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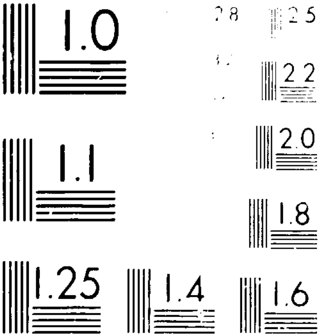
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UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

"BALANITES AEGYPTIACA"*

An Unutilized Raw Material Potential Ready for Agro-Industrial Exploitation

TF/INT/77/021

Product and process development in view of the industrial utilization of Balanites aegyptiaca fruits for the production of a variety of human food and animal feed products as well as steroid compounds.

A review made by Dr. I. M. Abu-Al-Futuh of a project initiated by UNIDO and implemented in close co-operation with the Industrial Research and Consultancy Institute, Khartoum, Sudan and the Research and Productivity Council, Fredericton, Canada

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General

Word in parenthesis indicates common name e.g. (Lalobe)

Figures in parenthesis ( ) indicate reference.

Words underlined indicate Latin names e.g. Balanites aegyptiaca.

Double dots (:) are used to denote a specific statement or name.

Asterisk (*) used to mark words for a foot explanatory note.

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands and millions

A slash (/) is used to indicate per: for example US$/tonne.

A hyphen (-) between two figures indicates the full range including the first and last figure.

"Tonne" refers to metric tonne.

"Gallon" refers to imperial gallon.

Prices are given in United States dollars ($) unless otherwise specified.

Mention of organizations does not imply the endorsement by the United Nations Industrial Development Organization.

Organizations

AOCS	American Oil Chemists Society
IRCI	Industrial Research and Consultancy Institute - Sudan
IUPAC	International Union of Pure and Applied Chemistry
RPC	Research and Productivity Council - Canada
TPI	Tropical Products Institute - United Kingdom
UNIDO	United Nations Industrial Development Organization
WHO	World Health Organization

Technical Abbreviations and Symbols

Bkc	Balanites kernel cake
^{o}C	degree Celcius
cm	centimeter
Del	Delile
e.g.	for example
g	gramme
gal	gallon
i.e.	that is to say
imp	imperial
I.P.	Intra Peritoneal
kg	kilogramme
kj	kilojoule
km	kilometer
L	Linnaeus
m	meter
mg	milligramme
min	minute
mm	millimeter
M.wt.	Molecular weight
P	Pressure
ppm	parts per million
psi	pounds per square inch
rps	rotation per second
T	Temperature
tcp	total crude protein
w/w	weight per weight
%	per cent
$<$	less than
$\simeq$	approximately
$\equiv$	equivalent to.

INTRODUCTION

Realizing the need for an optimum utilization of agricultural raw materials both traditional and non-traditional for the production of human food, consumer goods and other human needs, UNIDO has commissioned detailed product and process development work in view of the beneficial utilization of the so far unutilized Balanites aegyptiaca potential in Africa.

With the permission and valuable assistance of the relevant authorities of the Government of the Sudan, a model scheme was created with the aim to develop new non-traditional products and relevant industrial production processes based on Balanites aegyptiaca fruits as raw material. The product and process development work carried out and the very promising results obtained are described and discussed in this report for the consideration and use of all concerned and interested in making the so far unutilized Balanites aegyptiaca potential the raw material basis for a new agro-based industry to be set up in relevant developing countries to produce more quality food, provide new employment opportunities and improve national economies. The new Balanites aegyptiaca utilization scheme, in UNIDO's opinion is of particular value to those developing countries geographically situated in the Sahel zone of Africa.

The Balanites aegyptiaca (lalobe) fruit is composed of an outer fleshy part (mesocarp) rich in carbohydrates and also containing steroidal saponins. The mesocarp covers a shell enclosing a kernel with a high oil content and valuable protein combinations. Despite their food and pharmaceutical value, aegyptiaca fruits remained practically unutilized. Owing to their bitter taste, direct human consumption was never envisaged and the lack of processing know-how did not permit appropriate industrial utilization.

UNIDO shall be pleased to further support any industrialization efforts based on the utilization of the Balanites aegyptiaca potential particularly in Africa to the benefit of the developing countries involved and concerned.

ACKNOWLEDGEMENTS

UNIDO wishes to transmit its appreciation to the following active co-operators in this project, the valuable assistance of whom is herewith gratefully acknowledged.

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UNIDO also wishes to transmit its appreciation for the valuable advice and consultancy received from the following organizations:

- Unit of Medicinal and Aromatic Plants, National Council for Research, Khartoum, Sudan, c/o Dr. Abdel-Karim M. Saleh;
- Forest Administration, Ministry of Agriculture, Food and Natural Resources, P.O. Box 658, Khartoum, Sudan, c/o Mr. Kamal H. Badi, Director.
- University of Bath, School of Pharmacy and Pharmacology, Bath BA2 7AY, United Kingdom, c/o Dr. Roland Hardman.
- Tropical Products Institute (TPI), 56/62 Grays Inn Road, London WCIX 8LU, United Kingdom, c/o Mr. John J. Coppen.

S U M M A R Y

In this study, the Balanites tree (Heglig) is described with special consideration to its characteristics, habitat, geographical distribution, uses of its fruits and resources. The classification and vernacular names of Balanites aegyptiaca tree are also given. The common african Balanites species are briefly described.

The composition of Balanites aegyptiaca fruit (Lalobe) and chemical constituents of its various parts are given. The chemical constituents of Balanites fruit kernel, including its amino acid profile, are compared with other oil seeds. The Balanites kernel oil is compared with other vegetable oils.

The processing of Balanites fruit to separate the mesocarp, wooden shell and kernel is defined. The mechanical pressing of Balanites fruit kernel for oil is described and the optimum conditions are stated. A flow diagram of the process and the material balance is drawn out. The necessary data for processing Balanites kernel is tabulated. Analytical data is presented for the produced Balanites crude oil and kernel- cake.

The processing of Balanites fruit mesocarp for fermentation products (e.g. ethanol, carbon dioxide, ...) and steroidal sapogenins is outlined. The processing of Balanites fruit kernel to food products (e.g. peanut like products) is stated. The removal of the bitter principle from Balanites kernel is discussed (debittering). The refining of crude Balanites oil is marked out: data on the material balance of refining are given together with the physico-chemical properties of the refined oil and its market analysis. The processing of crude Balanites oil for soap production is formulated and the properties of the produced soap are given. The production of spray dried saponins from Balanites kernel- cake is described.

The utilization of Balanites fruit processed products for the Food, Feed, Drug, Fermentation and other industries are pointed out. Trials on the use of Balanites cake for animal and poultry feed, trials on the biological activity of Balanites saponins, trials on the market acceptability of Balanites kernel as a food product, trials on the market acceptability of Balanites refined oil for use in frying and trials on acceptability of laundry soap produced from crude Balanites oil, are conducted.

The economic aspects of Balanites fruit products are discussed, including their uses and market prospects. Statistical data is given on world production, consumption and prices of products equivalent to Balanites products (i.e. vegetable-oils, oil-meals, diosgnein,.....). The gross and net values of Balanites fruit products are estimated. The general layout of Balanites fruit processing is outlined.

In view of this study, it is concluded that the Balanites fruits can be processed for food, feed, drug and fermentation products: the shell of the fruit is an energy source within the process. Some of these products such as oil, cake, ethanol, carbon dioxide and animal slop, would support existing local industries in the country of production. Whereas, other products, such as diosgenin and activated charcoal, present valuable commodities for export.

The huge potential of Balanites fruits in Sudan would introd new industries to the sites of the fruit production (i.e. Kordo and Darfur Provinces) and would increase the standard of living in these localities.

This report provides the substantive framework for the setting-up of Balanites processing industries in the Sudan and other developing countries. Such industries, however, have to be based on the results of detailed and comprehensive techno-economic feasibility studies to be carried out on a case by case basis.

