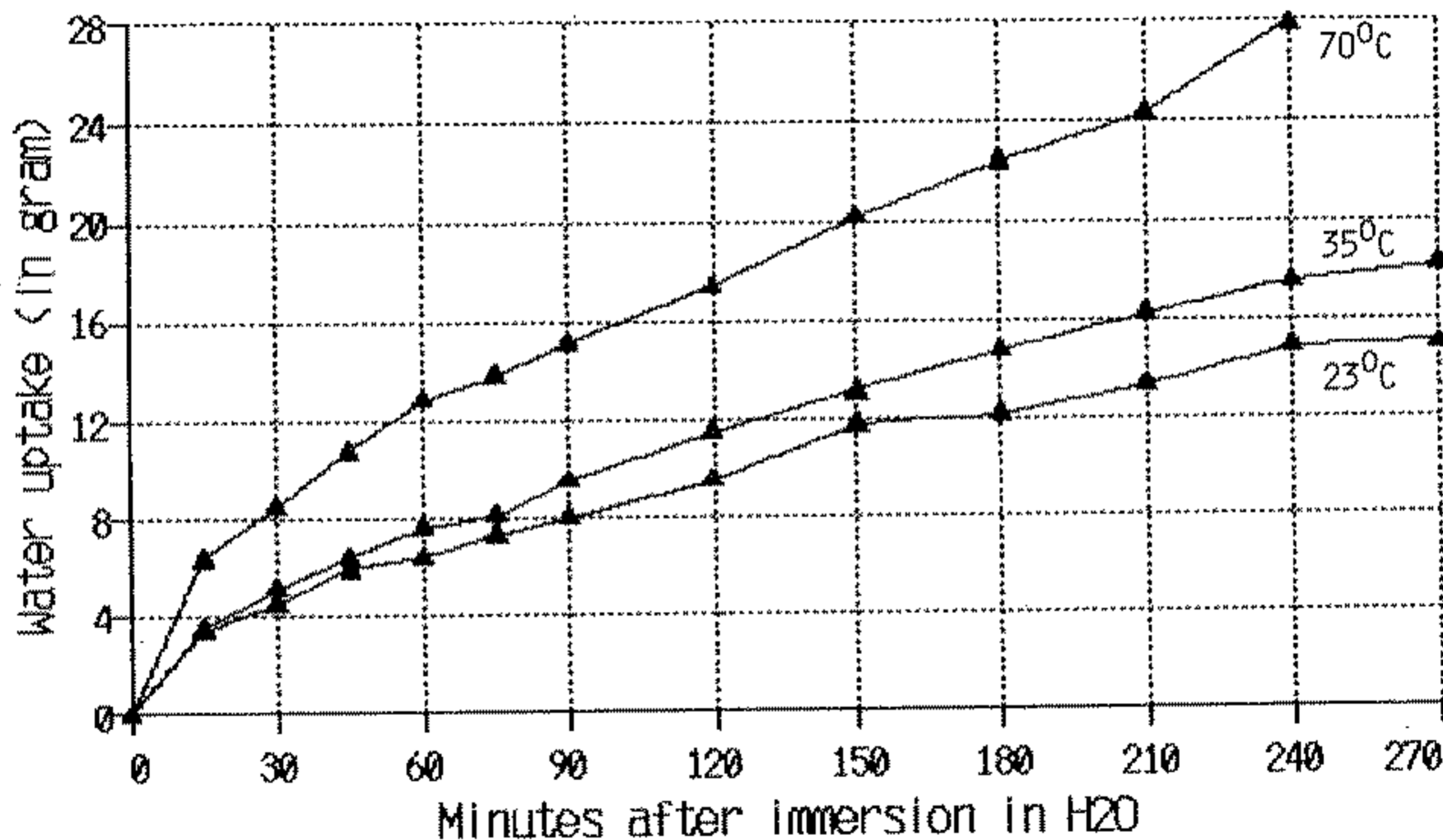
A) Wet process :

When endosperm splits are soaked in water, the galactomannan swells up considerably. The seed coat itself absorbs little water only and the endosperm can be peeled off the seed coat quite easily. The optimal swelling of the gum was measured as follows:

- 2g of Fraction C are given in flat weighing boats ( 8 cm wide; 2 cm deep) with twenty 1 mm wide holes in the bottom.
- Three such dishes are placed into beakers, which are filled with distilled H<sub>2</sub>O at different temperatures ( 23 °C; 35°C; 70 °C), so that the weighing boats are completely filled with water.
- The samples are stirred for 20 seconds every 3 minutes and are weighed every 15 minutes (after the water is dripped off and the weighing boats are dried with absorbing paper to eliminate surface water.
- The weight difference of the samples is equivalent to the absorbed water.

Figure 38 shows the results . It can be seen, that higher water temperatures increase the speed of absorption, and that a immersion time of 240 minutes is adequate for all temperatures.

Figure 38: Water uptake of Fraction C at different temperatures



The weight of the sample soaked at 70°C increased its weight dramatically after 200 minutes. The sample swells up so much, that surface water can not be removed anymore.

Once that 240 minutes were proven to be sufficient to allow maximal water absorption (and subsequently easiest removal of the endosperm from the seed coat) a second experiment with the same setup was performed to determine the yield of galactomannan:

- The endosperm splits are allowed to absorb water for 240 minutes, as described for "water uptake".
- The splits are removed from the weighing boats, and the remaining water in the beakers is freeze-dried to determine lost galactomannan (L).
- The splits are given in a Omni-mixer, where the endosperm can be removed from the seed coat.
- The mixture is filtered (FILTRATE= G1); the preceding step is repeated with the material retained by the filter and some added water, and this mixture again filtered (FILTRATE= G 2)
- Both filtrates are separately freeze-dried and weighed.
- The seed coats retained by the filter are dried and weighed as well.

Table 33 shows that a soaking temperature of 70°C provides the highest yield of pure gum and requires only one mixing step. Thanks to the low viscosity at this temperature, handling is also simplified.

Analysis of the such prepared gum showed for all temperatures the following impurities: protein < 4 % crude fiber < 1 %

Nevertheless, this procedure involves many steps and requires considerable amounts of water and would therefore be a very expensive method, justified only if the resulting gum would have outstanding functional properties.

Table 33: Yield of galactomannan obtained by a wet process at different soaking temperatures

Quantities in g	Soaking temperature		
	23°C	35°C	70°C
=====			
Gum lost in bath (L)	0.05	0.1	0.14
Gum yield in 1. mix (G1)	0.61	0.51	1.05
Gum yield in 2. mix (G2)	0.45	0.5	0.18
Gum recovered (L + G1 + G2)	1.11	1.11	1.37
Seed coat	0.36	0.48	0.33
Total material recovered	1.47	1.59	1.70
	73 %	79 %	85 %
 <b>ACTUAL GALACTOMANNAN YEALD:</b>			
G 1 + G 2 - L	1.06	1.01	1.23
IN % OF INPUT	78 %	75 %	91 %
=====			

Sample size: 2 g Fraction C containing 1.3 g galactomannan

B) Dry milling:

As an alternative to the wet process, dry milling was studied to produce a relatively pure galactomannan.

-The endosperm splits are first of all run through a UDY-cyclone mill (equiped with a rubber rotor and an abrassive surface, at 2200 rpm for 30 seconds). This produces some fine material (F), which originates primarely from the seed coat, as well as partially dehulled splits (D). These two fractions can easily be separated in a air-classifier.

-The splits (D) are again run through the same mill but this time with a stainless rotor at 3000 rpm for 20 seconds, which results in a fine ground gum powder, that can be classified into the sizes G2 <140 mesh and G3 >140mesh.

Table 34 shows the composition of the produced gum and its residual fraction:

Table 34: Analysis of endosperm split fractions obtained by dry milling

Fraction in %	Quantity	H2O	Crude fiber	Protein
Input:				
Splits, untreated	100	7.0	6.1	4.3
Output:				
Splits, dehulled (D)	90	5.0	5.3	3.5
Hullmaterial (F)	10	5.0	10.6	13.7
(D) milled				
G2 <140 mesh	45	5.0	5.3	3.2
G3 >140 mesh	45	5.0	5.5	3.8

The fractions F, G2 and G3 were further analyzed in order to evaluate the sucess of the purification of the gum fraction (G) and accordingly the purity of the galactomannan (Table 35).

Table 35: Ultimate analysis of endosperm split fractions after purification through dry milling

FRACTION in %	Protein	Crude fiber	Ash	Insoluble*	Galacto- mannan
G2 <140 mesh	3.2	5.3	1.15	30.0	64.0
G3 >140 mesh	3.8	5.5	1.2	45.0	43.0

\*Insoluble/ soluble determined by centrifugation of a 5% solution at 12'000 rpm and freeze drying of the supernatant and drying the insoluble material respectively.

**SUMMARY:**

The wet and dry process resulted in the following three different grades of gums, with which the viscosity studies in Chapter 2.5.2.3.2. were performed.

- GRADE 1 : Prepared by wet process      Galactomannan-conc. 85-95 %
- GRADE 2 : Drymilled, <140 mesh      Galactomannan-conc. 55-65 %
- GRADE 3 : Drymilled, >140 mesh      Galactomannan-conc. 40-55 %

Trace elements and minerals as indicators for gum purity

The two grades of gum obtained by dry milling as well as the remaining hull material (page 102) were analyzed for minerals and trace elements.

It has been found, that some minerals and trace elements are primarily found in either one of the two grades or the hull material. This suggests that these elements are primarily associated with either the galactomannan or the seed coat. The quantity of these compounds is much easier to determine than the amount of galactomannan. Therefore minerals and / or trace elements could serve well as indicators for gum purity. Results of this investigation are shown in Table 36 and Figure 39.

Table 36: Distribution of trace elements and minerals in Fraction C ( in ppm )

Element	G2 < 140 mesh	G3 >140 mesh	Hull material
Iron	21.4	55.5	314.7
Manganese	11.4	12.9	25.4
Zinc	32.7	57.8	147.0
Copper	17.8	107.8	181.2
Nickel	23.2	63.3	3.0
Cobalt	1.7	7.2	11.4
Calcium	2210	2310	3530
Magnesium	531	567	1310
Potassium	3125	2745	5510
Sodium	200	860	1390

The result shows, that all elements except nickel decrease with higher gum content. In order to support these figures, minerals and trace elements of a pure MESQUITE galactomannan and of a sample of pure seed coats were determined as well. The result (Table 37; Figures 39-41) indicate, that the correlation is true for the following elements only:

Manganese, calcium, magnesium

All the other elements occur in some cases linear as far as the three products in Table 36, but the comparison with pure seed coat or gum does not held up a theory of a correlation with gum purity.



Table 37: Elements correlating with gum purity in Fraction C

FRACTION	% Galactomannan	Manganese ppm	Magnesium ppm	Calcium ppm
Pure seed coat	0-5	26.5	1310	6057
Hull material (F)	2-8	25.4	1276	3530
G3 >140m	45	12.9	567	2310
G2 <140m	60	11.4	531	2210
Pure gum	90	8.0	457	1607