Chapter 1

GENERAL DESCRIPTION OF THE BALANITES TREE (THE HEGLIG)

1.1 Classification:

The Balanites tree belongs to the flowering plants which are herbs, shrubs or trees and the seeds of which have two cotyledons. It is thus classified under:

Phylum:	Angiospermae
Subphylum	Dicotyledons
Grade:	Archiclamydeae
Order:	Geraniales
Family:	Zygophyllaceae - Previously classified under the family Simaroubaceae
Genus:	Balanites

The Balanites tree (Heglig) referred to in this report is the African species which is known botanically as Balanites aegyptiaca (L.) Del. to which the Indian species known as: Balanites roxburghii Planch, is regarded as identical.

It worth to mention that the genus Balanites includes twenty-five different species. (41)

1.2 Vernacular Names

The Balanites tree is known as: HEGLIG (Arabic): MUSONGOLEE (Luganda of Buruli); MUTETE (Lynyoro); LOBA, LOGBA (Lugbara and Madi), TO (Lue A and Acholi); ECHOMAI (Atesa): EKORETE (Ateso K): CHOMIANDET (Sebei): ZOMAL (Lugishu); KINACHOMA (Lugwere); SHASHOBA (Hadendow and Bishariu): Q-OG-G-OGAT (Beni Amer): TAU,TU (Dinka, Shilluk, Jur, Nuer); KORAK and KURI (Nuba); TIRA (Nuba and Dilling): SARONGO (Gola: KHA, GA (Hamej).

Figure 1.3

Balanites Tree from Blue Nile Province in Sudan

1.3 Description

The Balanites tree is a Savanna tree which usually attains a height of 4.5 to 6 meters, occasionally reaching ten meters in height. The tree is crown spherical in shape with a tangled mass of long thorny branches. The branches are green and smooth with cream coloured lenticels which become denser from the tip towards the main stem where they are greyish in colour. The bark is grey to dark-brown with thick ragged scales and long vertical fissures. Thorns are green, straight and forward-directed, rarely forked, measuring up to 5 cm long and are situated in the axils of the leaves. The leaf consists of two grey-green leaflets on a short petiole 1 to 2 cm long. Leaflets are obovate to orbicular-rhomboid measuring 2.5 to 5 cm long and 1.2 to 2.5 cm broad, either subsessile or with petiolules up to 1 cm long. Flowers are yellow-green formed in spikes or sometimes shortened to round clusters in the leaf axils. Each flower measures about 1 to 1.2 cm in diameter and consists of 5 small deciduous sepals, 5 petals, ten stamens and a disc surrounding the ovary. The fruit is green turning yellow as it ripens, leaving a space between the epicarp (skin) and the mesocarp (flesh). The fruit is a drupe, broadly oblong to ellipsoid, measuring 2.5 to 4 cm in length and about 1.5 cm in diameter. The ripe fruit is composed of a leathery wrinkled skin (epicarp) covering a yellow brown sticky edible flesh (mesocarp) which surrounds a hard-pointed woody shell (endocarp) in which the kernel* (seed) is embeded. The wood of Balanites tree is moderately well figured, compact and lustrous, it is yellow brown in colour. (39)

1.4 Characterstics

The Balanites tree is a relatively deep rooting tree with a strong tap root. Due to its thick bark, the tree is very resistant to grass fires. The tree is semi-deciduous, dropping part of its leaves during the dry season, but always retaining some leaves. It flowers from November until April, according to its geographical source.

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*Known in Sudan as: Damalouge.

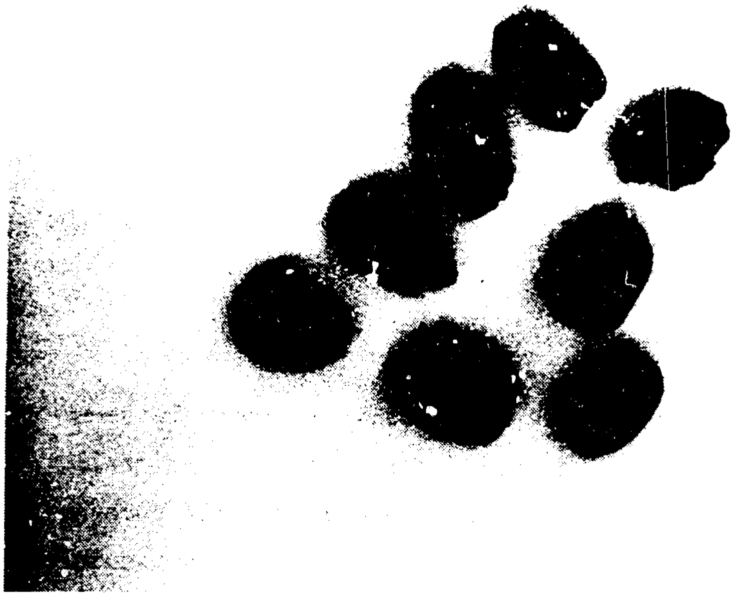
Fig. 1.3.a

Flowering Branch and Fruit of Balanites aegyptiaca.

Natural size

Figure 1.3.b

Balanites Fruits:



Balanites Kernels

Ripe fruits may be collected starting from Jan ary until August. The Balanites tree begins to fruit in about five to seven years and reaches maturity in twenty-five years and thereafter is long lived (over one-hundred years). An average mature tree would yield annually from one hundred up to one-hundred and fifty kilogrames of ripe fruit (eight thousands to twelvethousands individual whole fruits). The young Balanites trees are subjected to possible overgrazing by nomadic animals (sheep, goats, camels). The fruits may be consumed by both animals and birds whilst still on the trees. The seed of the fruit may be infested by an insect borer. Regeneration of Balanites tree is usually by the scattered seeds, effected by man or animal.

1.5 Habitat

The Balanites tree grows on dark cracking clay soil between rainfalls of 500 to 1,000 mm and on sandy soil where the rainfall exceeds 250 mm. It is also found in water receiving sites such as Valleiesand River banks; and on hard surfaced sandy clays particularly on the slopes at the foot of rocky hills. It also occurs on the Red Sea Coast.

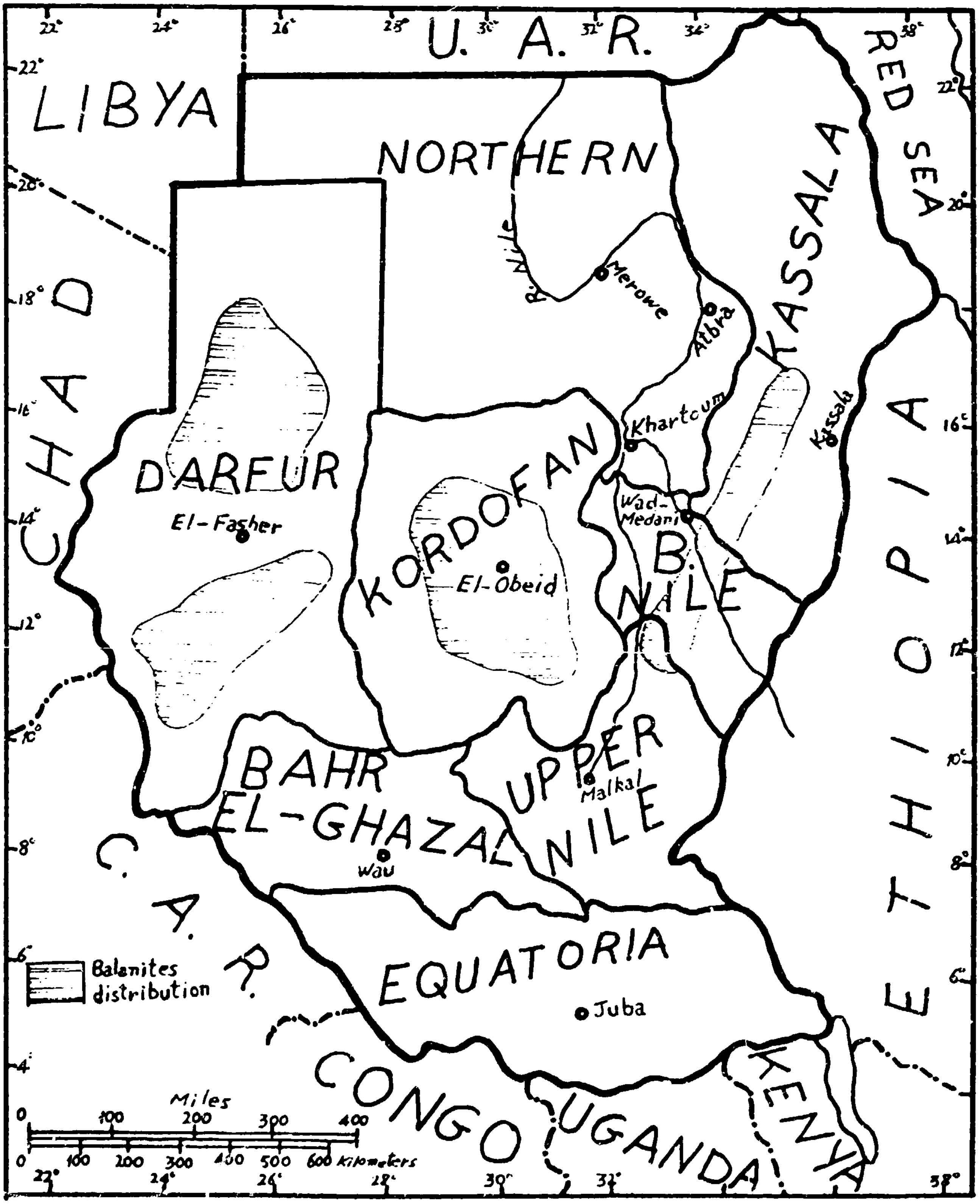
1.6 Geographical distribution

The Balanites tree is usually found mixed with talh, Acacia Seyal in what is known as the Acacia Seyal-Balanites Savanna, in the wide tropical belt of Africa, extending from Tanzania to the Ivory Coast and also to a smaller extent, in Asia Minor. Balanites aegyptiaca trees are thus indigenous to: Sudan, Gambia, Chad, Nigeria, Tanzania, Upper Volta, Northern Guinea, Ivory Coast, Senegal, Kenya and Uganda.

In Sudan the major distribution of Balanites trees occur in the Provinces of Darfur, Kordofan, Blue Nile and Kassala.

Figure 1.6

Distribution of Balanites Tree in the Provinces of Sudan



1.7 Uses

Balanites fruits, commonly known in Arabic as (Lalobe), also called: The Heglig Berries of Sudan. The name: Dessert Date, is given to the dried fruit and the name: Egyptian Myro-balan, is given for the unripe fruit.

The Balanites fruit is considered as an article of diet among the Madi, Acholi and the Nilotic tribes. Lalobe is also sucked by school children as an article of confectionary. In folk medicine, the aqueous decoction of the fruit is used as purgative, vermifuge and in the treatment of stomach ailments. In Nigeria a drink is prepared from the fruit and some times an alcoholic beverage. In Uganda, a very strong infusion of the fruit is used as fish poison.

The oil from the kernel of the fruit is used by villagers for cooking and in sometimes to treat skin diseases.

The wood of Balanites tree is considered as a compact, fine-grained timber, it is easy to work, it planes readily and is resistant to insects attacks.

1.8 Wild Resources of Balanites Fruits in Sudan

In Sudan, the major occurence of the Balanites tree (Heglig) is in Darfur, Kordofan, Blue Nile and Kassala Provinces. It is estimated that up to 1/3 of the total tree population in these areas may be of Balanites aegyptiaca.

Primary survey done in 1979 indicates that approximately 72,000 (seventy-two thousands) acres in the Blue Nile Province are covered with Heglig trees at an average density of fifteen mature tree per acre, amounting to about one million tree in that area which will provide a minimum of one-hundred thousand tonnes lalobe fruit per annum. However, it is estimated that the total wild resources of lalobe fruits in Sudan exceeds four-hundred thousands tonnes per annum at an estimated price of US$ 30 - US$ 80 per ton. Only 2 per cent of this estimated lalobe potential is actually traded in Sudan.(9)

Based on the previous estimate (four-hundred thousands tonnes lalobe per year) and on a given assumption that the lalobe fruit yields ten per cent of its weight kernel, then it is estimated that a minimum of fourty-thousands tonnes of Balanites kernels can be made available yearly from the wild Balanites resources in Sudan at an estimated price of US$ 400 to US$ 500 a tonne.

1.9 African species of Balanites fruits (41)

There are about twenty-five species in the genus Balanites, four of which are well known to be indigenous to Africa namely:

Balanites aegyptiaca (L) Del. = Balanites roxburghii Planch. This is a savanna tree common in the drier parts of Africa, Burma and India; it attains a height of 4.5 to 6 m, rarely 10 m, the spines are simple or rarely forked; fruits measuring 2.5 - 4 cm long and about 1.5 cm in diameter.

Balanites wilsoniana Dawe and Sprague. This is a deciduous forest tree of West Africa which attains a height of up to 40 m, the spines are forked or rarely simple, fruits measuring 4 to 7 cm long and 3 - 6 cm in diameter.

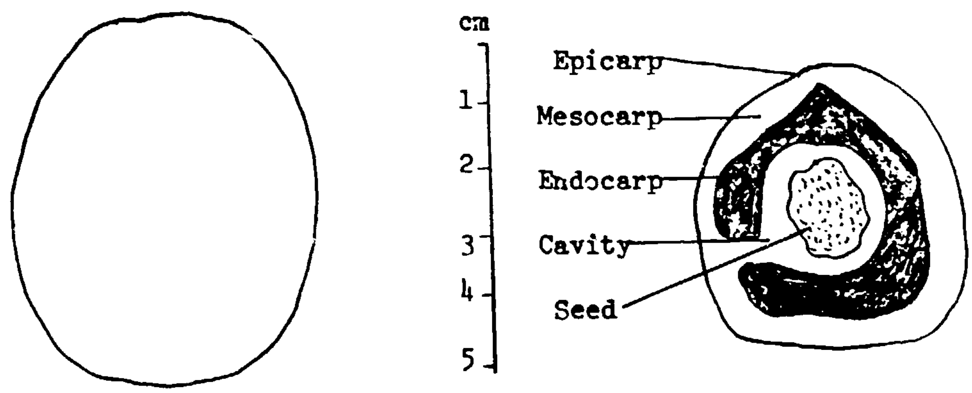
Balanites orbicularis Sprague. This is a savanna shrub or small tree common to East Africa which attains a height up to 4.5 m, usually has multi-stemmed spines, straight and stout, fruits measuring 2.5 - 3 cm long and 1.2 to 1.5 cm in diameter.

Balanites pedicellaris Mildbr and Schlecht. This is a dense savanna shrub or small tree attaining a height up to 4.5 m, spines are straight, stout and sharp, fruits measuring up to 2 cm long and about 1.2 cm in diameter.

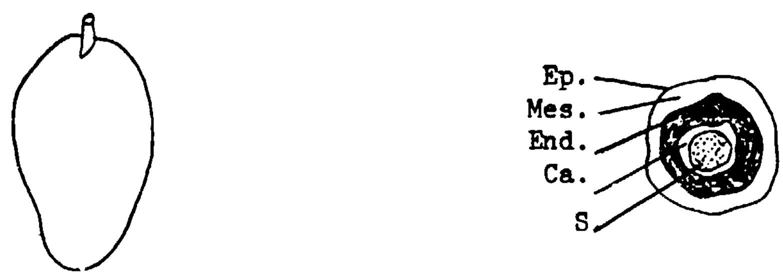
Figure 1.9 shows the fruits of the above species and their transverse sections.