Figure 39: Corelation between MAGNESIUM  
and galactomannan content

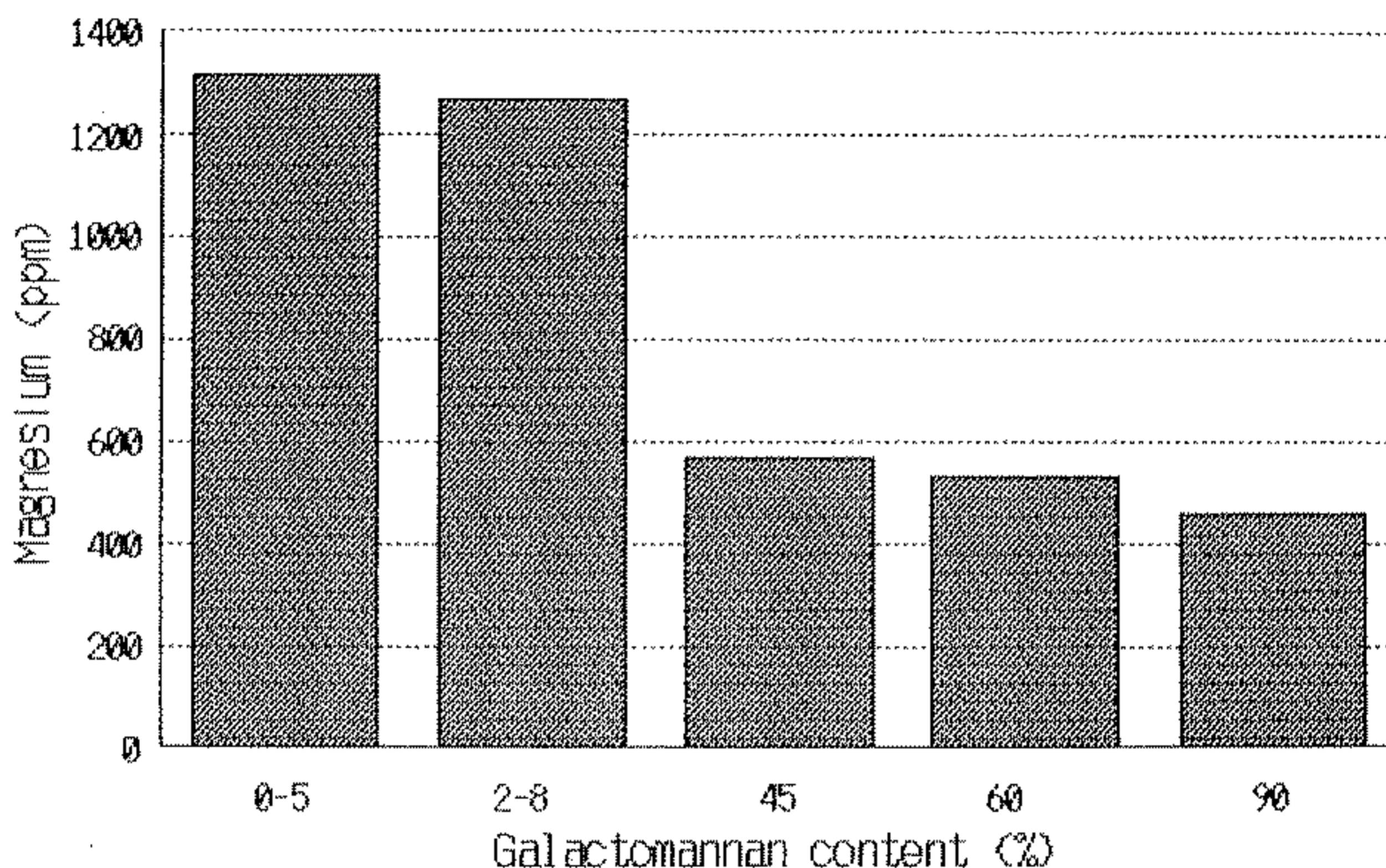


Figure 40: Correlation between MANGANESE and galactomannan content

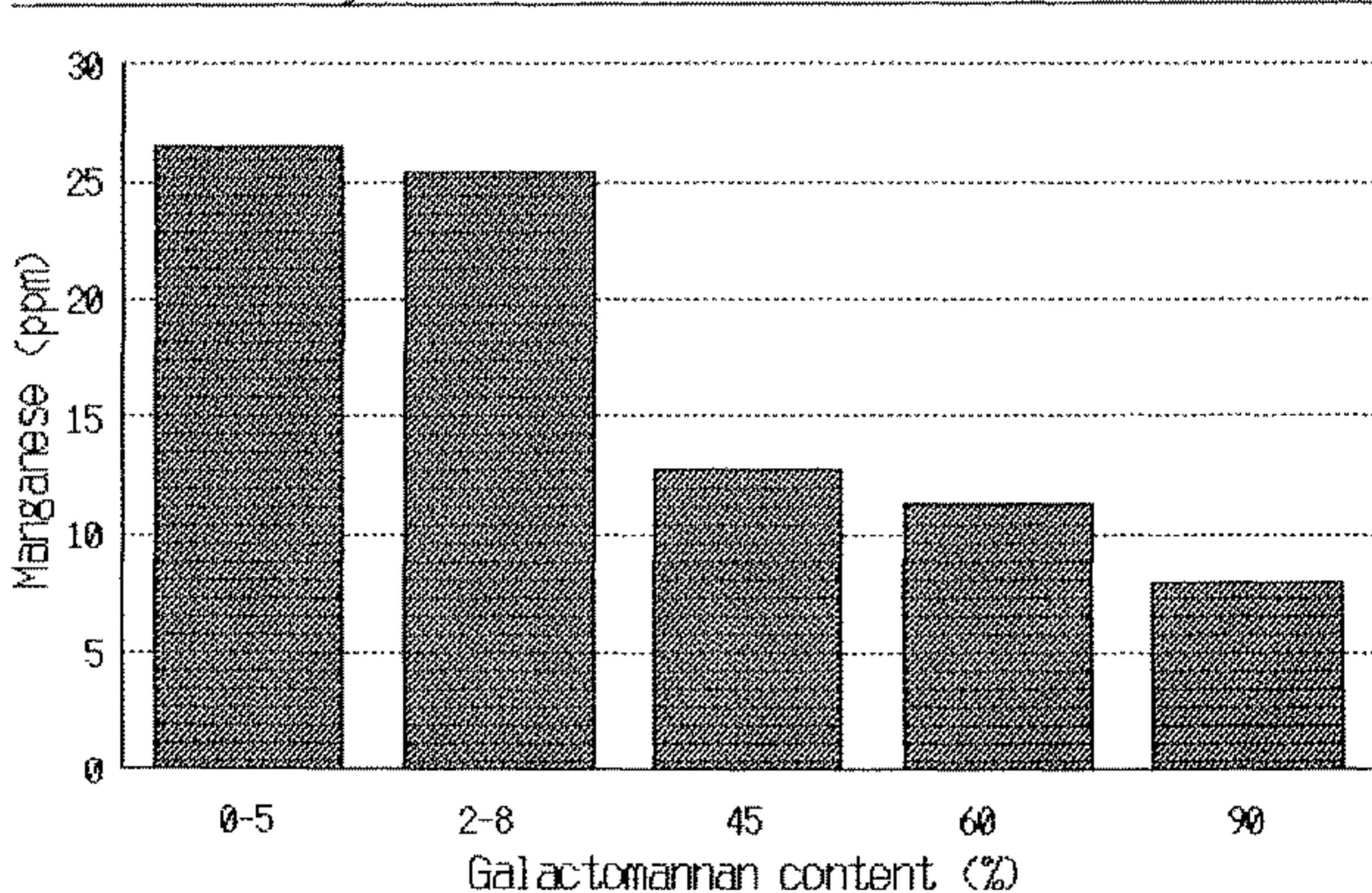
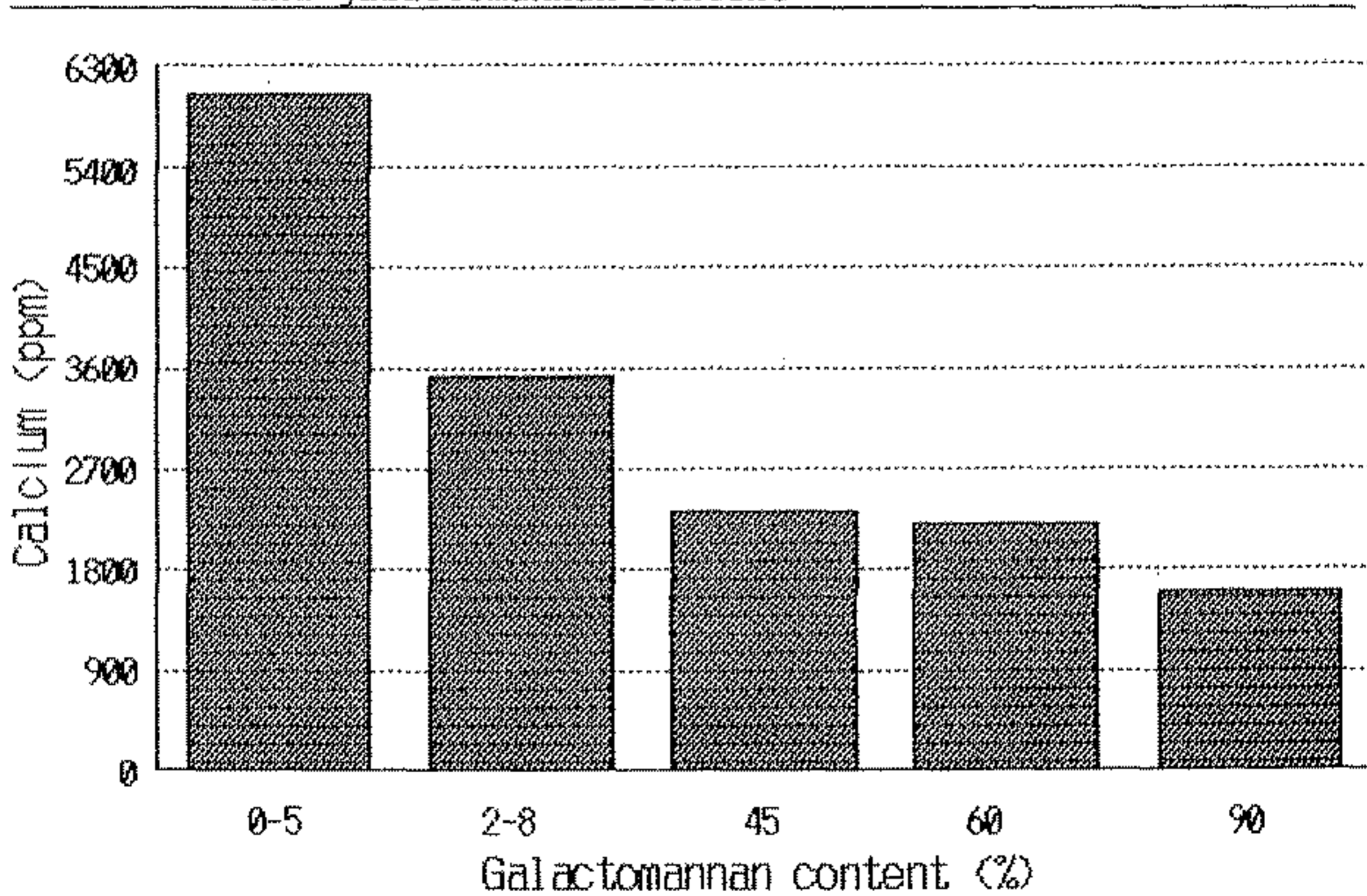


Figure 41: Correlation between CALCIUM and galactomannan content



#### 2.5.2.3.2. Viscosity studies on the galactomannan

Galactomannan gums are used in industries such as oil-well drilling, pharmaceuticals, food and pet-food (61;86). The gum that is chosen for a given application depends on two crucial criterias: Functional characteristics and price

This chapter deals with the functional characteristics, whereas cost and price of the MESQUITE galactomannan will be discussed in Chapter 3.4.

The functional properties of a gum, which consist only of galactomannan are mainly determined by its mannose:galactose-ratio and are quiet predictable once this ratio is known. When used together with another hydrokolloid such as xanthan, the molecular structure plays an important role as well (87).

The mannose:galactose-ratio of the MESQUITE galactomannan in Fraction C has been found to be around 1.6 : 1 (see 2.4.2.3.), which is quite close to guar gum or leucaena gum (88). This would therefore justify comparison of one or both of the gums with MESQUITE. The determination of the molecular structure would definitely go beyond the scope of this work, but the similarities (discussed in the following) of the functional properties between guar- and MESQUITE gum would suggest similarities in their molecular stucture as well.

The viscosity studies were performed with GRADE 2 MESQUITE galactomannan (prepared through drymilling; G2<140mesh).

Preliminary tests showed, that the viscosity of a 1%-solution of GRADE 1 (1.1g/100 ml= 1g pure galactomannan) did not differ from a 1%-solution GRADE 2 (1.65g/100 ml= 1g pure galactomannan). The concentration is always given as absolute galactomannan concentration, by using 1.65 as multiplier to determine the amount of dry matter in solution.

(Example: The viscosity of a 0.5% gum solution is based on  $1.65 \times 0.5 \text{ g} = 0,825 \text{ g}$  Grade 2)

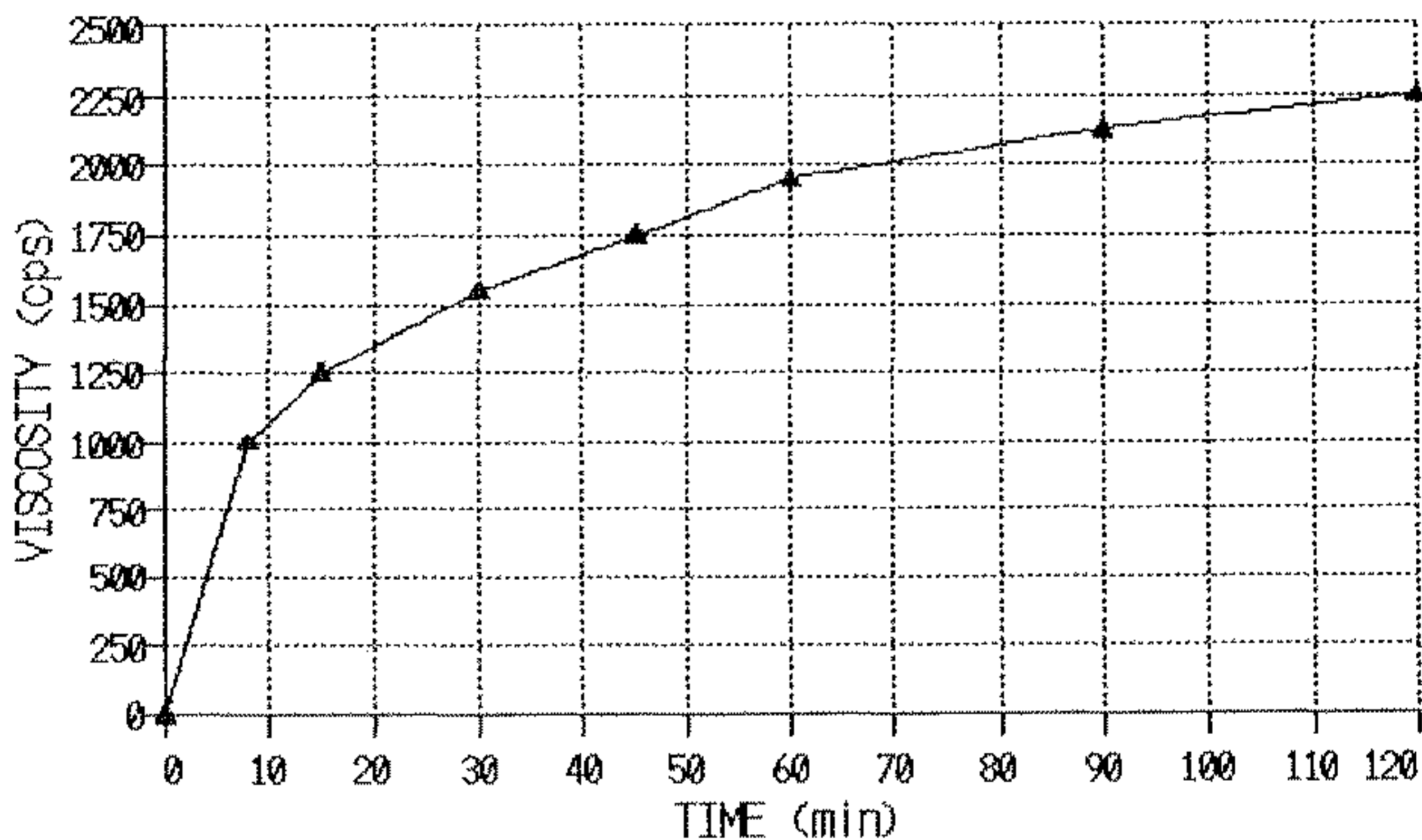
The solutions were prepared by adding 5ml methanol/ g gum to a given amount of dry MESQUITE gum and pouring this dispersion in distilled H<sub>2</sub>O at 25°C. The samples were mixed for 2 min at speed 8 with a Polytron high-speed mixer. The viscosity was then determined using a Brookfield viscometer (model RTV).

Increase in coldwater-viscosity versus time

For the use in products which do not undergo a heating process, coldwater-solubility and subsequent coldwater-viscosity are of importance. The behavior of MESQUITE galactomannan is shown in Figure 42.

Figure 42: Increase in coldwater-viscosity versus time

Brookfield viscometer (20 rpm; Spindle #3; 25°C)  
Concentration: 1%



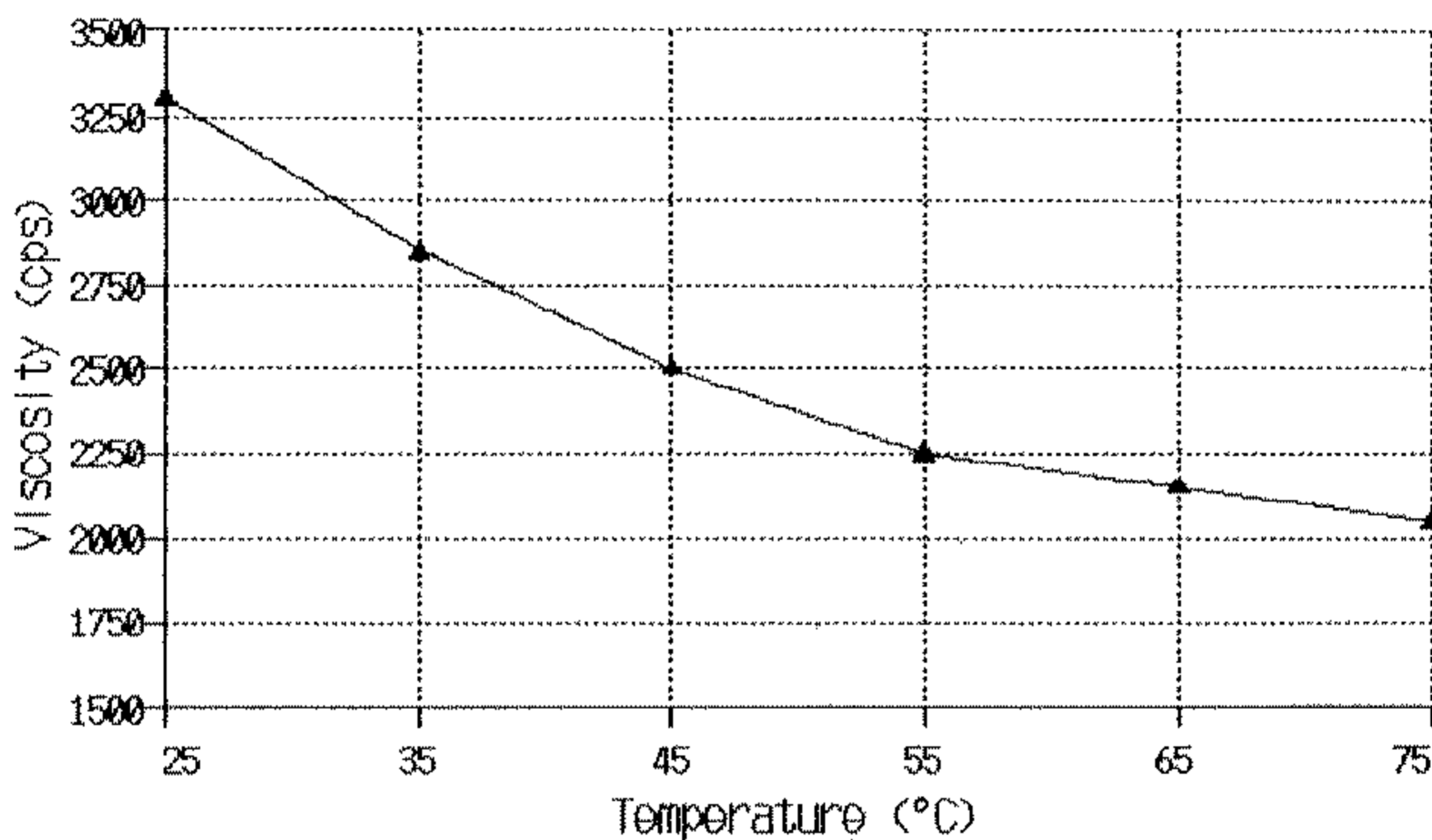
Viscosity at different temperatures

Heating a MESQUITE gum solution reduces the viscosity and increases again upon cooling to a maximum value which is about 30% higher than at the same temperature when the solution has not been preheated. MESQUITE gum is therefore not completely coldwater soluble.

The temperature stability can be determined by reheating a solution and checking the viscosity along the temperature increase (Figure 43).