Figure 1.9

Balanites Fruits of African Species; whole and transverse sections



Balanites wilsoniana



B.aegyptiaca

B. orbicularis

B. pedicellaris

Chapter 2

CHEMICAL CONSTITUENTS OF BALANITES AEGYPTIACA FRUIT

2.1 The composition of Balanites fruit

The individual weight of *Balanites aegyptiaca* fruit ranges between 10 and 15 g per fruit. The average proximate percentage composition (w/w) of the parts of the fruit is as follows.

Epicarp (outer skin)	5 to 9
Mesocarp (soft fruit wall or flesh)	28 to 33
Endocarp (hard woody shell)	49 to 54
Kernel (oil-seed)	8 to 12

However, these compositions may vary within the same species growing in different geographical area. Table 2.1 indicates the variation in the proximate compositions of fruits of *Balanites aegyptiaca* obtained from different sources in Sudan.

Table 2.1

Proximate composition of Balanites Fruits obtained from different sources in Sudan, Percentage w/w.

Source	Composition			
	Epicarp	Mesocarp	Endocarp	Kernel
1. Elobeid	4.6	33.0	53.7	7.9
2. Kassala	7.9	28.0	51.4	11.5
3. Elrosseires	8.2	30.5	50.3	10.2
4. Wad El Nail	9.3	31.0	48.9	9.8

2.2 The chemical constituents of Balanites Fruit (obtained from Sudan)

The outer skin (epicarp) of the Balanites fruit encloses a soft edible sugary fruit wall (mesocarp) which is composed primarily of sugar namely, glucose, fructose and sucrose; total carbohydrates = 64 to 72 % w/w . In addition, the mesocarp contains steroidal saponins which, on hydrolysis, yield up to 4 per cent w/w yamogenin/diosgenin; the mesocarp also contains significant amount of crude protein: 3.2 to 6.6 % w/w; crude fibre: 0.9 to 1.6 % w/w and vitamin C :12 to 27 mg/100 g . The mesocarp surrounds a hard woody stone (endocarp) which is fibrous in texture, mainly cellulosic and is free of saponins. Embeded inside the endocarp is an almond-shape oil-seed (kernel) which is composed mainly of fixed oil: 44 to 51 % w/w . In addition, the kernel contains crude protein: 26 - 30 % w/w steroidal saponins which, on hydrolysis, yield up to 2 % w/w diosgenin/yamogenin: and crude fibre: 2.4 to 3.3 % w/w.

Table 2.2.1. shows the proximate chemical constituents of four samples of Balanites fruits obtained from different sources in Sudan. Table 2.2.2. shows the comparative chemical constituents of some oil-seeds.

2.3 Balanites protein composition

The most exploitable protein from Balanites fruit is found in the kernel: crude protein = 26 - 30% w/w, with a comparatively low content in the flesh: crude protein = 3.2 - 6.6 % w/w. The amino acid profile of Balanites kernel and some oil-seeds is shown on Table 2.3.1. (1, 25, 32).

2.4 Balanites oil composition

The oil of Balanites kernel: content = 44 - 51 % w/w, is golden yellow in colour with acceptable scent and taste. It is characterised by high stability towards auto-oxidation. The oil components are mainly triglycerides with small quantities of diglycerides phytosterols, sterol esters and tocopherols (30). The fatty-acids composition of Balanites kernel oil are presented comparatively with other vegetable oils as shown in Table 2.4.1. (1, 25, 32).

2.5 Balanites sugars

Sugars are the main constituents of the total carbohydrates: 64 % to 72 % w/w, present in Balanites mesocarp. They constitute 56.65 % w/w , expressed as total free sugars, of the mesocarp. Only 0.57 % w/w is sucrose and the rest (i.e. 56.08 % w/w) is free reducing sugars: glucose and fructose.

Table 2.2.1

Chemical Constituents of Balanites Fruits Obtained from Diffierent Sources in Sudan. % w/w

	El-Obeid Source		Kassala Source		Elrosseires Source		Wadelnail Source	
	Flesh	Kernel	Flesh	Kernel	Flesh	Kernel	Flesh	Kernel
Moisture	24.6	4.5	17.9	3.5	18.7	3.8	19.7	3.9
Ash	5.3	2.9	5.4	2.8	6.9	3.1	5.5	3.3
Crude Protein	6.6	28.5	4.8	29.9	4.9	26.4	3.2	27.1
Fat	0.1	48.3	0.1	46.0	0.1	50.6	0.7	50.4
Crude Firbre	1.6	3.3	0.9	2.4	1.6	2.9	4.4	3.2
Total Carbohydrates	63.6	15.8	72.0	17.9	69.5	16.4	71.0	15.4
Diosgenin/Yamogenin	3.7	2.0	3.8	2.3	4.1	2.0	3.3	1.8
Vitamin C	0.02	-	0.01	-	0.02	-	0.02	-

Table 2.2.2

Comparative Constituents of Some Oil-Seeds, Including Balanites Kernels - % w/w

Oil-seed	Crude-Protein	Fat	Crude-Fibre	Ash
1. Balanites-kernel	26.4 - 29.9	46.0 - 50.6	2.4 - 3.3	2.8 - 3.3
2. Sesame-seed	25.0	50.0	4.0	5.0
3. Soyabean	42.0	20.0	5.0	---
4. Peanut	19.0	48.0	2.8 - 3.0	2.5 - 3.0
5. Cottonseed	21.0	19.0	10.0	4.4
6. Sunflower-seed	13.6	39.6	14.4	3.5

Table 2.3.1

Amino-Acid Profile of Some Oil-Seeds , Including Balanites Kernels , mg/g Nitrogen

Amino-Acid	Balanites Kernels	Soyabean	Peanut	Sesame	Cotton seed	Sunflower seed
Alanine	100	266	243	282	254	263
Arginine	394	452	697	756	700	499
Aspartic Acid	1200	731	712	513	586	579
Cystine + Gysteine	106	83	78	113	97	93
Glutamic Acid	1520	1169	1141	1213	1249	1365
Glycine	1106	261	349	305	264	338
Histidine	119	158	148	153	170	145
Iso-Leucine	256	284	211	226	206	267
Leucine	331	486	400	419	370	401
Lysine	319	399	221	171	276	225
Methionine	94	79	72	176	81	119
Phenyl Alanine	194	309	311	277	326	278
Proline	113	343	272	231	236	279
Serine	525	320	299	291	277	270
Threonine	100	241	163	223	206	230
Tryptophan	63	80	65	84	78	85
Tyrosine	113	196	244	195	180	118
Valine	263	300	261	288	290	317

Table 2.4.1

Comparative Fatty-acids Composition of Some Vegetable Oils
Including Balanites-Oil, % w/v

	Palmitic Acid	Stearic Acid	Oleic Acid	Linoleic Acid
Balanites kernel[*]	10 - 12	9 - 10	30 - 40	40 - 48
Soyabean[+x]	7 - 11	2 - 6	15 - 33	43 - 56
Sesame seed[+]	7 - 9	4 - 5	37 - 49	35 - 47
Peanut[+]	6 - 9	3 - 6	53 - 71	13 - 27
Cotton seed[+]	20 - 23	1 - 3	23 - 35	42 - 54
Sunflower[+]	3 - 6	1 - 3	14 - 43	44 - 75

[*] Data obtained from the analysis of refined Balanites-oil: Source IRCI, Khartoum, Sudan.

[+] Data obtained from AOCS Standards.

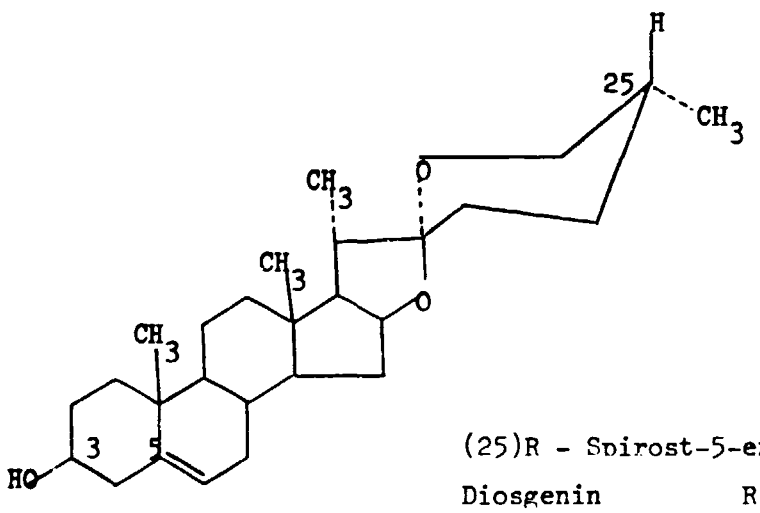
[x] Linolenic content = 5 to 11 % w/v.

2.6 <u>Balanites Saponins/Sapogenins</u> (6, 15, 18, 19, 20, 21, 29, 37, 38, 46)

The Balanites Saponins are a mixture of yellowish amorphous hygroscopic substances, M.wt > 860, with a very bitter taste. Being steroidal saponins, they are mainly composed of triglycosides of the steroidal sapogenin: diosgenin/yamogenin, M.wt. = 414.61. They constitute up to about 8 per cent w/w of the mesocarp and up to about 4 per cent w/w of the kernel. On hydrolysis, acid or enzymatic, the steroidal saponins yield theoretically about 48 per cent w/w steroidal sapogenins. The content of steroidal sapogenin in the Balanites mesocarp reaches up to 4 per cent and up to 2 per cent w/w in the kernel. These steroidal sapogenins are mainly a mixture of the two epimeric forms; 25α and 25β - Spirost - 5-en 3β - ol, with traces of epimeric dehydrocompounds probably spirostadienes. In the Balanites mesocarp, the major sapogenin epimer is yamogenin: 25β - spirost - 5 - en - 3β - ol, which forms nearly 2 : 1 of its epimer diosgenin: 25α - spirost - 5 en - 3β - ol. However, in the Balanites kernel, the major sapogenin is the diosgenin epimer which constitutes nearly 7 : 3 of its epimer yamogenin.

Figure 2.6.

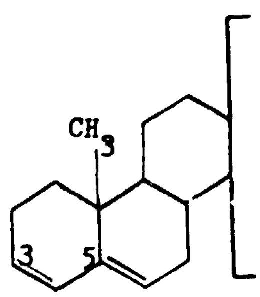
Steroidal Sapogenins of Balanites



(25)R - Spirost-5-en-3β -ol

Diosgenin R = α

Yamogenin R = β



Spirost .diene
(Dehydr o-compound)

Chapter 3

INTERMEDIATE PRODUCTS FROM BALANITES FRUIT

Balanites mesocarp, being mainly composed of carbohydrates in form of free sugars, can easily be softened by water into which it is taken as a slurry. The remaining hard-shell, if dried and cracked will release the oil-kernel from the wooden shell, after which they are separated from each other.

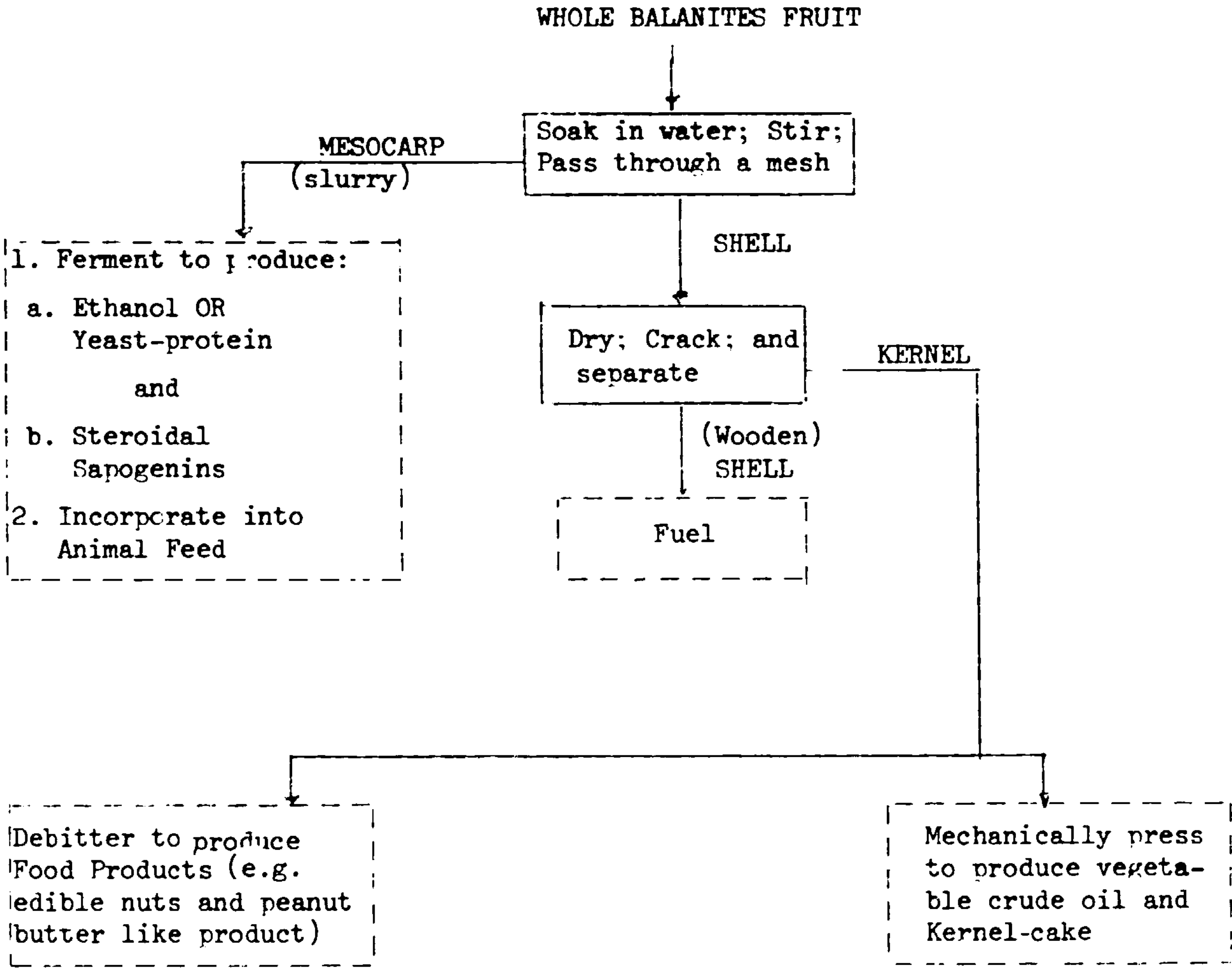
The mesocarp is a rich source for fermentable carbohydrates and for steroidal sapogenins; the kernel is a rich source for vegetable oil and protein; the hard woody shell is mainly cellulosic and is a source for fuel (see Figure 3).

3.1 Separation of the Balanites mesocarp

Whole Balanites fruits are placed in a suitable container, preferably wooden barrel, to cover nearly one-quarter of the container's capacity, water is added to cover up to three-quarters of its capacity. The material is left to stand overnight, about 18 hours, before it is stirred manually with a hard wooden stick or otherwise mechanically agitated for a while: half to 2 hours depending on capacity of container and mode of stirring. The stirred (agitated) material is then passed over a mesh with pores wide enough to hold the shells (i.e. size of pore is 0.8 - 1.0 cm in diameter). The retained shells are washed and dried in the open air: 18° - 39°C, for at least 72 hours; or alternatively with hot air at 60°C for 18 hours. The slurry of the mesocarp passing through the mesh together with the washings are fermented to produce ethanol or yeast protein, and steroidal saponins.