Figure 43: Temperature stability of solubilized MESQUITE gum

Brookfield viscometer (20 rpm; Spindle #3)  
Concentration: 1%



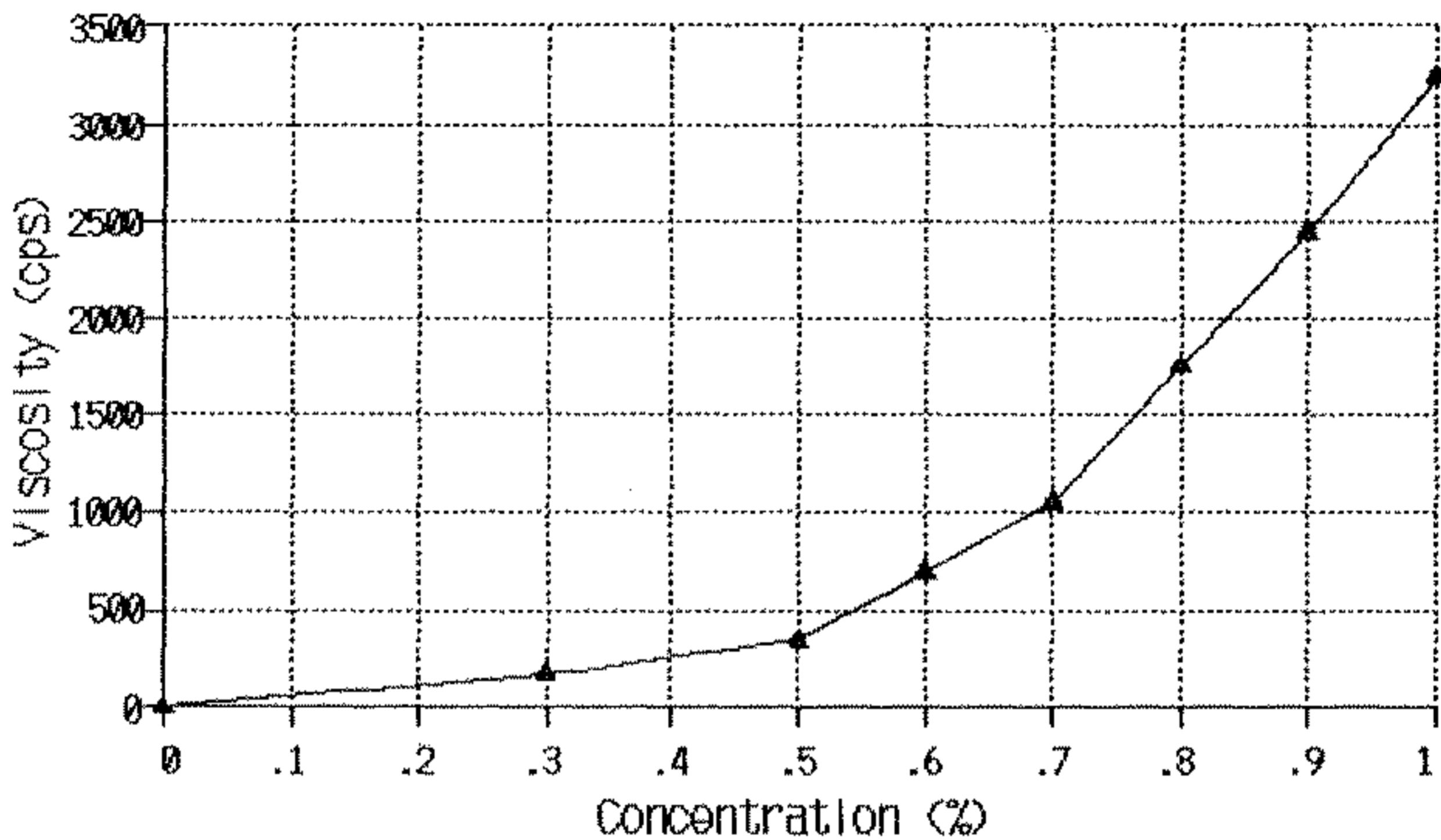
Viscosity at different concentrations

Galactomannan gums are commonly used in foods in concentrations of around 1%. Figure 44 shows the viscosity of the MESQUITE galactomannan in concentrations from 0.1-1.0%. It can be seen, that the viscosity increases exponentially.

Figure 44: Viscosity of solubilized MESQUITE gum at different concentrations

---

Brookfield viscometer (20 rpm; Spindle #3; 25 °C)



2.5.2.3.3. Interaction of MESQUITE galactomannan with xanthan gum

---

The synergistic reaction of xanthan with galactomannan gums and other hydrocolloids is widely used in the food and petfood industry. This interaction has been called a "useful incompatibility" (89). The mechanism has been extensively studied in the last few years and it is believed to be caused by some kind of physical association of the molecules of the two gums (90). A drastic viscosity increase is observed by combinations of the two hydrocolloids with lower percentages of total gum. The combination with xanthan gum results in a more temperature stable end product. It is therefore important for the market value of a galactomannan that it shows this interaction with an other hydrocolloid.

Optimal ratio of MESQUITE gum to xanthan

The maximum interaction occurs at different ratios of galactomannan to xanthan, depending on the source and structure of the galactomannan. Table 38 shows the viscosity of different ratios of MESQUITE/xanthan at 1% total concentration. Samples were prepared by dry-blending the two gums, wetting with 0.5ml ethanol and heating to 75°C. The viscosity was measured during heating and again at 25°C.

Table 38: Viscosity at different MESQUITE:xanthan-ratios (in cps; total concentration 1%)

---

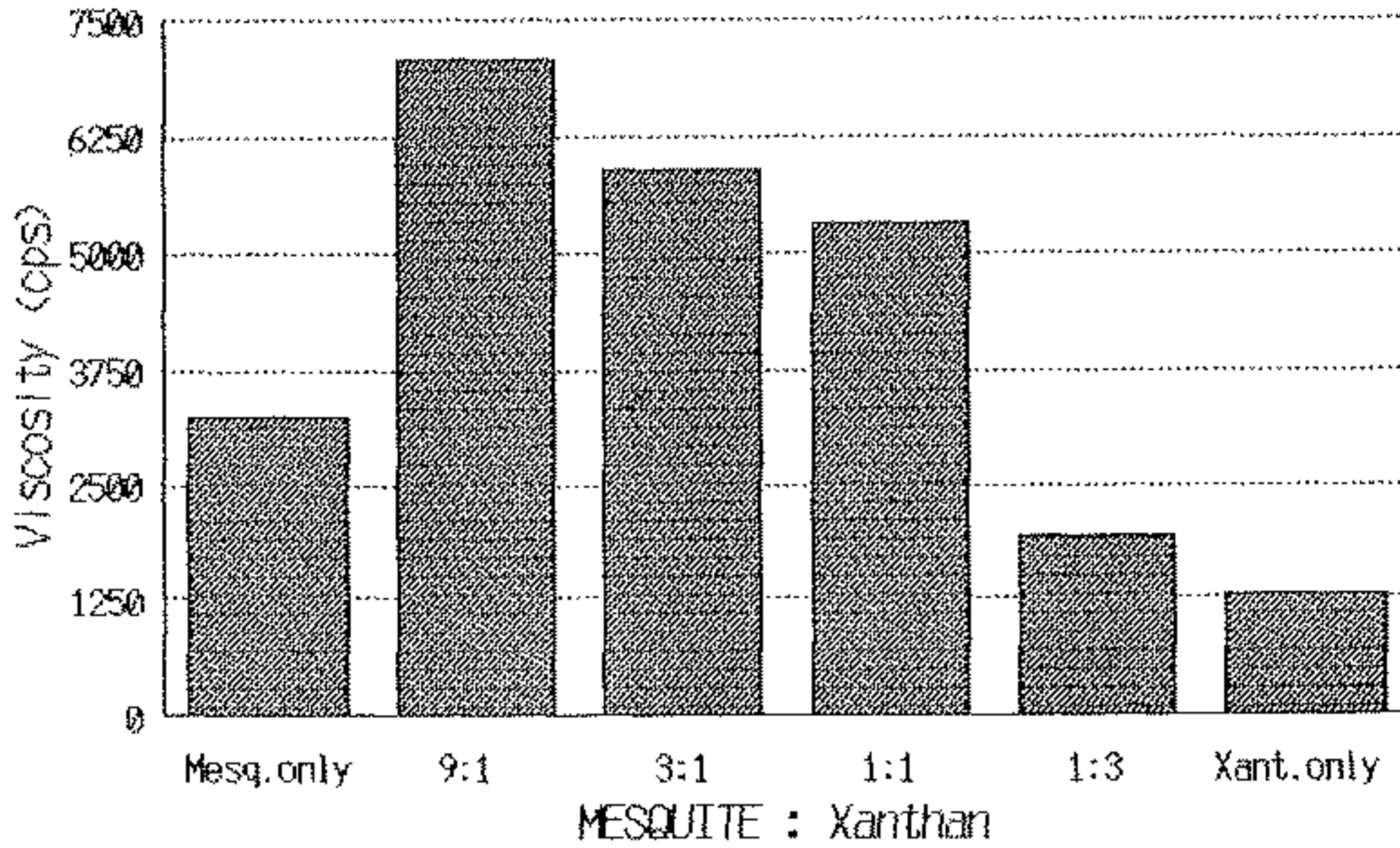
Brookfield Viscometer; Spindle #3, 20 rpm)

Temperature	MESQUITE : Xanthan			
	9:1	3:1	1:1	1:3
25°C (unheated)	750	800	1100	1450
75°C	2500	2300	1900	1500
60°C	3300	3100	2700	1700
50°C	3750	3350	3100	1750
40°C	4300	4000	3400	1800
35°C	5500	4500	3600	1850
30°C	6050	4800	4300	1900
28°C	6500	5450	4600	1950
25°C	7050	5900	5700	1950

The highest viscosity can be achieved by adding 10% xanthan gum to the MESQUITE galactomannan; it reaches a value more than twice as high of the MESQUITE-only sample. Intensity of the interaction diminishes with higher percentages of xanthan.

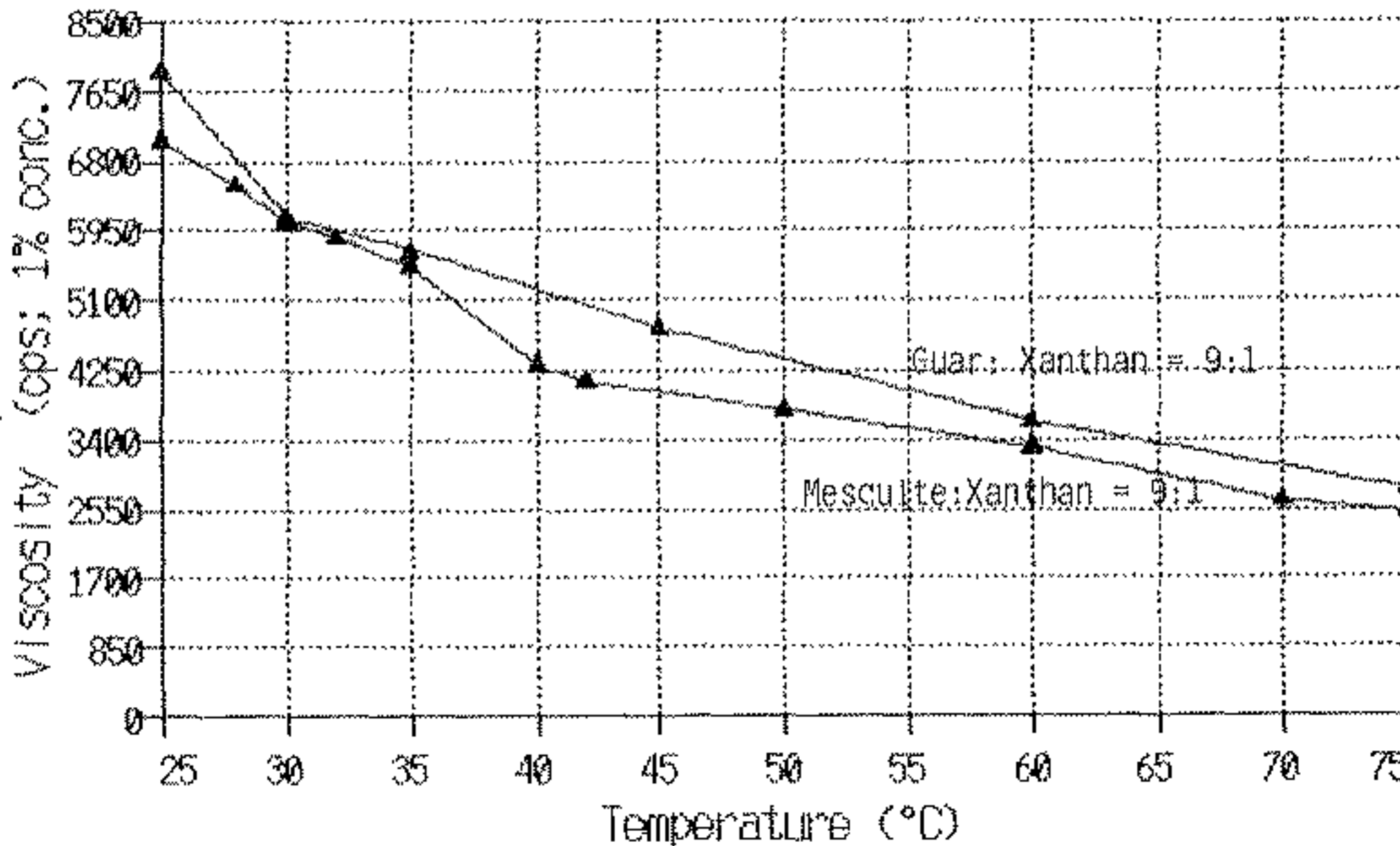
The viscosity of different hydrocolloid mixtures at 25°C (after heating) as well as the comparable viscosities of the single gums are illustrated in Figure 45.

Figure 45: Viscosity of MESQUITE/xanthan combinations (at 25°C)



The temperature stability of the best combination (9:1) is shown in Figure 46: The strength of the interaction is reduced with increased temperature.

Figur 46: Temperature stability of MESQUITE/xanthan (9:1)





#### 2.5.2.4. Fraction D

Fraction D is made up of the cotyledons and the germ of the MESQUITE seed and represents 12-15% of the whole, dried pod (Chapter 2.2.). Its main constituents are protein (61 %) and fat (8 %).

Many protein products from leguminous seeds as well as from other sources, are used in the food industry for two different reasons :

- fortification and balancing of the amino acid composition
- functional properties (e.g. foaming; stabilizer)

The amino acid composition of Fraction D as shown in Chapter 2.4.2.4., reveals that the protein of this fraction is typical for a leguminous seed, which would basically qualify it for fortification purposes.

The significantly improved protein efficiency ratio (PER) of flakes containing 20% Fraction D (Chapter 2.5.2.1.2.2.), would be an other argument for the utilization of the MESQUITE Fraction D for such purposes. However, this protein has no clear nutritional advantages over any other leguminous seed protein such as soy or peas protein. It is therefore questionable whether Fraction D could compete as a protein for fortification purposes since the obtainable quantity is far beyond the quantity of already widely used proteins. The only exception is certainly the utilization of Fraction D in the local market on LDC's, where hardly any other protein material can be obtained.

Therefore, the following experiments concentrate on the study of the functional properties of Fraction D, which would give the MESQUITE protein the necessary competitive edge along with the resulting wider price autonomie, provided that it showed some unique characteristics.

The most desirable functional properties of a protein in the food industry are emulsification, fat and water absorption, texture modification, color control and whipping properties (91;92;93;94;95).

#### Preparation of a protein concentrate from MESQUITE Fraction D

- Mill Fraction D in a Willey-mill through the 30 mesh screen
- Extract fat with hexan during six hours
- Filter extract through Millipore 0.5 $\mu$  filter
- Evaporate hexane
- Dry protein-residue in vacuum oven at 40°C during one hour
- Reduce size of protein concentrate in a ball mill to <60mesh

Yield: 100g Fraction D results in 91 g protein concentrate and 9 g oil.

Protein content of concentrate: 63.1% (N x 6.25)

All the following experiments were done with this protein concentrate.

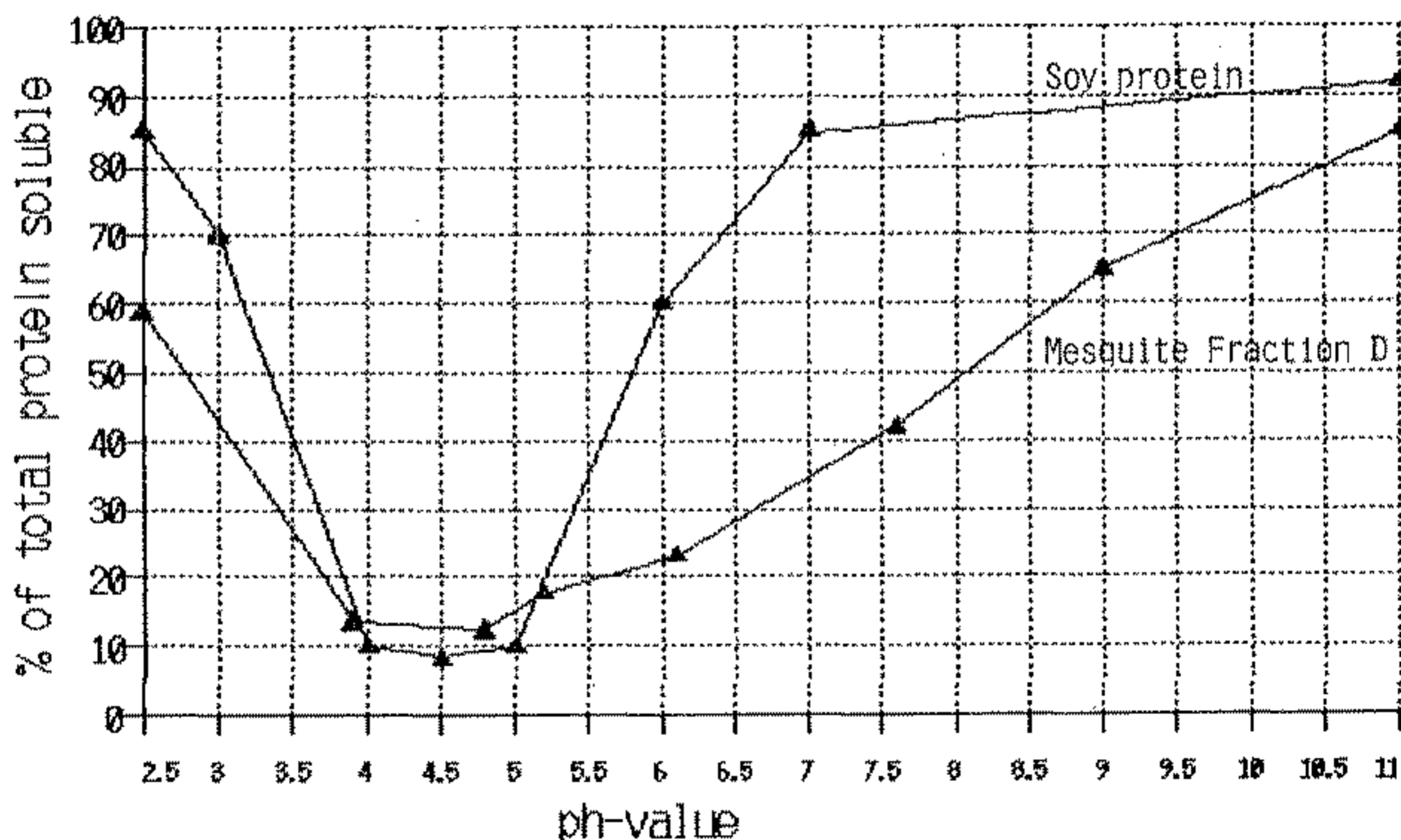
Protein solubility (93;96)

- 0.3g of Fraction D protein concentrate are given to 30 ml tap water in centrifuge tubes
- pH-value is adjusted to different levels with HCl or NaOH
- The samples are stirred with magnetic stirrers for 60 min.
- Centrifugation of samples at 5000 rpm for 40 min. at 25°C
- The supernatant is decanted and analyzed for nitrogen
- The precipitate is dried in a vacuum-oven for 12 hours at 60°C and weighed

The percentage of soluble protein was determined as % soluble nitrogen of total nitrogen.