Figure 3

Processing of Balanites Fruit



Alternatively, the mesocarp slurry can be incorporated into animal feed. The mesocarp slurry can also be evaporated to a semi-solid form if required for transportation to a different industrial site.

3.2 Separation of Balanites kernel

The dried Balanites shells, as obtained in paragraph 3.1, are subjected to cracking either manually by crushing between two hard stones or mechanically by jaw crusher or roll mill with corrugated surface. The kernels are then separated from the wooden shells either manually or by centrifugal separation using a blender, followed by passing through a mesh: pore size 0.25 cm in diameter.

The kernels are used either for processing to food products or for mechanical pressing to produce crude vegetable oil and kernel cake. The wooden shells are used as a fuel.

3.3 Mechanical pressing of Balanites kernels

Three tonnes of raw Balanites kernels were studied for mechanical pressing to crude oil and kernel cake. Pressing of the kernel was carried in Rosedown Maxoil Duplex Expellers. The optimum parameters reached were: cooking the whole Balanites kernel for a total residence time of twenty-five minutes, followed by single pressing at high presure. The oil-yield was 36.5 per cent w/w with an industrial loss of three per cent w/w, and residual oil-in-cake of 11.2 per cent w/w. The crude oil produced was low in foreign matter: 3 per cent w/w, the filtered crude oil was high in neutral oil content: 99.1 per cent w/w, predicting low refining losses. The kernel cake was high in protein: 47.7 per cent w/w, and low in fibre: 5.0 per cent w/w, which makes it comparatively a good source for animal feed.

3.3.1 Source of raw material: Balanites kernel

Fresh whole Balanites kernels* were obtained from the Blue Nile Area in Sudan at a price of LS 45** per sack: 70-80 kg These kernels were relatively clean with average impurities not exceeding 1 per cent w/w. The individual whole kernel had an average weight of 0.9 grams and measured in average 0.8 cm in width and 2.1 cm in length. The oil content of these kernels was in the range of 46.0 - 50.6 per cent w/w, protein content 26.4-30 per cent w/w on a fresh base; the moisture content was 2.3 - 4.5 per cent w/w.

3.3.2 Experimental processing of Balanites kernel

This is the first trial in history for studying the mechanical processing of Balanites kernel to oil and oil-kernel cake. Reviewing most of the oil-seeds (e.g. soyabean, peanut, sesame, etc.) it was found that peanut is the most closely related oil-seed to Balanites kernel when considering its oil content, shape and size to some extent.

Hardness test, using Shore A[49], for both Balanites kernels and peanuts, revealed that there is not much difference in the hardness of these two seeds, See Table 3.3.2. Relevant to these common properties, processing of Balanites kernels was based on the general processing procedure known for peanuts processing[14,36].

Table 3.3.2

Comparative properties of Balanites kernel and peanut

Composition/property		Balanites kernel	Peanut
Moisture content	% w/w	2.3 - 4.5	3.9
Crude protein	% w/w	26.4 - 29.9	19.0
Fat	% w/w	46.0 - 50.6	48.0
Crude fibre	% w/w	2.4 - 3.3	2.8 - 3.0
Ash	% w/w	2.8 - 3.3	2.5 - 3.0
Mean hardness, whole seed		83.44	78.04

*In some rural areas in Sudan, it is common practice to crack the Balanites shell manually and sell out the whole kernels.

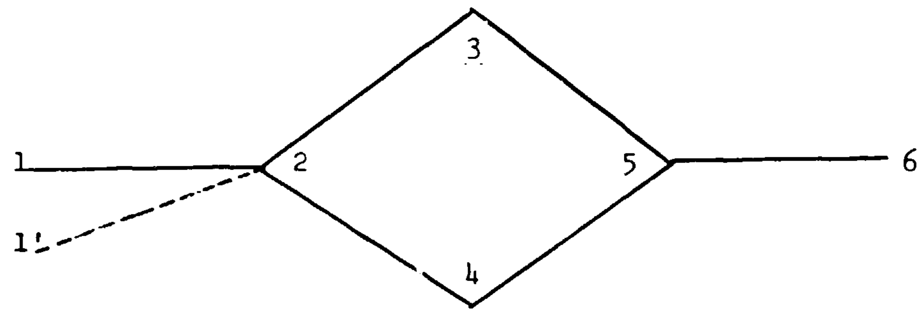
**Dealer's price to IRCI. Large scale commercial price estimated at LS 26 - 31 per sack.

3.3.2.1 Preliminary experimental trials in processing (mechanical pressing) of Balanites kernels

In order to determine the optimum conditions for processing Balanites kernels into oil and oil-kernel cake, a set of experiments were carried out with special emphasis on the following main parameters.

- The effect of size reduction on overall processing (i.e. pre-treatment)
- The short time conditioning at elevated temperature
- The effect of cooking at a temperature ranging from 85 - 120°C
- The effect of total residence time and direct steaming time.

Whole Balanites kernels, as received (i.e. without treatment) are subjected to different physical conditioning in the cooker (i.e. various temperatures and residence times for cooking). The moisture content, before and after cooking, of the kernels is recorded. The conditioned kernels are studied simultaneously for different pressing procedures (i.e. high pressure single pressing and double pressing) to see the effect on oil-yield. After pressing, the expressed oil is allowed to sedement in tanks and aliquots of the oil are analysed to determine the oil characteristics. Similarly, Balanites kernels, pre-treated by reducing their size with a hammer mill, average particle size $\simeq$ 2 mm, are subjected to the above system approach which is summarized below.



1 - Balanites kernels, as received

1' - Balanites kernels, pretreated by hammer mill

2 - Physical conditioning:

- Cooking temperature
- Moisture content before cooking
- Moisture content after cooking
- Residence time

3 - Pressing; High pressure, single pressing

4 - Pressing: Double pressing

5 - Oil-yield "quantity"

6 - Settling and filtration

All experiemntal trials were conducted in a Rosedwon Maxoil Screw-press of a capacity three to five tonnes per day[33]. The weight of Balanites kernels put into each trial was 70 kilogrammes. Size reduction was carried out by locally made hammer mill. The average size of crushed Balanites kernels was 2 mm. The moisture content, at down spout, during processing was determined at a temperature of 107°C. The results of the above trials are shown in Table 3.3.2.1. These trials were conducted using small capacity (i.e. 70 kilogrammes for each trial). It is expected that on full capacity of the expellers, results will be obtained similar to those given on processing other oil seeds.

Table 3.3.2.1

Results of the preliminary experimental trials in processing Balanites kernels

Factors	Exp. 1	Exp. 2	Exp. 3	Exp. 4	Exp. 5	Exp. 6	Exp. 7	Exp. 8
I. INITIAL CONDITION OF KERNEL								
i. Moisture Content (% w/w)	2.5	2.1	2.5	2.5	2.5	2.5	2.7	2.0
II. PRETREATMENT OF KERNEL		No	No	No	No	No	No	No
i. Size Reduction (SR)	1.9 mm	SR	SR	SR	SR	SR	SR	SR
III. CONDITIONING OF KERNEL	120	120	90-102	90-105	90 -105	88-90	80	85-90
i. Cooking Temperature (°C)	15	30	50	35	35	15	25	25
ii. Total Residence Time (minute)	20	300	1200	300	300	30	10	10
iii. Direct Steaming Time (seconds)	2.7	3.0	7.0	3.5	3.5	3.0	2.0	2.5
iv. Moisture Content at DS (% w/w)								
IV. EXPRESSION OF KERNEL	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
i. Feed Rate (kg/minute)	PBL	DSB	CRIO	Elastic	Elastic	Normal	Normal	Normal
ii. Cake Characteristics	-	5.0	5.0	5.0	5.0	5.0	5.0	5.0
iii. Cake Thickness (millimeter)	-	12.0	40.0	17.2	11.2	12.1	13.4	11.2
iv. Residual Oil in Cake (% w/w)	-	3.0	8.0	4.0	4.5	4.0	4.0	3.0
v. Moisture Content of Cake (% w/w)								
V. OIL CHARACTERISTICS	-	Y35,R5,BO	Y35,R3,BO	Y35,R3,BO	Y35,R3,BO	Y35,R3,BO	Y35,R2,BO	Y35,R3,BO
i. Colour	-	1.4469	1.4468	--	1.468	1.4468	1.4468	1.4469
ii. Refractive Index (20/20°C)								
VI. REMARKS	HPSP	Single Pressing	Single Pressing	Single Pressing	HPSP	Double Pressing	Double Pressing	HPSP

Abbreviations: PBL = Peanut Butter Like, DSB = Dark Slightly Burned, CRIO = Coarse Rich in Oil,
HPSP = High Pressure , Single Pressing

*Upper Kettle 100 p.s.i.
Lower Kettle 120 p.s.i.

3.3.2.2 Final processing of Balanites kernels

As a result of the preliminary experimental trials in processing Balanites kernels, size reduction was ruled out and the final large-scale processing was carried out with the following working conditions:

i. Cooking Temperature:	
Upper Kettle	80 - 85°C
Lower Kettle	95 - 98°C
ii. Steam Pressure	
Upper Kettle	100 lb/sq.in.
Lower Kettle	120 lb/sq.in.
iii. Total Residence Time	25 minutes

Three expellers -Rosedown Maxoil Duplex (Long Cage Type)[34] were installed at H.P. 40, steam consumption 400 lb/hr at 100 lb/sq.in. The crude oil was collected in an underground tank: 1.2 x 1.2 x1.5 m^3. The oil was left to settle in the tank for 24 hours before packing into plastic tins: capacity four gallons each. The cake was automatically conveyed to the cake department where it was bagged in jute sacks.

Figure 3.3.2.2 presents the flow diagram for the mechanical processing of Balanites kernel. Figure 3.3.2.2.a shows the material balance during the processing of Balanites kernels. Table 3.3.2.2 gives necessary data on the processing operation.

Figure 3.3.2.2

Flow Diagram for the Mechanical Processing of Balanites Kernels

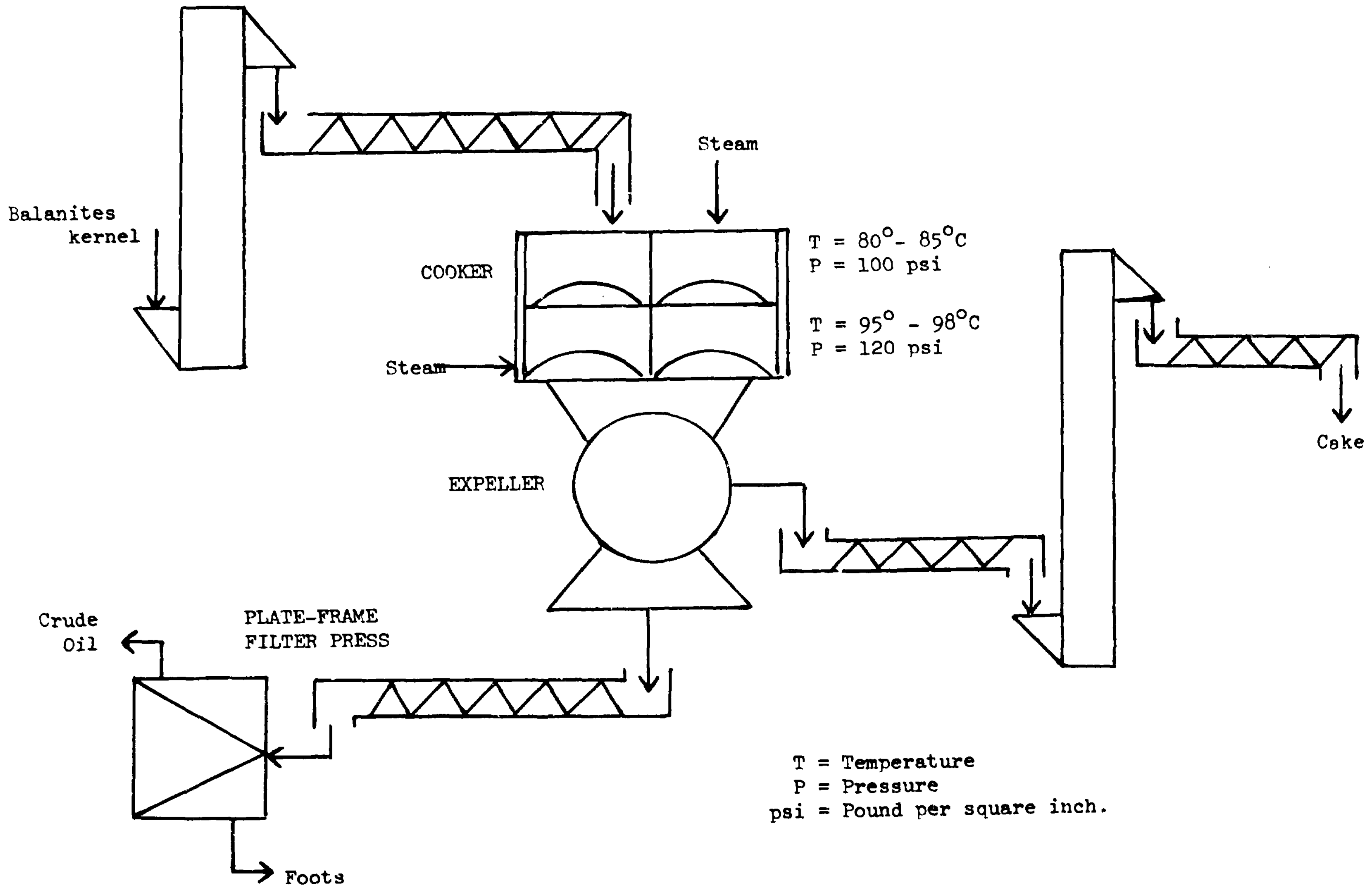


Figure 3.3.2.2.a

Material Balance During the Processing of Balanites Kernels,

Basis : 1 hour

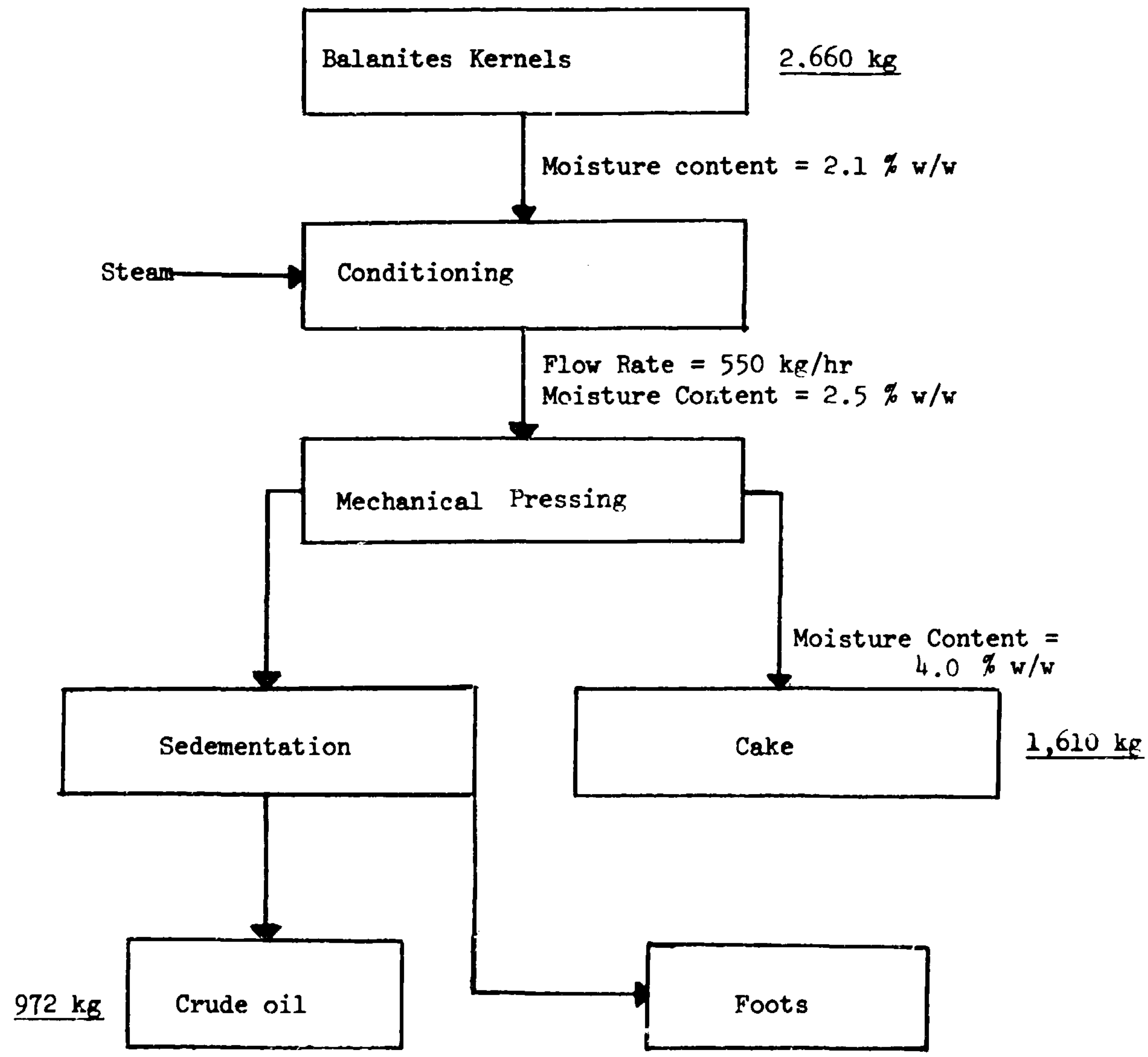


Table 3.3.2.2

Data on Processing Balanites Kernels

I. RESULTS:				
i	Initial Moisture Content	(% w/w)		2.1
ii	Moisture Content at Downspout	(% w/w)		2.5
iii	Flow Rate of Cooked Cake	(kg/hr)		550.0
iv	Cake Characteristics: Dry and light in colour			
v	Oil in Cake	(% w/w)		11.2
vi	Moisture Content of Cake	(% w/w)		4.0
vii	Oil Characteristics: Dull yellow, flows readily			
viii	Oil Colour: Y35, R3, BO			
ix	Refractive Index at $20^{o}/20^{o}C$			1.4469