The results are shown in Figure 47, along with the protein solubility of soy protein for comparison. It can be seen, that the protein concentrate of MESQUITE Fraction D has a rather low solubility. Almost complete precipitation occurs between pH-value 4 and 5.

Figure 47: Protein solubility of MESQUITE Fraction D



Heat denaturation

Solutions were prepared containing 1% Fraction D protein and were heated to 55°C and 70°C respectively. After centrifugation the supernatants were analyzed for nitrogen. As a reference, two samples were not heated.

The differences in percentages of soluble protein (N x 6.25) were found to be insignificant:

Unheated= 15.7%;            55°C= 17.0%;            70°C= 17.6%

Whipping properties: Foam expansion, foam stability (93;97;98)

Foam expansion and foam stability of MESQUITE Fraction D protein concentrate was studied as a single ingredient as well as compared and combined with skim milk.

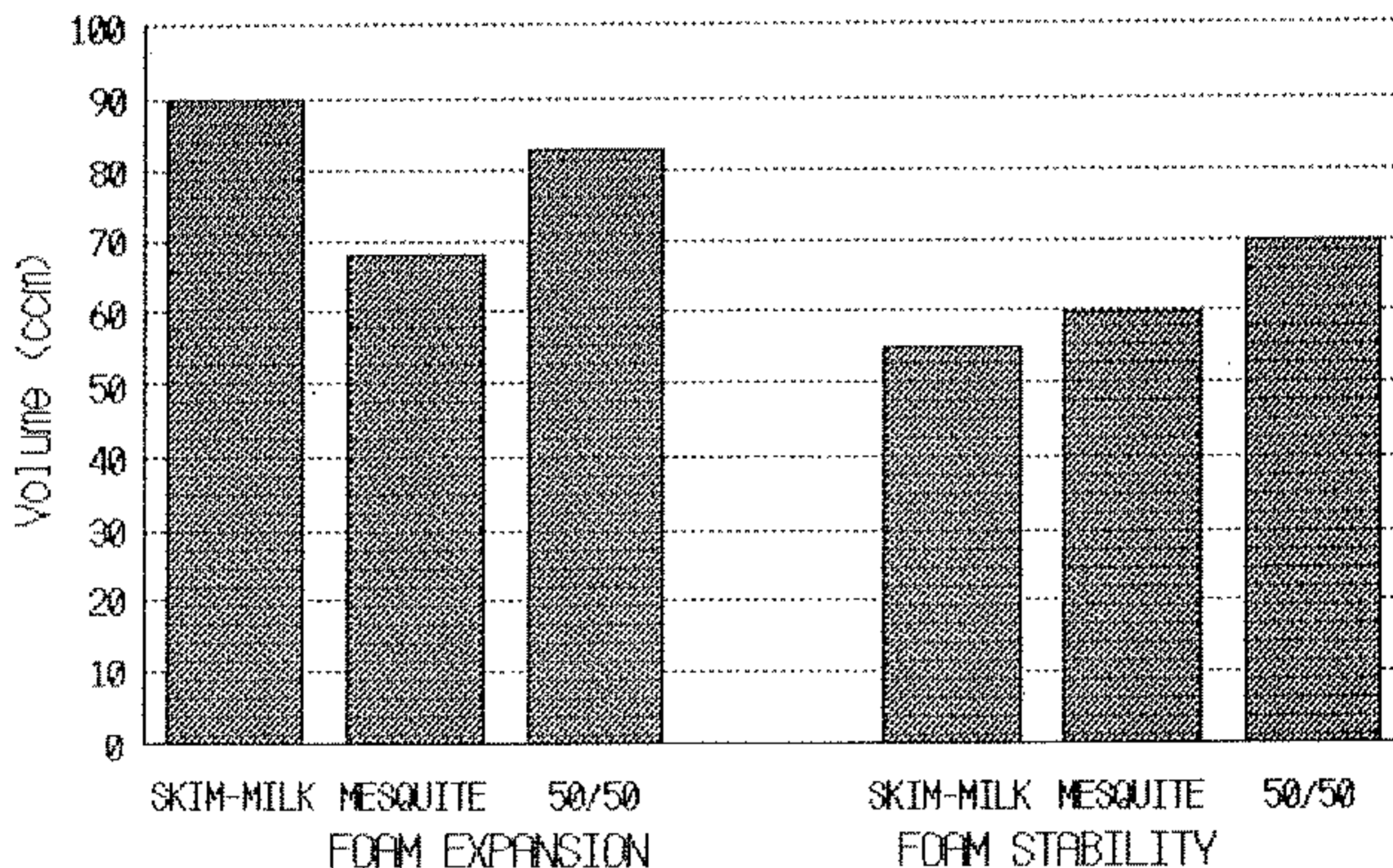
Samples:

- A: Skim milk only (Carnation nonfat, instant dry milk)
- B: MESQUITE Fraction D protein concentrate
- C: 50% skim milk + 50% MESQUITE Fraction D protein concentrate

- Procedure:
- Dissolve samples in water to give a 4% protein concentration by mixing with a Polytron at speed 7 for 5 min.
  - Shake samples horizontally for exactly 60 sec.
  - Measure volume = FOAM EXPANSION
  - Allow samples to stand and measure volume again after 60 min. = FOAM STABILITY
  - Repeat 5 times

The results (Figure 48) show that the MESQUITE product has good foam expansion and an even better foam stability. Combination with skim milk seem to cause a synergistic reaction that causes a better foam stability than either product alone.

Figure 48: Foam expansion and -stability of MESQUITE Fraction D



Emulsifying properties (91;93;98;104;105)

The **emulsion-capacity** measures the ability of a product to emulsify a solution of water and oil as percentage of the whole solution.

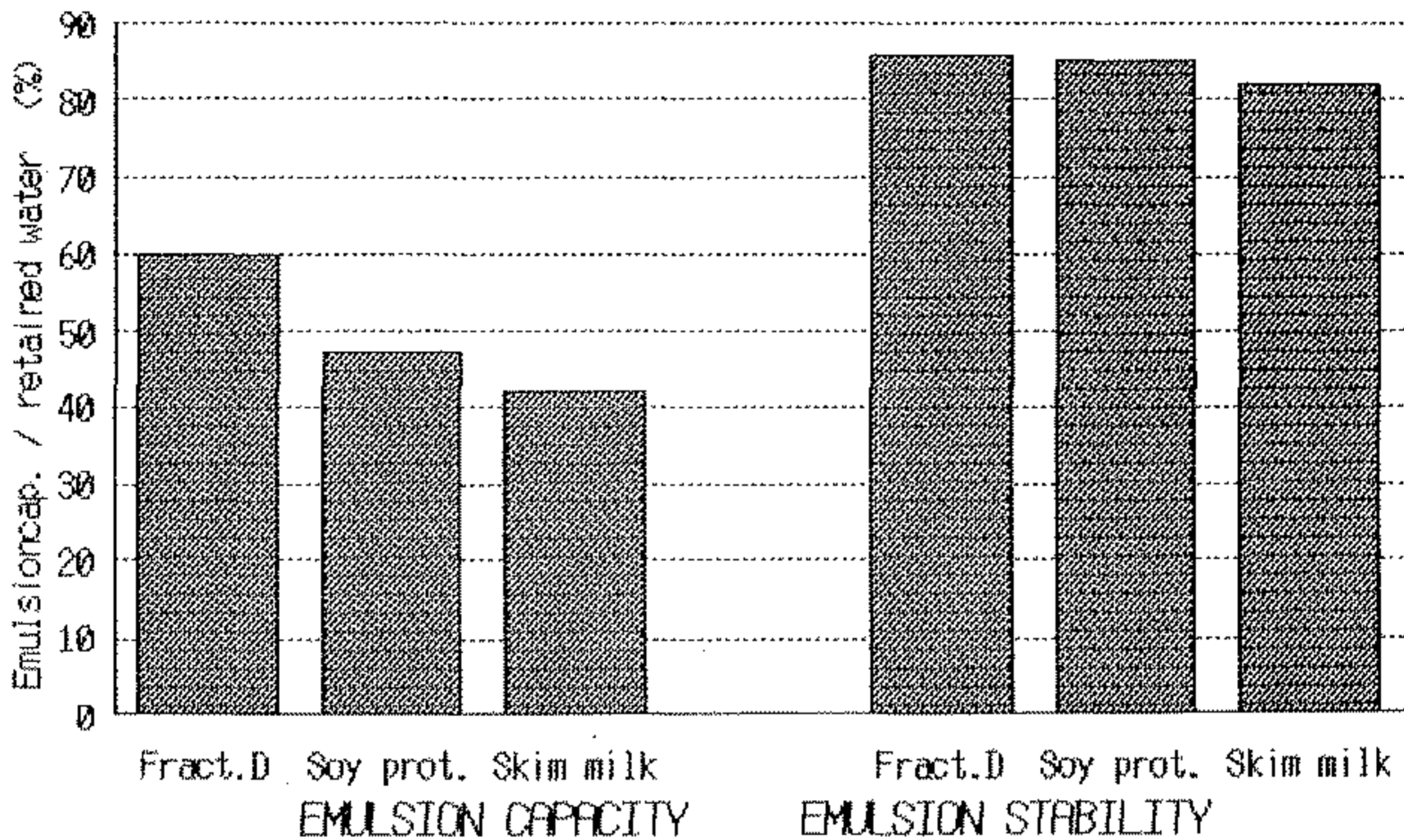
In the following experiment MESQUITE Fraction D protein-concentrate is being compared to a soy-bean concentrate (Archer Daniels, Bakers Nutrisoy with 52% Protein) and to skim milk.

- Procedure:
- Add protein concentrate to distilled water to produce a 4% total protein concentration
  - Add vegetable oil, equal to the amount of water
  - Give oil-soluble stain to the emulsion, mix with a Polytron high-speed mixer at speed 7 for 1 min
  - Divide the sample in glass centrifugal tubes (25 ml each) and centrifuge 10 min at 3500 rpm.
  - Read "height of emulsified layer x100 : height of whole layer" (in the center of tube) = **Emulsion-capacity**

The **emulsion-stability** is determined by measuring the amount of water released from the emulsion following centrifugation using the samples of above experiment . The value is expressed as:  
Total ml water in emulsion - water released x100 : total water in emulsion = **Emulsion-stability**

The results (Figure 49) indicate that the MESQUITE products compares favourably with the control products in both experiments

Figure 49: Emulsion capacity and -stability of MESQUITE Fraction D



Emulsion viscosity

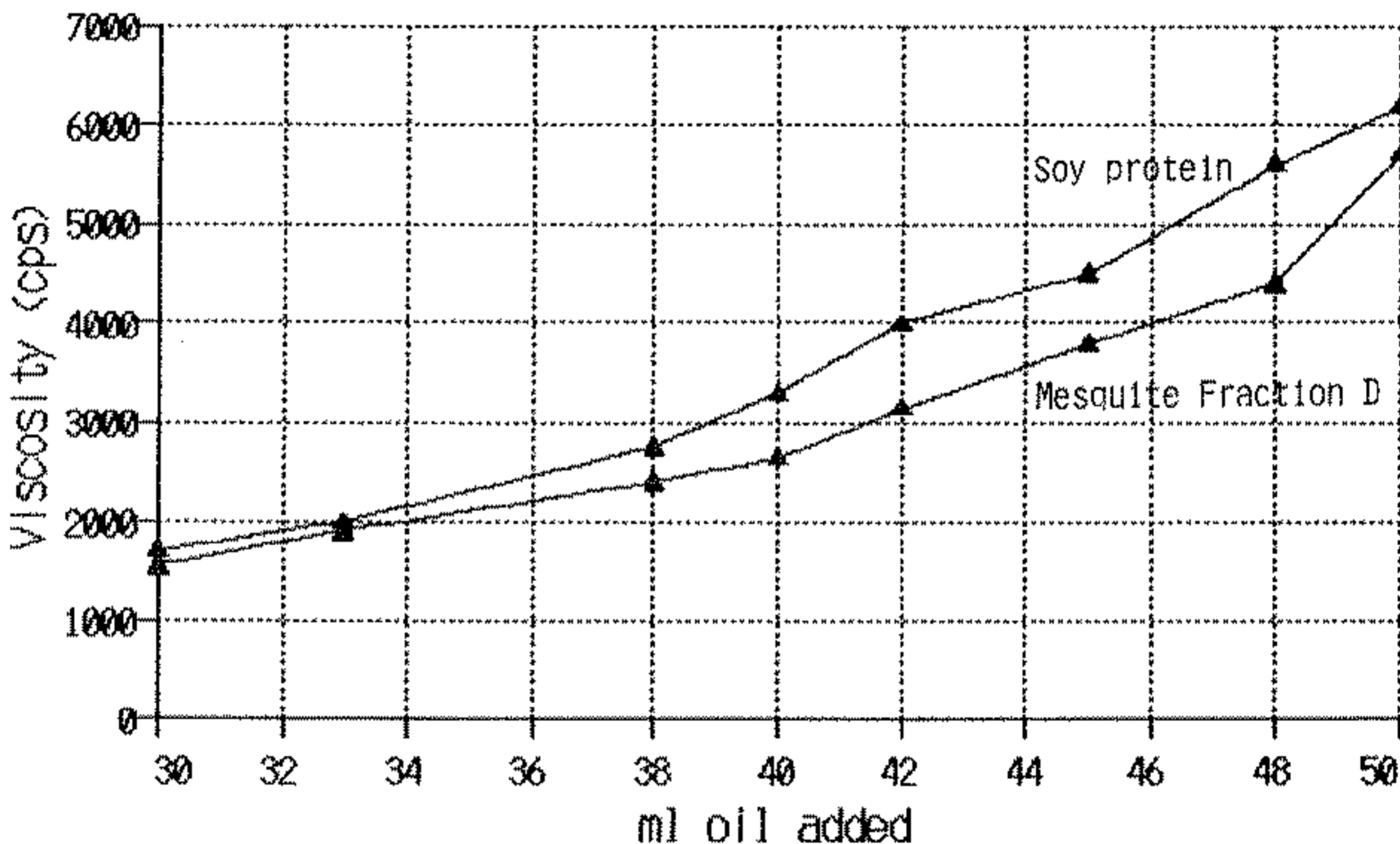
The viscosity of an emulsion prepared with Fraction D (or soy bean flour for comparison) was determined at a protein concentration of 5% in water.

Procedure:

- Dissolve protein concentrate in tap water to give a 5% protein concentration
- Slowly add hydrogenated soybean oil while the solution is permanently mixed with a magnetic stirrer
- Before each viscosity measurement (with Brookfield viscometer; spindle #3 at 20rpm) the solution has to be mixed with the Polytron mixer at speed 6 for 1min.

The results are shown in Figure 50 and reveal very little difference between soy and MESQUITE Fraction D.

Figure 50: Emulsion viscosity of MESQUITE Fraction D and soybean flour (5% protein)



#### 2.5.2.5. Storage and shelf-life of MESQUITE pods

When storage and shelf-life are to be discussed, one has to distinguish between unprocessed whole pods on one side and the single fractions on the other side.

The whole pods survive long periods of exposure to the elements when they fall from the tree. They are nevertheless subject to infestation by a serie of insects, which usually starts already on the tree, and to rain which however occurs very rarely during MESQUITE season in arid zones.

As long as the MESQUITE pods are being processed close to the growing-areas and therefore remain in the same climatic region, storage of unprocessed pods poses no problems (again with the exception of insect damage and rain).

The situation is different as soon as either the pods are relocated into areas with different climats (humidity), or the pods are processed into their fractions.

Humidity then becomes the major storage and shelf-life problem. This was evident during the time of this work. The whole pods were collected in the Southern Californian Desert but processed and stored in the relatively humid San Francisco Bay Area.

It is well known that almost all chemical, enzymatic and microbiological reactions that negatively affect food products occur more intensely at high relative humidity or moisture contents (99).

Along with the absolutely mandatory moisture level necessary for milling the pods (see Chapter 2.3.), it is highly advisable to dry the pods immediately before or after relocating the pods to humid areas, and to keep them stored in dry places. Insect damage however occurs even when the pods are dried and an additional fumigation (e.g. Phosphin) is therefore necessary. Freezing is only recommended when pods are stored in their original state for analytical purposes and to avoid insect damage and mold without fumigation.

The same problems are valid and even more important when the pods are milled and fractioned. Fraction A, due to its high sucrose content, is most sensitive to high relative humidity. Improper storage leads immediately to the formation of clumps and at higher humidities even to mold growth.

Fraction B is subject to similar effects but is less problematic as the fraction is not milled into a powder.

To obtain more information about storage conditions, the sorption isotherms of Fraction A and B were determined, and shown in Figure 51.

Regarding oxidation it was found, that Fraction A flour is almost not subject to oxidation or development of rancidity. The hexanal value (70;71; also Chapter 2.5.2.1.2.3.) has been determined on two samples:

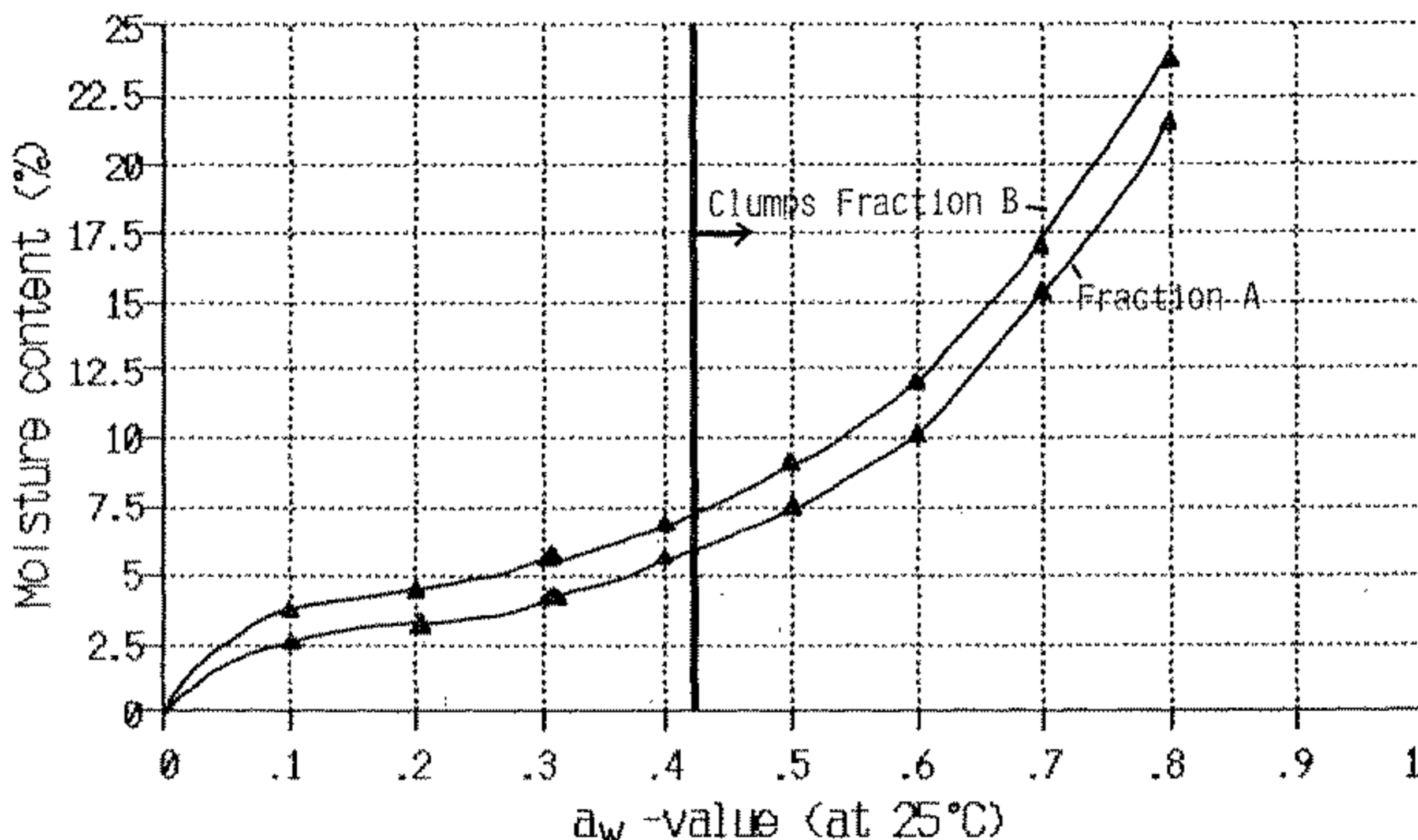
- A1 = stored in glass jar at roomtemperatur for 8 month
- A2 = stored in glass jar, dark at 38°C for 4 month

The hexanal value was found to be 1.6 for A1 and 9.2 for A2.

Fraction C has an almost unlimited shelf-life. No loss in viscosity could be found during a storage period of two years.

Fraction D shows surprisingly good stabilitiy even against oxidation which one might expect to be critical due to the relatively high oil content. No organoleptical changes could be detected during storage in glassjars for 6 month. This is however understandable considering the rather low iodine number of the oil, 95.6 (50).

Figure 51: Sorption isotherms of MESQUITE Fraction A and B at 25°C





### 3. PROPOSAL FOR A MESQUITE PROCESSING PLANT

#### 3.1. Objectives

The preceding chapters answered the question whether and how MESQUITE pods can be processed into one or more raw materials for the food industry and studied possible applications of the different fractions. Therefore, the technological and chemical problems have in principle been solved.

This chapter goes one step further: It presents a project for a small MESQUITE processing plant with a capacity of 1000 kg pods per hour. The objective is to provide the potential entrepreneur with detailed information on the plant lay-out and the type of machinery to be purchased (\*).

In addition, the chapter presents information concerning the necessary financial investment and approximate operating costs of such a plant. The figures consider only the processing aspects including pod purchase, but no distribution, management or other non-technical areas. This is a model only, based on certain assumptions that might vary considerably depending on factors such as location or size of the processing facility.

#### 3.2. Process description

The processing capacity of the proposed plant is assumed to be 1000 kg of pods per hour. It is basically a scaled up version of the process described in chapter 2.3.1. and in several cases the same but machinery of a larger scale is used. This chapter contains a great deal of technical information which was developed in voluntary cooperation with Buehler-Miag (Minneapolis, Minn.) (\*). For better understanding, the following process description should be read along with the plant lay-out (Figure 52).

The equipment specifications are listed in chapter 3.4., and are not necessary for the understanding of the process, but for readers seriously interested in such a plant. The logical conclusion, a budget and the economics, are discussed in the last two paragraphs of chapter 3.

---

\* It is a policy of the U.S.D.A. to state, that mentioning of a manufacturer is not an endorsement and that other brands might also be used.

### Section 0: Product delivery

The pods are delivered in trucks to the plant and contain the original moisture content of about 6% with a pod density of 140 kg/ m<sup>3</sup>. The pods are discharged in a product bin located outside the actual building. They are stored until conveyed by a cleated belt conveyer to the drier.

### Section 1: Drying

The drying tunnel which will also be located outside the building, holds two containers, each with a holding-capacity of maximal 1300 kg pods. With a drying time of 2 hours at 55°C, and one container changed every hour, this results in a sufficient product flow to the next section. The containers, designed with a sliding bottom, are rolled above the horizontal part of the belt conveyor and discharge the pods on it.

### Section 2: Milling

The pods are conveyed to a crusher that reduces the pods to a length of about 3 cm, and pass through a suction conveying line to the stone mill. The mill is equipped with corrugated discs by which the seeds are released from the pericarp along with the two other pericarp-fractions.

### Section 3: Separation, seed cleaning and seed splitting

An other suction conveying line transports the outlet from the stone mill to the grain separator, where the seeds are separated from Fraction A and B by means of aspiration and a cyclone. Fraction A and B (along with pericarp fragments separated from the seeds in the cyclone) are sucked to the intermediate storage bins, whereas the seeds pass to the strato-huller.

The seeds are splitted into Fraction C and D in the strato-huller and are separated in a second compartment of the grain separator. The two seed fractions C and D are then transported to intermediate storage bins as well.

#### Section 4: Fine-milling

The four fractions of the MESQUITE pod are now stored in their respective bins from where they can be milled individually in the grinder to a desired mesh size, or in case of Fraction B directly conveyed to the bagging section. The flour from the grinder passes a screener from where material in the desired mesh size goes to the product storage bin, whereas material above the correct size returns to the grinder.

#### Section 5: Material storage and packaging

The milled fractions are temporarily stored in finished product bins, until they are bagged in the packaging section.

#### Options:

- If the pods are not be delivered free from stones or heavy mudballs, a destoner would be necessary in Section 2
- Depending on the delivery system of the finished products, the capacity of section 5 might have to be changed significantly.

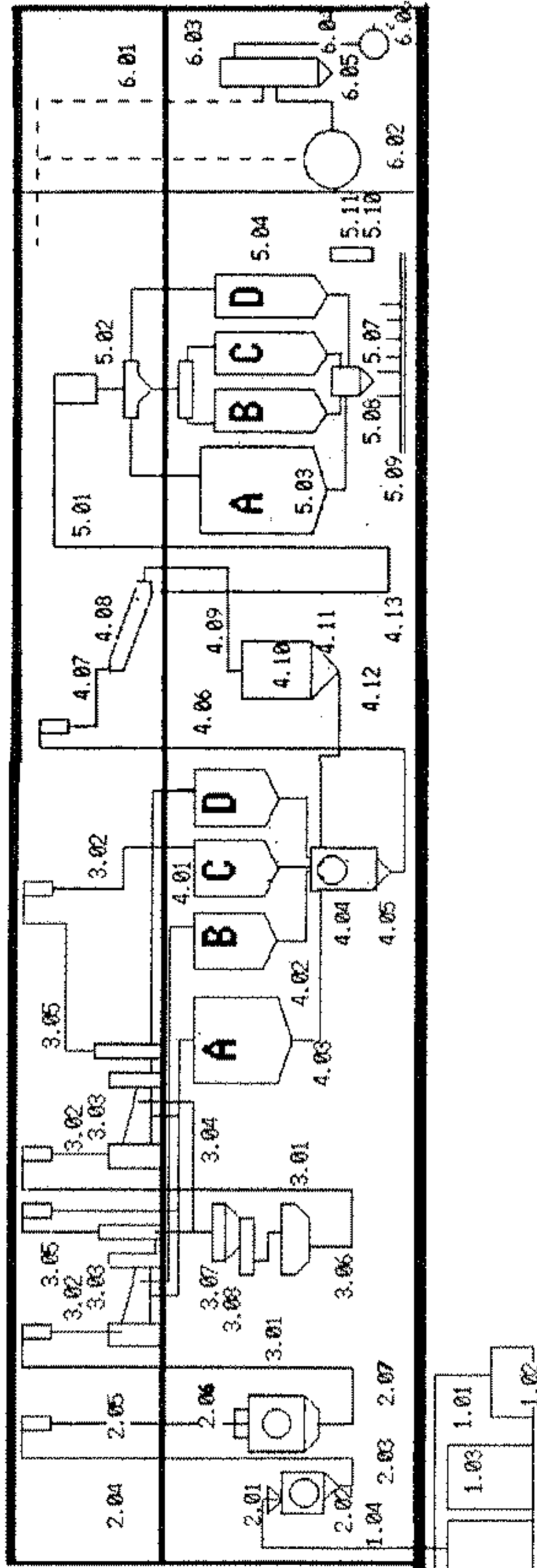
### 3.3. Plant-layout and equipment list

Table 39 lists all the equipment which is shown in the plant lay-out (Figure 52) and serves as a legend. The quantity of each equipment relates to the processing capacity of 1000 kg/h.

Table 39: Equipment list for a MESQUITE-processing plant

Item	Quant.	Equipment	Item	Quant.	Equipment
1.01	1	Drying Tunnel	1.02	lot	Heating Equipment
1.03	2	Containers for 1.01	1.04	1	Belt Conveyor
1.05	1	Belt Conveyor			
2.01	1	Inlet Hopper	2.02	1	Single Roll Crusher
2.03	1	Outlet Hopper for 2.02	2.04	1	Conveying Line
2.05	lot	Spouting	2.06	1	Stone Mill
2.07	1	Outlet Hopper			
3.01	2	Suction Conveying Line	3.02	lot	Spouting
3.03	1	Grain Separator	3.04	lot	Spouting
3.05	2	Aspiration for 3.03	3.06	1	Strato Huller
3.07	1	Hopper	3.08	1	Screw Conveyor
4.01	4	Hopper	4.02	4	Screw Conveyors
4.03	lot	Spouting	4.04	1	Grinder
4.05	1	Outlet Hopper	4.06	1	Conveying Line
4.07	lot	Spouting	4.08	1	Screener
4.09	lot	Spouting	4.10	1	Hopper
4.11	1	Srew Conveyor	4.12	lot	Spouting
4.13	lot	Spouting			
5.01	1	Suction Conveying Line	5.02	lot	Material Distributer
5.03	1	Finished Product Bin	5.04	3	Finished Product Bin
5.05	4	Screw Conveyors	5.06	lot	Spouting
5.07	1	Inlet Hopper	5.08	1	Autom. Net Weigher
5.09	1	Belt Conveyor	5.10	1	Bag Closer
5.11	1	Reel-Type Suspension			
6.01	lot	Ductwork	6.02	1	High Pressure Fan
6.03	1	Filter	6.04	1	Hopper
6.05	1	Airlock Package	6.06	1	Exhaust Fan

Figure 52: Plant lay-out for a MESQUITE processing plant with a capacity of 1000 kg / hour



### 3.4. Equipment and engineering specifications

#### 3.4.1. Milling and separation

##### SECTION 0: PRODUCT DELIVERY

=====

##### 0.1 Storage-bin

Capacity: 64 000 kg; 4.75 m dia, 6.4 m high. Allows product storage for about one week

##### SECTION 1: DRYING

=====

##### 1.01 Drying tunnel

Approximatly 3 m wide, 2.4 m high, and 4 m long ; located outside the actual plant. Brick construction, with doors on both ends for quick loading and unloading the raw material. Holding capacity 19 m<sup>3</sup> of beans (=2700 kg).

##### 1.02 Heating and air circulating equipment

Containing the necessary electrical heating coils, fans for air circulation and exhaust for the drying tunnel.

##### 1.03 Containers for drying oven

Approximatly 1.2 m wide, 2.1 m high and 3.6 m long. Each of the two containers holds maximal 1250 kg. Containers equipped with three 15 cm dia. steel V-grooved casters and six 20 cm dia. plain casters. Including 20 m (2x10 m) track bolted in two rows inside the drying tunnel for guiding the the containers. With sliding bottom for dried beans.

##### 1.04 Belt Conveyor

A) For discharging the containers.

Conveying Capacity: 0.11 m<sup>3</sup>/min.

Arrangement: 7.8 m horizontal with 30° inclined by a discharge height of 2.1 m

Conveying Belt: 60 cm wide with 10 cm cleat heighth

Overall Width: 75 cm

Complete with motor, drive, supporting legs. Including 10.8 m track, bolted to the floor on one side of the horizontal belt for guiding the containers.

B) For loading the containers.

Conveying Capacity: 0.34 m<sup>3</sup>/min

Arrangement: 3 m horizontal with 30° inclined by  
a discharge height of 2.7 m

Same specifications as Item #1.04. Including 10.8 m track,  
bolted on the floor under the discharge of the belt for guiding  
the containers.

## SECTION 2: MILLING

=====

### 2.01 Inlet Hopper

Bolted to the inlet of the single roll crusher.  
10 Ga. HRS construction.

### 2.02 Single Roll Crusher, Model MBP

In all metal construction with spiked discs on the cast iron  
crushing roll. Including automatic safety release, V-belt  
drive, and 5 HP motor. Without concrete support.

### 2.03 Outlet Hopper for Crusher

10 Ga. HRS construction with flange to match the crusher, and  
an outlet stub to match spouting to the destoner.

### 2.04 Suction Conveying Line

Including the necessary pick-up shoe, straight tubing, elbows,  
couplings, sightglasses, cyclone, air regulator and airlock.  
Mounted on an airlock bench, including motor and gear reducer.

### 2.05 Spouting from Cyclone to Stone Mill

Including the necessary straight spouting, elbows, transitions,  
sightglasses and couplings.

### 2.06 Stone Mill, Model, MJSG-67C

Cast iron construction with 2 metal grinding discs, including  
product inlet spout with vibratory feeder, feeder control unit,  
and inlet magnet, Model MMUA-20. Complete with V-belt drive,  
guard and 20 HP motor. Without concrete support.

### 2.07 Outlet Hopper for Stone Mill

10 Ga. HRS construction, with flange to match the stone mill,  
and an outlet stub to match the pick-up shoe.

OPTION:

Dry Destoner, Model MTSB-50

Frame and support in steel, housing in polyester, with safety windows, built-in distributing frame, hardened steel wire deck. Including a booster fan with drive and 3 HP motor.

SECTION 3: SEPARATION, SEED CLEANING AND SEED SPLITTING

3.01 Suction Conveying Line

Same specifications as Item #2.04

3.02 Spouting from Cyclone to Separator and Bins

Same specifications as Item #2.04

3.03 Grain Separator, Model MTMA-15100 DS

Double sieve compartments with two separating stages. All steel construction with two sieve layers, rubber ball cleaners, two aspiration channels on the product outlets, including V-belt drive, and 1.5 HP motor on the separator and a 0.16 HP motor on the aspiraton channels.

3.04 Spouting for MTMA-15100 DS

Same specification as for item 2.05

3.05 Aspiration Airduct and Cyclone

For the MTMA-15100DS Separator, including the necessary machine transitions, elbows and ducting.

3.06 Strato-Huller, Type DMHB-51

All metal construction with inlet glass, conocal hopper, support legs. With 10HP motor for the rotating disc and moveable baffle ring.

3.07 Hopper

Same specifications as Item 4.10

3.08 Screw Conveyor

Same specifications as Item 4.11



SECTION 4: FINE-MILLING

=====

4.01 Hopper

Capacity: 2 m3 each

10 Ga. HRS construction with one level indicator, and outlet flange to match the screw conveyor.

4.02 Screw Conveyor

15 cm dia. x 1.2 m long. Complete with variable frequency drives.

4.03 Spouting

From the screw conveyors to the pulverizer. Same specifications as Item 2.05.

4.04 Grinder, Model Sturtevant #00 Swing Sledge Mill

Including cast iron frame with manganese steel liners, complete with drive and motor. Excluding any concrete foundation.

4.05 Outlet Hopper for Grinder

10 Ga. HRS construction, with flange to match the grinder, and an outlet stub to match the pick-up shoe.

4.06 Suction Conveying Line

Same specification as Item 2.04

4.07 Spouting to Rotex Screener

Same specifications as Item 2.05

4.08 Rotex Screener, Model 201

Single screen machine in all metal construction, complete with aluminum top cover and sieve frames, and stainless steel bottom, ground smooth but not polished. Including V-belt drive, motor bracket, 1.5 HP motor and three spare screens.

4.09 Spouting

From outlet screener to hopper above screw conveyor. Same specifications as Item 2.05.

4.10 Hopper

Capacity: 1 m3

In 10 Ga. HRS construction, with one high level indicator, and outlet flange to match the screw conveyor.

4.11 Screw Conveyor

0.15 m dia x 1.2 m long, complete with drive and motor.

4.12 Spouting

Same specifications as Item 2.05.

Including one manually operated diverter valve.

4.13 Spouting

From Rotex screener to pick-up shoe.

Same specifications as Item 2.05.

SECTION 5: MATERIAL STORAGE AND PACKAGING

=====

5.01 Suction Conveying Line

Text as per Item 2.04

5.02 Material Distribution Components

Including one 3-way flow diverter and one 2-way flow diverter, both 0.1m O.D., pneumatically operated. Including the necessary spouting, elbows, and clamps to spout to the finished product bins.

5.03 Finished Product Bins

Capacity: 3 m3

In 10 Ga. HRS construction, including one high level indicator one low level indicator, one bin vibrator, and outlet flange to match the screw feeder.

5.04 Finished Product Bin

Capacity: 2 m3 each

Text same as Item 2.05.

5.05 Screw Conveyors

0.15 m dia. x 1.2 m long, complete with variable frequency drives.

5.06 Spouting

From screw conveyor to inlet hopper of weigher.  
Same specifications as Item 2.05

5.07 Inlet Hopper

Located above the weigher, 10 Ga. HRS construction.

5.08 Edtbauer-Duplex Automatic Net Weigher, Model 4E

5.09 Belt Conveyor

2.55m long, located under the weigher.

5.10 Fishbein Portable Bag Closer, Model "E+"

5.11 Reel-Type Suspension, Model 1550

SECTION 6: ASPIRATION SYSTEM

=====

6.01 General Exhaust Ducting

Ducting from the equipment to the dust filter, from the cyclones to the high pressure fan to the filter, and from the filter to the exhaust fan. Including machine transitions, straight ducting, elbows, flanges and gaskets.

6.02 High Pressure Fan, Aerovent Model 475-150 Series 14

For a capacity of 35 m<sup>3</sup> per minute. Complete with direct drive arrangement #4, vibration isolators, flanged outlet, access door, inlet damper and 10HP, 3600 RPM motor.

6.03 Dust Filter, Model RPDC-81/8

Filter area 90 m<sup>2</sup>. Air to cloth ratio of 7.1:1. Complete with 12 Ga. reinforced air plenum, housing, compressed air header assembly, solid state timer, inspection port, access door internal grid, and flange to match the outlet hopper.

6.04 Outlet Hopper for Dust Filter

12 Ga. HRS construction, with dirty air inlet in the housing with an internal baffle for bag protection. Including support legs, and outlet flange to match the airlock.

6.05 Airlock package, Model MPSX-27

Cast iron construction, with mild steel fabricated rotor, sidemount motor base, and 3/4 HP right angle gearmotor.

6.06 General Exhaust Fan, Aerovent Model MH-800 BW

For a capacity of 650 m<sup>3</sup>/min. Complete with V-belt drive, guard, langed outlet, access door, base with vibration isolators and a 25 HP, 1800 RPM motor

SECTION 7: INSTALLATION MATERIAL AND STRUCTURAL SUPPORT

=====

7.01 Installation Material

7.02 Structural Support

Approximatly 8 m long x 8 m wide and 4 m high to be used as a mezzanine floor, consisting of steel construction with hand rails, floor grating, and structural stairway.

SECTION 8: ELECTRICAL EQUIPMENT, PANEL, MOTOR CONTROL CENTER

=====

Consisting of a NEMA-12 control panel with motor running lights, hand/off/auto selector switches, motor starters, alarm System, necessary interlocking, transformer (control circuit IMNCC), and all field connections to terminal strip on the sub-panel.

SECTION 9: CRATING, FREIGHT & INSTALLATION OF EQUIPMENT

=====

9.01 Installation of Electrical Equipment and Wiring

9.02 Installation of Mechanical Equipment

9.03 Crating and Freight Charges

SECTION 10: COMBUSTION SYSTEM FOR FRACTION B

=====

Ni-Burner Incinerator to produce hot air to be used as alternative in Item 1.01 to dry MESQUITE pods. Complete with all controls.

SECTION 11: ELECTRICAL ENERGY SOURCE

=====

200 HP Diesel Generator to deliver electricity to all motors.

SECTION 12: VARIAS

=====

12.01 Engineering and Start-up Services

12.02 Operating Supplies (Spare parts, Lubricants)

12.03 Pressurized Air Connecting Pipes and Fittings

12.04 Concrete Support for Heavy Motors and Machines

SECTION 13: BUILDINGS

=====

Site preparation, buildings, manlifts, sanitary installation, water piping, boiler, air conditioning, offices including furnitures, laboratory including equipment and chemicals.

3.4.2. Energy requirements and supply

Several motors along the processing line require various amount of electricity. Their specific requirements are listed in Table 40.

Since a MESQUITE processing plant would be set up in rather undeveloped areas, possibly with now electrical hook-up, it might be necessary to produce the electricity through a diesel-generator.

Such a diesel-generator should be able to run approx. 10 hours a day, and be set up that it requires the least possible maintenance. The motors in the processing line could be switched on in serie. For that purpose an Ingeneering-company (Stamm, Aarbon-CH) recommends a 190 Hp generator. Such a generator (US\$ 25000.-, including all controls) has under given conditions a life expectancy of 6000 hours and requires a revision every 100-300 hours. It requires approx. 35l diesel fuel oil / hour.

A substantial amount of hot air necessary for drying the pods could be obtained through combustion of Fraction B in a Ni-Burner Incinerator (more information available through W.K. Nider, Allied Engineering & Production Corp. 4221 Blanding Ave., Alameda CA 94501 USA). Such a unit could burn 200 kg Fraction B per hour which would release approximatly 560 000 kcal per hour.

Table 40: Energy requirements for a MESQUITE processing plant

Item	Quantity		Hp-requirements
Belt Conveyor	3	1 Hp each	= 3 Hp
Screw Conveyor	10	1 Hp each	= 10 Hp
Single Roll Crusher	1	5 Hp	= 5 Hp
Stone Mill	1	20 Hp	= 20 Hp
Destoner	1	3 Hp	= 3 Hp
Grain Separator	1	2 Hp	= 2 Hp
Strato Huller	1	10 Hp	= 10 Hp
Grinder	1	10 Hp	= 10 Hp
Screeener	1	2 Hp	= 2 Hp
Bag Closer	1	1 Hp	= 1 Hp
High pressure Fan	3	10 Hp each	= 30 Hp
Airlock Package	1	1 Hp	= 1 Hp
Exhaust Fan	1	25 Hp	= 25 Hp
-----			
Total known electricity requirement			122 Hp
Necessary spare capacity			approx. 50-70 Hp
-----			
TOTAL RECOMMENDED POWERSUPPLY			150-190 Hp
=====			

3.5. Budget

3.5.1. Investment for the set-up of a MESQUITE processing plant with a capacity of 1000 kg/hour

The cost estimates for a MESQUITE processing plant are based on the equipment specified in Chapter 3.4. The figures are based on information obtained by Buehler-Miag as far as sections 1-9 and 12 are concerned, whereas prices of section 10 were estimated by Allied Engineering. Sections 11 and 13 are based on either average prices for similar equipment or comparable plants. Especially the figures in Section 13 are to be taken as very variable, since location (e.g. Mexico or USA) could cause substantial differences.

The prices in Table 41 were quoted in November 1983 and are understood to be F.O.B. jobsite, California. All prices are for budget estimate purposes only.

Land purchase is included in the budget estimate as a pro memoriam expense only. Land in arid zones is of practically no cash-value and accounts for an absolute minor expense only.

Table 41: Budget estimates

Land purchase		US\$	1000.00
Section 0	Product delivery	US\$	9000.00
Section 1	Drying	US\$	61000.00
Section 2	Milling	US\$	25500.00
Section 3	Separation, Seed cleaning ...	US\$	57500.00
Section 4	Fine milling	US\$	57000.00
Section 5	Material storage & packaging	US\$	54000.00
Section 6	Aspiration system	US\$	38000.00
Section 7	Structural support	US\$	29500.00
Section 8	Electrical equipment	US\$	41500.00
Section 9			
9.01/9.02	Installation of equipment	US\$	222000.00
9.03	Crating & freight charges	US\$	17500.00
Section 10	Combustion system	US\$	45000.00
Section 11	Electrical energy source	US\$	25000.00
Section 12			
12.01	Engineering and start-up services	US\$	50000.00
12.02	Operating supplies	US\$	45000.00
12.03/12.04	Pipes /Concrete support	US\$	3800.00
Section 13	Buildings (700m3 * US\$ 150.-)	US\$	105000.00
-----			
TOTAL INITIAL INVESTMENT FOR PLANT SET-UP:		US\$	887300.00
=====			

This budget estimate does NOT include:

- any warehousing or insurance cost after equipment has been delivered,
- any heavy sundry erection tools such as cranes, etc.
- any truck for moving the containers,
- workshop machinery, tools,
- laboratory equipment, chemicals, etc.
- office furniture and equipment,
- any federal, state, local or other taxes,
- any safety features unless specified,
- in other words, any items or materials not specifically mentioned herein

### 3.6. Economics

#### A) Production costs based on plant location in Mexico

For this model the plant would be set up in:  
**Matehuala, Mexico, State of San Luis Potosi**

This location has been chosen because MESQUITE grows extensively in this area. The pods have traditionally been collected by rural inhabitants for whom this income was of social economic importance. They have either sold the pods to ranchers and feed dealers or used it themselves as a cheap substitution up to 50% in feed formulas. This situation is described in a report by the Instituto Mexicano de Recursos Naturales Renovables (100) and presents probably the only information about semi-commercial MESQUITE gathering. However, the figures have to be taken cautiously, since this report has been written in 1970 and very few newer information is currently available.

The City of Matehuala is the principal center for storage of MESQUITE pods and it was confirmed that in 1965 some 8000 tons were gathered there, along with 4000 tons in the rest of the state. The average price was 350 Pesos or 28 US\$ per ton (1965: 12.5 Pesos = 1US\$).

According to personal correspondance, MESQUITE pods could be bought in Mexico in 1980 from commercial dealers for 87 US\$ per ton.

It is therefore assumed for this model, that up to 10 000 tons per season of MESQUITE pods could be purchased at a price of 90 US\$ in the area of Matehuala.



The operating costs are based on a normal product supply and processing situation over an entire season. A season would cover a processing period of three months with six working days (8 hours/day) per week. This results in 576 processing hours or 576 tons of processed MESQUITE pods per season.

1. Capital cost:

-----  
 The total investment cost (Table 41) is capitalized with 10% and the annual depreciation of the plant set at 10 %.

Investment capitalized	US\$	90000.-/year
Depriciation	US\$	90000.-/year

2. Rawmaterial:

-----

Undried clean pods, delivered to the plant	US\$	90.-/ton
---	------	----------

3. Personnel

-----

8 untrained farmworkers (per worker)	US\$	250.-/month
1 Plant mechanic	US\$	1000.-/month
1 Supervisor/ Administrator	US\$	2500.-/month

4. Energy

-----

Diesel 280 l/ day (1l= US\$ 0.15 ;1984)	US\$	42.-/day
---	------	----------

5. Maintenance

-----

2% of initial investment annually	US\$	18000.00/year
-----------------------------------	------	---------------

All items are calculated per season and per ton in Table 42a.

Table 42a: Production costs per season or per ton of MESQUITE pods, based on 576 tons per season

Item	US\$ per season	US\$ per ton
Capital	90000.00	156.25
Depriciation	90000.00	156.25
Raw material	51840.00	90.00
Personnel	16500.00	29.10
Energy	3024.00	5.25
Maintenance	18000.00	31.25
<b>TOTAL</b>	<b>269364.00</b>	<b>467.64</b>
	US\$ 0.47 / kg	

If the season could be extended to an all year operation, the price per ton would decrease significantly; the only change in the plant set-up would be to use bigger storage bins along with fumigation of the pods. This would cause an increase in the budget at Section 0 by approx. US\$ 10000.00 . Also the annual depreciation should be increased to 15%, and the maintenance would be 4% annually of the initial investment.

On the other hand, the processing-capacity would increase to about 2300 tons per year. Such an operation would result in the following cost structure (Table 42b):

Table 42b: Production costs per year and per ton of MESQUITE pods, based on all year operation (2300 tons / year)

Item	US\$ per year	US\$ per ton
Capital	90000.00	39.10
Depriciation	135000.00	58.70
Raw material	207000.00	90.00
Personnel	45000.00	19.53
Energy	12100.00	5.25
Maintenance	36000.00	15.65
TOTAL	525100.00	228.30
	US\$	0.23/kg

The above calculated operating-costs do not include:  
 -Insurances  
 -Taxes  
 -Chemicals  
 -In other words any items not specifically mentioned herein.

B) Production costs based on plant location in the USA

If a MESQUITE processing plant would be set up in the USA, the situation would be somewhat different:

Currently MESQUITE pods can not be purchased on the market, since its utilization as feed has either not yet been recognized, or the cost would be prohibitive compared to other often subsidized feed.

The situation could certainly change immediately if a market would be created by the demand of a potential processor.

As another possibility, it has been suggested by Felker (80) to cultivate MESQUITE for ethanol production. Such a utilization, even though very promising, has not yet been established since an oil-shortage does not seem likely at the moment. Nevertheless, Felker showed, that MESQUITE could be produced in orchards for US\$ 46.00 per ton (with insecticide application) or for US\$ 25.00 per ton only, if insect resistant varieties could be used.

A processing plant in the USA would basically require the same budget for an initial set-up, whereas the production costs would be higher (Table 43).

The major changes in production costs would be caused by higher salary for the personnel:

Untrained farmworkers	US\$ 720.00 / month / person
Plant mechanic	US\$ 1500.00 / month
Supervisor	US\$ 2500.00 / month

Fuel cost would be US\$ 0.25 /l

As a major disadvantage, it would seem unlikely to be able to run the plant all year from the beginning, since the pod-production would not be sufficient for at least the first five years until the trees would produce enough pods. An ideal situation would be to set up a MESQUITE processing plant within an other food/feed-plant. Infrastructure and personnel could be used from the existing plant. This would even be a opportunity for industries such as sugarbeet processors to run their plant during off-season of their product.

Table 43: Production cost per ton of MESQUITE pods, based on a seasonal operation (576 tons) ; location USA

Item	US\$ per season	US\$ per ton
Capital	90000.00	156.25
Depreciation	90000.00	156.25
Raw material	26496.00	46.00
Personnel	29280.00	50.83
Energy	5040.00	8.75
Maintenance	18000.00	31.25
-----		
TOTAL	258816.00	449.33

US\$ 0.45/kg

=====

Actual cost of final product

It is assumed that Fraction B would be burned for energy purpose. Therefore, the price per kilo processed MESQUITE (Tables 40-43) needs to be divided by the yield of the three remaining fractions, where a loss of 5% of the input is also included. The costs would increase to the figures shown in Table 44 (the value of Fraction B is in the reduction of energy costs).

Table 44: Comparison of the production costs of each Fraction of processed MESQUITE in US\$ ,including a loss of 5% of the input

A) Seasonal operation; location Mexico

Production costs: 47.00 US\$ per 100kg

True output:	Fraction A	50kg= 31.50	100kg= 63.00
	Fraction C	12kg= 7.56	100kg= 63.00
	Fraction D	12kg= 7.56	100kg= 63.00
	Fraction B	no value	no value
-----			
Total		74kg= 47.00	100kg= 63.00
=====			

B) Year-round operation; location Mexico

Production costs: 23.00 US\$ per 100kg

True output:	Fraction A	50kg= 15.55	100kg= 31.10
	Fraction C	12kg= 3.75	100kg= 31.10
	Fraction D	12kg= 3.75	100kg= 31.10
	Fraction B	no value	no value
-----			
Total		74kg= 23.00	100kg= 31.10
=====			

The costs for location in the USA (US\$ 45.00) results in practically the same figure as for seasonal operation in Mexico.

#### 4. CONCLUSIONS

The goal of this work has been to develop a processing system for MESQUITE pods, in order to achieve maximal utilization of the pod as a raw material for the food industry, and to evaluate the characteristics of the pod material.

Already a first superficial study of the pod structure revealed, that the pods would have to be fractionated according to their morphological structure. Otherwise it would not be possible to obtain homogenous raw materials.

The milling and separation process developed in this study, resulted in four fractions which turned out to be not only morphologically different, but also show chemically and functionally different properties.

The process uses mostly existing machinery (crusher, stone mill and several different classifiers) and represents a relatively easy processing system.

Comparison of the proximate analysis of more than a dozen pods from different trees revealed that their composition varies less than their visual differences might suggest. However, it would be possible to select or breed pods that are high in a desired compound (cross-breeding would limit the success).

The four fractions offer completely different applications:

The major part of the pod, Fraction A (55% of the pod), represents a legume-flour with a unusually high sucrose content of up to 60 %. Its uses range from a raw material for sucrose extraction, composite flour in baked cereal products to drum dried flakes and tortilla chips.

Even though the flour itself is of no extraordinary nutritional value, feeding studies revealed that a combination with cereal based products leads to a desirable improvement of the amino acid composition of such products. The incorporation of MESQUITE Fraction A causes no significant reduction of the PER, even at a reduced digestibility.

Taste panels with a snack product (corn tortilla chips with MESQUITE Fraction A) revealed preference of the product over a corn-only standard in all criterias, i.e. taste, color, structure and odor.

Nevertheless, applications or incorporations of Fraction A are limited by its specific flavor and the lack of a structure-maintaining compound.

Use of Fraction A as raw material for sucrose-extraction showed no problems, but would currently not be the most profitable utilization.

**Fraction B (20% of the pod)** must be regarded as the least valuable part of the pod. The fibrous endocarp hulls do not appear to be a promising raw material for the food-industry, except as a possible source for fiber in dietary products. Nevertheless, it represents a very good material for combustion with a burning value of 17000 KJ/kg (comparable to sawdust) and low percentage of remaining minerals. Taking advantage of the publicity of MESQUITE wood for barbecue in the US (44) and the success of fire-logs for private households, it might be very interesting to utilize Fraction B in such logs. The Fraction could also serve as an energy source to provide a substantial amount of the necessary hot air through combustion, to dry MESQUITE pods before the milling and separation process.

The endosperm splits of the seed, designated as **Fraction C (15% of the whole pod)**, contain about 65% galactomannan with a composition that is almost identical to guar gum (mannose:galactose= 1.6:1), a widely used hydrocolloid in the food- and other industries. Therefore, it was no surprise to find that the viscosity, temperature stability and characteristics in the interaction of MESQUITE gum solutions with xanthan were all practically identical to guar. A paper reporting a mannose:galactose-ratio of 4.2:1 in a South American Prosopis juliflora (which would be very similar to locust bean gum) offers even greater possibilities (108).

However, it was not possible to find ways to obtain a high purity gum by a method that would allow projection to a profitable larger scale process, due to the extremely tough adhesion of the seed coat to the endosperm. In that connection, it could be shown that certain minerals (magnesium, manganese and calcium) are associated with the endosperm and are useful in the determination of the gum purity.

The relatively low grade gum obtained in this work would limit applications of the MESQUITE galactomannan to products where a colorless grade is not required.

The cotyledons, Fraction D (15% of the pod), represent a protein concentrate with nutritional qualities similar to soybean protein. It is limited in sulfur amino acids. Its functional properties qualify it as alternative to proteins such as soy or skim milk, especially for solutions where improved foam stability and emulsion capacity are desired.

Based on the wide array of possible application of the different fractions, a project has been defined for a small MESQUITE processing plant with a capacity of 1000 kg pods per hour. Again, existing equipment that could be purchased from different manufacturers can be used.

A budget estimate showed that approximately US\$ 900000.00 would be required to set up the whole plant. The estimated production cost, including the capitalization of the investment, would result in product prices ranging from US\$ 0.30 - US\$ 0.65 per kilo processed MESQUITE, depending on location of the plant and whether processing would be seasonal or all year round .

A comparison of the prices for each fraction with its most likely competitor on the market is shown in Table 45.

The possible margin (including transport, storage, profit, calculation errors) is also listed. The margin range is calculated as:

Minimum margin= "low price competitor" minus  
"production cost high for MESQUITE"

Maximum margin= "high price competitor" minus  
"production cost low for MESQUITE"

A minus (-) sign before the figure in the "minimum /maximum margin" column of Table 45 indicates, that the MESQUITE product would have to be sold at a loss, whereas a plus (+) sign means that a profit could be made.

Table 45: Prices for MESQUITE products compared with products similar in application range

Product	Price per kg in US\$ at production cost	
	low	high
<b>Fraction A</b>	<b>0.31</b>	<b>0.62</b>
Whole wheat flour	0.50	0.70
Minimum / maximum margin	-0.12 to + 0.39	
Carob powder	0.20	0.30
Minimum / maximum margin	-0.11 to - 0.32	
Corn	0.30	0.35
Minimum / maximum margin	-0.32 to + 0.04	
Refined sugar	0.40	0.50
Minimum / maximum margin	-0.22 to + 0.19	
<b>Fraction C</b>	<b>0.31</b>	<b>0.62</b>
Guar gum minimal foodgrade/petfoodgrade	0.70	1.40
Minimum / maximum margin	+0.08 to + 1.09	
<b>Fraction D</b>	<b>0.31</b>	<b>0.62</b>
Soy Protein concentrate (60%)	1.00	1.20
Minimum / maximum margin	+0.38 to + 0.89	
Skim milk	1.40	1.60
Minimum / maximum margin	+1.29 to + 0.78	

Prices of competing products are current 1984 world market prices.

The overall comparison of the prices of the different fractions with possible competing products reveals, that MESQUITE Fraction A would hardly be profitable or allow only a rather small margin.

Fraction C and D however offer a very good profit so that this two fractions could even pay for eventual losses on Fraction A.



It would certainly be very shortsighted to measure the success of the utilization of MESQUITE-pods in its potential return of investment only.

All other positive effect of a cultivation of MESQUITE trees have also to be taken into account (Figure 7, Chapter 1.2.2.), even though their cash value is difficult to determine:

- Keeping back desertification trough the function of soil stabilizing and wind-braking;
- Proving shade to raise animals;
- Employment in rural areas;
- Local production of food, which is often not possible in such regions;

Considering all these aspects, it becomes clear that MESQUITE offers the unique chance to achieve all the above mentioned goals along with the establishment of a crop that can be profitable even without subsidizing through governments.

In addition, MESQUITE could become a very important food crop in the fight against hunger in countries in arid and semi arid zones.

## 5. SUMMARY

MESQUITE is a leguminous plant that grows wild in arid and semi arid areas around the world. Depending on the specie, it occurs as a shrub or tree and requires no fertilizer or watering.

MESQUITE produces indehiscent pods with a most complicated morphology. They were used by ancient cultures as a staple food, whereas in current times only consumption as a syrup in Southamerica is reported. A commercial utilization of MESQUITE has never been studied seriously. This is first of all due to the lack of a processing technique and the image of MESQUITE as a weed.

This work covers the following aspects of a commercial utilization of the pods:

- 1) A milling and separation process that results in four fractions with the potential for different applications. The fractions are:  
Fraction A: A flour with up to 60% sucrose  
Fraction B: A high fiber residual fraction  
Fraction C: A galactomannan gum  
Fraction D: A high protein flour
- 2) The possible applications of the fraction as a raw material for the food industry (baking; snackfood; sweetener; gum; protein concentrate) including taste panels and feeding studies.
- 3) A comparison of the composition of different pods
- 4) A project for a small MESQUITE processing plant with a plant lay-out, detailed listing of the necessary equipment, budget and calculation of the production costs.

The results show that MESQUITE pods offer an interesting crop for industrialized countries with wide application in the food industry, as well as a potential food crop in lesser developed countries that are short on basic foodstuff.

The study could eventually serve as a manual how to set up a MESQUITE processing plant and how to utilize the products. At the same time it represents as an investigation on the composition and possible utilization of a desert plant in its ecological context.

## 5. Zusammenfassung

### Aufarbeitung, Einsatzmoeglichkeiten und Wirtschaftlichkeit von MESQUITE Schoten als Rohmaterial fuer die Lebensmittel-Industrie

=====

MESQUITE (sprich: MESCIIT) ist ein Leguminosen-Gewaechs, welches in Trockengebieten auf der ganzen Welt zu finden ist. Allein in den USA belegt MESQUITE rund 35 Millionen Hektaren. Je nach Species ist die Erscheinungsform von MESQUITE ein Strauch oder ein Baum von bis zu 8 Metern Hoehe.

MESQUITE produziert Schoten mit einer sehr komplizierten Morphology. Obwohl die Schoten in frueheren Zeiten als Grundnahrungsmittel genutzt wurden, ist heutzutage nur noch die Verwendung der Schote in Suedamerika, als Rohmaterial fuer einen Syrup bekannt. Bis anhin hat es sowohl an einer Technologie zur Aufarbeitung der Schoten als auch am Wissen ueber funktionelle Eigenschaften der Inhaltsstoffe gefehlt. So war man bisher allgemein der Ansicht, dass es sich bei MESQUITE nur um ein nutzloses Unkraut handle.

Die vorliegende Arbeit befasst sich mit den folgenden Aspekten einer kommerziellen Nutzung der Schoten:

- 1) Beschreibung eines Verarbeitungs-Prozess, welcher in vier Fraktions-Produkten resultiert, die unterschiedliche Einsatzmoeglichkeiten offerieren. Die Fraktionen sind:  
Fraktion A: Ein Mehl mit einem Saccharosegehalt von 60%  
Fraktion B: Eine Fraktion mit sehr hohem Rohfasergehalt  
Fraktion C: Ein Galactomannan-Gummi  
Fraktion D: Ein Proteinkonzentrat
- 2) Einsatzmoeglichkeiten der Fraktionen als Rohmaterial in der Lebensmittelindustrie (Backwaren, Snacks, Verdickungsmittel, Proteinkonzentrate), einschliesslich Degustationsstudien und Fuetterungsversuchen mit den entsprechenden Produkten.
- 3) Vergleich der Zusammensetzung verschiedener Schoten.
- 4) Projekt fuer einen kleinen kommerziellen Verarbeitungs-betrieb mit einer Verarbeitungskapazitaet von 1000 kg pro Stunde, einschliesslich Plaenen, Auflistung der notwendigen Maschinen, Budgets sowie Berechnung der Produktionskosten.

Die Ergebnisse zeigen, dass MESQUITE eine hoechst interessante Nutzpflanze darstellt und dass die Schoten breitgefuecherte Einsatzmoeglichkeiten in der Lebensmittelindustrie offerieren.

Kosten-vergleiche erlauben die Schlussfolgerung, dass der Anbau und die Aufarbeitung von MESQUITE profitabel sein kann.

Ebenso koennte MESQUITE eine wichtige Rolle im oekologischen System von Trockengebieten spielen und eine wichtige Nahrungsgrundlage in Hungergebieten darstellen.

Die vorliegende Arbeit ist so gestaltet, dass sie als Grundlage dienen koennte, wie ein MESQUITE Verarbeitungs-betrieb aufgebaut, und die Fraktionen verwertet werden koennten. Gleichzeitig kann die Arbeit als eine Studie ueber die Zusammensetzung und Verwertungs-moeglichkeiten einer Wustenpflanze gelesen werden.

6. LITERATURE

- (1) BURKART A., A monograph of the genus *Prosopis* (Leguminosae Subfam. Mimosideae), *J. Arnold Arboretum* 57(3):219 (1976)
- (2) Report of an ad hoc panel of the Advisory Committee on Technical Innovations: "Tropical legumes", National Academy of Science, Washington D.C. (1979)
- (3) KAMALAM A., THAMBIAH A.S., *Prosopis spicaria* and skin granulomas, *Mykosen* 26(5):258 (1982)
- (4) SOLBRIG O.T., CANTINO P.D., Reproductive adaptations in *Prosopis* (Leguminosae, Mimosideae), *J. Arnold Arb.* 56:185 (1975)
- (5) FISHER C.E., MEADORS C.H., BEHRENS R., ROBISON E.D., MARION P.T., MORTON L.H., Control of Mesquite on grazing lands, *Texas Agric. Exp. Sta. Bull.* 935:1 (1957)
- (6) SUDZUKI F.H., Absorción foliar de humedad atmosférica en tamarugo (*P. Tamarugo*) en la localidad de Canchones, *Boletín técnico* 30, Estado Facultad de Agronomía, Universidad, Chile (1969)
- (7) SEN D.N., Ecology of Indian desert 3. Survival and adaptation in dry environment, *Vegetatio* 27:206 (1973)
- (8) STRAIN B.R., Field measurement of tissue water potential and carbon dioxide exchange in the desert shrubs *Prosopis juliflora* and *Larrea divaricata*, *Photosynthetica* 4:118 (1970)
- (9) BAZILEVICH N.I., RODIN L.E., The biological cycle of nitrogen and ash elements in plant communities of the tropical and sub-tropical zones, *Forestry Abstr.* 27:357 (1966)
- (10) AHMED G., Evaluation of dry zone afforestation plots, *Pakistan J. Forestry* 3:168 (1961)
- (11) Report of an ad hoc panel of the Advisory Committee on technology innovation, Underexploited tropical plants with promising economical value, National Academy of Science, Washington D.C. (1975)
- (12) YADAV J.S.P., SINGH K., Tolerance of certain forest species to varying degrees of salinity and alkali, *Indian Forester* 96:587 (1970)

- (13) FELKER P., CANNELL G.H., CLARK P.R. OSBORN J.F., screening *Prosopis* (Mesquite) germplasm for biomass production and nitrogen fixation, Proceedings of the International Congress for Study of Semi-Arid and Arid Zones, La Serena, Chile (1980)
- (14) SIMPSON B.B., SOLBRIG O.T., in Simpson B.B. (ed.), "Mesquite- its biology in two desert ecosystems", Dowden, Hutchinson and Ross Inc., Stroudsburg, Penn.:1 (1977)
- (15) MEYER R.E., HAAS R.H., WENDT C.W., Interaction of enviromental variables in growth and development of Honey Mesquite (*Prosopis juliflora*), Bot. Gaz. 134(3):173 (1973)
- (16) HABIT M.A., *Prosopis tamarugo*: fodder tree for arid zones, FAO Plant Production and Protection Paper, Rome (1981)
- (17) SCIFRES C.J., BROCK J.H., Moisture-temperature interrelations in germination and early seedling development of Honey Mesquite, Texas Agric.Exp. Sta. PR- 2816:63 (1970)
- (18) GLENDENING C.E., PAULSEN H.R.jr., Reproduction and establishment of Velvet Mesquite as related to invasion of semidesert grassland, U.S.D.A. Tech. Bull. 1127 (1955)
- (19) WINER N., Germination of pretreated seed of Mesquite (*Prosopis chilensis*) under arid conditions in Nothern Sudan, Forest Ecology and Management 5:307 (1983)
- (20) FISHER C.E., Mesquit and modern man in southwestern North America, in Simpson B.B. (ed.), "Mesquite- its biology in two desert ecosystems", Dowden, Hutchinson and Ross Inc., Stroudsburg, Penn.:177 (1977)
- (21) DAHL B.E., Mesquite as a rangeland plant, Proceedings of the symposium: Mesquite utilization, College of Agricultural Sciences, Texas Tech University, Lubbock, TX :A-1 (1982)
- (22) PRAJAPATI M.C., NAMBIAR K.T.N., *Prosopis juliflora* shelterbelts help increase crop production, Indian Farming 27 (9):15 (1977)
- (23) DOUGLAS J.S., Three dimensional forestry, Science Journal 8 (1968)

- (24) KINGSOLVER J.M., JOHNSON C.D., SWIER S.R., TERAN A.L.,  
Prosopis fruits as a resource for invertebrates, in  
Simpson B.B., (ed.) "Mesquite- its biology in two desert  
ecosystem", Dowden, Hutchinson and Ross, Inc.,  
Stroudsbouurg, Penn.:108 (1977)
- (25) UECKERT D.N., Effect of leaf-footed bugs on Mesquite  
reproduction, J. Range Management 26:227 (1973)
- (26) SWENSON W.H., Comparison of insects on Mesquite in  
burned and unburned areas, M.S. thesis, Texas Tech  
College, Lubbock, TX (1969)
- (27) KINGSOLVER J.M., Description of a new species of  
Algarobius Bridwell (Coleoptera: Bruchidae), Coloeop.  
Bull. 26:116 (1972)
- (28) VORHIES C.T., TAYLOR W.P., Life history and ecology of  
jack rabbits, Lepus alleni and Lepus californicus, in  
relation to grazing in Arizona, Ariz. Agric. Exp. Sta.  
Tech. Bull.49 (1933)
- (29) DAVIS C.A., Sealed quail foos in Southeastern New  
Mexico, J. Wildlife Managm. 39(3):496 (1975)
- (30) TALPADA P.M., PANDE M.B., PATEL J.S., SHUKLA P.C.,  
Note on the utilization of pods of Prosopis juliflora in  
the ratio of growing calves, Indian J. Anim. Sci.  
52(7):567 (1982)
- (31) EGGLER F., Arid Southeast Oaho vegetation, Hawaii,  
Ecological Monographs 17(4) (1947)
- (32) GASSER R.E., Hohokam use of desert food plants, Desert  
plants 3(4):216 (1981)
- (33) NABHAN G., WEBER C., BERRY J., Legumes in the Papago  
Pima Indian diet and ecological niche, KIVA 44:2 (1979)
- (34) FELGER R.S., Mesquite in Indian cultures of southwestern  
North America, in Simpson B.B., (ed,) "Mesquite- its  
biology in two desert ecosystem", Dowden, Hutchinson and  
Ross Inc., Stroudsbouurg, Penn. :150 (1977)
- (35) FELGER R.S., MOSER M.B., Seri use of Mesquite, KIVA  
37(1):53 (1971)
- (36) HAVARD V., Drink plants of the North American Indians,  
Torrey Bot. Club Bull. 22:98 (1896)
- (37) LATCHMAN R., La agricultura Precolombiana en Chile y en  
los paises Vecinos in Gomes P., "A Algarobeira", SIA  
865, Minist. Agric., Rio de Janeiro (1961)

- (38) VOGEL V., American Indian medicine, Univ. Okla. Press, Norman, Okla. (1970)
- (39) MARTINEZ M., Plantas utiles de la flora Mexicana, Ed.3, Ediciones Botas, Mexico City (1959)
- (40) CURTIN L.S.M., By the prophet of the earth, San Vincent Foundation, Santa Fe, New Mexico (1949)
- (41) FELGER R.S., MOSER M.B., Seri Indian pharmacopoeia, Econ .Bot. 28:414 (1974)
- (42) HAURY E., The Hohokam: desert farmers and craftsmen, excavations at Shaketown 1964-65, Univ.Ariz. Press., Tucson, Arizona (1975)
- (43) LARSON R.E., SODJOUDEE M., Mesquite utilization potential: from the stump to the finished product, in Proceedings of the symposium: Mesquite utilization, College of Agricultural Sciences, Texas Tech University, Lubbock, Texas :0-1 (1982)
- (44) BENET J., The mystique of Mesquite, San Francisco Chronicle June 15th:17 (1983)
- (45) GUPTA M.C., GHANDI B.M., TANDON B.N., An unconventional legume, Prosopis cineraria, Am. J. Clin. Nutr. 27(10):1035 (1974)
- (46) FLINT T.O., MORTON H.L., A device for threshing Mesquite seeds, Weed Science 17(1):302 (1969)
- (47) BROWN F.M., BELCHER E., Improved techniques for processing Prosopis seed (Arid land reforestation trials in developing countries), Tree Planters Notes, United States Forest Service 30(3):19 (1979)
- (48) WALTON G.P., A chemical and structural study of Mesquite, Carob and Honey Locust beans, U.S.D.A. Dep. Bull. 1194 (1923)
- (49) BECKER R., GROSJEAN O.K., A compositional study of pods of two varieties of Mesquite (Prosopis glandulosa, P.velutina), J. Agric. Food Chem. 28:22 (1980)
- (50) FIGUEREIDO A., Lebensmittelchemisch relevante Inhaltsstoffe der Schoten der Algarobeira (Prosopis juliflora), Dissertation Wuerzburg (1975)
- (51) FELKER P. BANDURSKI R.S., Protein and amino acid of tree legume seeds, J. Sci. Food Agric. 28:791 (1977)



- (52) BHARDWAY D.K., BISHT M.S., JAIN R.K., SHARMA G.C., Prosogerin-D, a new flavone from *Prosopis spicaria* seeds, *Phytochemistry* 19:1269 (1980)
- (53) BHARDWAY D.K., GUPTA A.K., JAIN R.K., SHARMA G.C., Chemical examination of *Prosopis spicaria* seeds, *J. Nat. Prod.* 44(6):656 (1981)
- (54) PANT R., BISHNOI P.L., Occurrence of two polysterenes in *Prosopis juliflora* seeds, *Current Science* 51(23):1124 (1982)
- (55) MALHOTRA S., MISRA K., An ellagic acid glycoside from the pods of *Prosopis juliflora*, *Phytochemistry* 20(4):860 (1981)
- (56) PAK N., ARAYA H., VILLALON R., TAGLE M.A., Analitical study of Tamarugo (*Prosopis tamarugo*) - an autochthonous Chilean feed, *J. Sci. Fd. Agric.* 28:59 (1977)
- (57) MEYER D., BECKER R., NEUKOM H., Milling and separation of *Prosopis* pod components, in Proceedings of the symposium: Mesquite utilization 1982, College of Agricultural Sciences, Texas Tech University, Lubbock Texas :L-1 (1982)
- (58) DEL VALLE F.R., ESCVOBEDO M., MUNOZ M.J., ORTEGA R., BOURGES H., Chemical and nutritional studies on Mesquite Beans (*Prosopis Juliflora*), *J. Food Sci.* 48:914 (1983)
- (59) SHALABI A., GHANEM S., ETMAN M., EL-HABIBI A., Phytochemical studies on the flora of Egypt I: Sugars and mucilage of *Prosopis stephania*, *Egypt J. of Botany* 19:221 (1976)
- (60) GAUR Y.D., Preliminary studies on titrable acididty in xerophytic plants: *Salvadora persica* Linn. and *Prosopis juliflora* D.C., *Experimenta* 24(3):74 (1968)
- (61) MEYER D., Untersuchungen ueber die Interaktion von Galactomannanen mit Xanthan, Diplomarbeit ETH Zuerich; (1981) (not published)
- (62) NITTNER E., "Galactomannane, Gewinnung, Aufbau und Eigenschaften" in Neukom H., und Pilnik W., *Gelier und Verdickungsmittel in Lebensmitteln*, Forster Verlag, Zuerich :95 (1980)
- (63) GLYCKSMAN M., *Gum technology in the food industry*, Academic Press, New York (1959)

- (64) SCHUSTER P., Untersuchung zur Interaktion der Polysaccharide Johannisbrotkernmehl und Xanthan, Diss. ETH 7370, Juris Druck und Verlag, Zuerich (1983)
- (65) BERI R.M., DOBHALL P.C., AYYAR K.S., Chemical examination of the seeds of *Prosopis cineraria*, Indian Forester 108(10):669 (1982)
- (66) MORO G.A., GRAZIANO M.N., COUSSIO J.D., Alkaloids of *Prosopis nigra*, Phytochemistry 14(3):827 (1975)
- (67) CHELLAMUTHU S., RAJ D., Contents and oil constants of vegetable oil from unconventional sources, The Madras Agricultural Journal 68(2):77 (1981)
- (68) SCHORMUELLER J., Lehrbuch der Lebensmittelchemie, Springer Verlag, Berlin-Heidelberg-New York (1974)
- (69) Tree crops for energy co-production on farms, U.S. Department of Energy, YMCA of the Rockies Estes Park, Colorado (1980)
- (70) FRITSCH C.W., GALE J.A., Hexanal as a measure of rancidity in low fat foods, J. Am. Oil Chem. Soc. 54:225 (1977)
- (71) HAURI J., ESCHER F., DENZLER A., NEUKOM H., Der Einfluss verschiedener Herstellungsverfahren auf die Haltbarkeit walzengetrockneter Getreideflocken, Lebensm.-Wiss. u. -Technol. 15(4):235 (1982)
- (72) JAFFE W.G., Nutritional aspects of common beans and other legume seeds as animal and human foods, Archivos Latino-americanos de Nutricion, Caracas, Venezuela (1975)
- (73) KON S., DUNLOP C.J., Snack foods from legumes, Food Product Development 11(7):77 (1977)
- (74) KON S., Process development adds scope to bean products, Food Product Development 13(7):48 (1979)
- (75) KON S., WAGNER J.R., BOOTH A.N., Legume powders, J. Food Sci. 39:897 (1979)
- (76) DANIELS R., Modern breakfast cereals, Food Processing Review 13, Noyes Data Corp. Park Ridge, New Jersey; (1970)
- (77) ROBINSON J.S., Fuels from biomass - Technology and feasibility, Noyes Data Corporation, Park Ridge, New Jersey (1980)

- (78) HALL D.O., BARNARD G.W., MOSS P.A., Biomass for energy in the developing countries, Pergamon Press, Oxford (1982)
- (79) STALLINGS J.W., OSWALD M., Energy recovery from wood residues by fluidized-bed combustion, in Jones J.L. and Radding S.B. "Thermal conversion of solid wastes and biomass, ACS Symposium Series 130:7 (1980)
- (80) FELKER P., CLARK P.R., OSBORN J.F., CANELL G.H., Utilization of Mesquite pods for ethanol production, in "Tree Crops for Energy Co-Production on Farms", YMCA of the Rockies, Estes Park, Colorado :65 (1980)
- (81) FREEDMAN D., Preliminary analysis of the potential for ethanol production from Honey Locust pods, in "Tree Crops for Energy Co-Production on Farms", YMCA of the Rockies, Estes Park, Colorado :121 (1980)
- (82) AVERGINOS G.C., WANG D., Utilization of Mesquite and Honey Locust pods as feedstock for energy production, in "Tree Crops for Energy Co-Production on Farms", YMCA of the Rockies, Estes Park, Colorado :209 (1980)
- (83) BUNGAY H.R., Energy-the biomass options, John Wiley & sons, New York (1981)
- (84) REED T.B., TREZEK G., DIAZ L., Biomass densification energy requirements in Jones J.L. and Radding S.B. "Thermal conversion of solid wastes and biomass, ACS Symposium Series 130:169 (1980)
- (85) SOFER S.S., ZABORSKI O.R., Biomass conversion processes for energy and fuels, Plenum Press, New York (1981)
- (86) WHISTLER R., Industrial gums, Academic Press, New York (1959)
- (87) PEDERSON J.K., Carragenan, Agar und Xanthan als Geliermittel und Stabilisatoren, in Neukom H. und Pilnik W. "Gelier- und Verdickungsmittel in Lebensmitteln" Forster Verlag, Zuerich :113 (1980)
- (88) LESNIAK A.P., LIU E.H., Chemical purification of the galactomannan in Leucena seeds, Leucena Research Report 2:75 (1981)
- (89) KOVACS P., Useful incompatibility of Xanthan Gum with Galactomannans, Food Technology 27:26 (1973)
- (90) REES D.A., Science J. 6(12) (1970)

- (91) McWATERS K.H., CHERRY J.P., Functional properties of peanut paste as affected by moist heat treatment of full-fat peanuts, *J. Fd. Sci.* 40:1205 (1975)
- (92) WOLF W.J., COWAN J.C., Soybeans as a food source, *CRC Critical Revius in Food Technol.* 2(1):81 (1971)
- (93) McWATTER K.H., CHERRY P.C., Emulsification, foaming and protein solubility properties of defatted soybean, peanut, field pea and pecan flours, *J. Fd. Sci.* 42(6):1444 (1977)
- (94) JNKLAAR P.A., FORTUIN J., Determining the emulsifying and emulsion stabilizing capacity of protein meat additives, *Food Technology* 23:103 (1969)
- (95) JOHNSON D.W., Functional properties of oilseed proteins, *J. Am. Oil Chem.* October:402 (1970)
- (96) SATHE S.K., DESHPANDE S.S., SALUNKHE D.K., Functional properties of black gram (*Phaseolus Mungo L.*) proteins, *Lebensm.-Wiss. u. -Technol.* 16:69 (1983)
- (97) ELDRIDGE A.C., HALL P.K., WOLF W.J., Stable foams from unhydrolyzed soybean protein, *Food Technology* 120:1592 (1963)
- (98) YASUMATSU K., SAWADA K., MORITAKA S., MISAKI M., TODA J., WADA T., ISHII K., Whipping and emulsifying properties of soybean products, *Agr. Biol. Chem.* 36(5):719 (1972)
- (99) SOLMS J., ESCHER F., *Lebensmittel-Technologie Vorlesungsscript*, ETH Zuerich (1982) (not published)
- (100) LORENCE F.G., POILLON J.S., MOREIRAS M., Mezquites y huizaches, *Ediciones del Instituto Mexicano de Recursos Naturales Renovables*, A.C. Mexico;(1970)
- (101) CONRAD E.C., PALMER J.K., *Food Technol.* 30(10):84 (1976)
- (102) FAO, Energy and Protein requirements, *Food and Agricultural Organisation*, Rome (1973)
- (103) MEXICO CITY NEWS, Sugar import up for record consumption, *Mexico City April* 28:5 (1984)
- (104) JOHNSON E.A., BREKKE C.J., Functional properties of acylated pea protein isolates, *J. Food Sci.* 48:722 (1983)
- (105) NIELSEN H.C., Corn germ protein isolates, *Cereal Chem.* 50:435 (1973)

- (106)HEGNAUER R., Pharm. Weekbl. 93:801 (1958)
- (107)ZOLFAGHARI R., HADORN M., HOPKINS L., Nutritional value of Mesquite beans (*Prosopis glandulosa*), in Proceedings of the Mesquite-Utilization symposium 1982, Lubbock TX; :K-1 (1982)
- (108)FIGUEIREDO A., Extracao,identificacao e caracteristicas do polissacarideo da semente de algarobeira (*Prosopis juliflora* DC), Cienc. Tecnol. Aliment. 3(1):82 (1983)
- (109)STAACKMAN M., GOODALE T.C., Rice hull utilization- Final report, URS Research Company, San Mateo, CA;(1970)
- (110)SPACKMAN D.H., STEIN W.H., MOORE S., Automatic recording apparatus for use in the chromatography of amino acids, Anal.Chem. 30(7):1190 (1958)



Curriculum vitae:

- 1957 Born June 18th in Zug/ Switzerland
- 1964-1970 Elementary-school in Zug
- 1970-1971 High-school at the Kantonsschule in Zug
- 1971-1976 High-school at the Instiut Dr.Pfister in Oberaegeri/ZG.
- 1976 Swiss Federal Maturity examination (Typus C)
- 1977-1981 Swiss Federal Institut of Technology in Zuerich, Faculty of Agriculture; Department of Food Science  
Practical training in several Food companies
- 1981 Degree in Food Technology (dipl. Lm.-Ing. ETH)
- 1981-1984 Research Associate at the Western Regional Research Center of the U.S.D.A. in Berkeley, CA (USA) as Ph.D. Student of the Swiss Federal Institut of Technology

---

Lebenslauf:

- 1957 Geboren am 18. Juni 1957 in Zug
- 1964-1970 Primarschule in Zug
- 1970-1971 Kantonsschule in Zug
- 1971-1976 Institut Dr. Pfister in Oberaegeri/ZG
- 1976 Matura Typus C
- 1977-1981 Studium an der Eidgenoessischen Technischen Hochschule in Zuerich, Abteilung fuer Landwirtschaft, Fachrichtung Lebensmittel-Technologie  
Praktika in verschiedenen Betrieben der Lebensmittel-Industrie
- 1981 Diplom als Lebensmittel-Ingenieur (dipl.Lm.-Ing. ETH)
- 1981-1984 Wissenschaftlicher Mitarbeiter am Western Regional Research Center des U.S.D.A. in Berkeley,CA (USA) als Doktorand der ETH Zuerich