II. MATERIAL BALANCE				
i	Quantity of Balanites Kernels	(kg)		2,660.0
ii	Quantity of Cake Produced	(kg)		1.610.0
iii	Quantity of Crude-Oil Produced	(kg)		972.0
iv	Sum of Cake and Oil Produced	(kg)		2,582.0
v	Industrial Loss	(kg)	i - iv	78.0
vi	Industrial Loss	(% w/w)		3.0
vii	Recovery of Oil	(% w/w)		36.5
viii	Recovery of Cake	(% w/w)		60.5
III. OIL BALANCE				
i	Quantity of Balanites Kernels	(kg)		2,660.0
ii	Average Oil Content	(% w/w)		46.0
iii	Total Quantity of Oil in Kernels	(kg)		1,223.6
iv	Quantity of Cake Produced	(kg)		1,610.0
v	Residual Oil in Cake	(% w/w)		11.6
vi	Total Quantity of Oil in Cake	(kg)		186.6
vii	Quantity of Crude Oil Produced	(kg)		972.0
viii	Sum of Crude Oil and Residual Oil in Cake	(kg)		1158.8
ix	Industrial Loss by weight	(kg)	iii - viii	64.8
x	Industrial Loss per cent	(% w/w)		5.3

3.3.2.3 Chemical composition of Balanites crude oil and oil-krenel cake

Table 3.3.2.3 shows the chemical composition of Balanites crude oil and oil-krenel cake as obtained from processing Balanites kernels in Section 3.3.2.2. Analysis were made according to the Official and Tentative Methods of the American Oil Chemist's Society[2].

Table 3.3.2.3

Analytical Data on Balanites Crude Oil and Oil-Kernel Cake

Composition	% v/w
I. CRUDE OIL	
i Moisture Content	0.6
ii Acid Value	4.1
iii Neutral Oil (of Filtered Oil)	99.1
iv Mucilage and Gums	3.0
II. OIL KERNEL CAKE	
i Moisture Content	4.0
ii Crude Protein	47.7
iii Crude Fat	11.6
iv Crude Fibre	5.0
v Total Ash	5.4

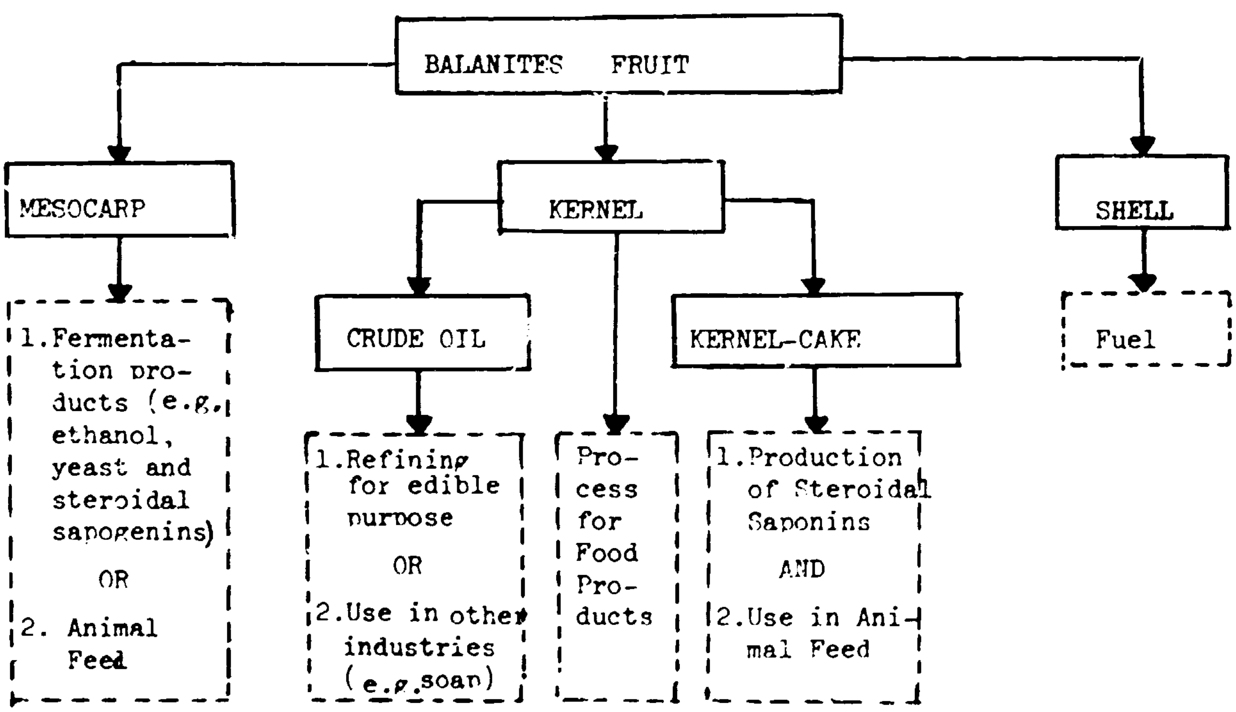
Chapter 4

PROCESSING OF BALANITES FRUIT INTERMMEDIATE PRODUCTS

Balanites fruit was processed to produce multi-purpose intermmediate products. The mesocarp of the fruit is a source for fermentation products (e.g. ethanol) and steroidal sapogenins: or can be incorporated into animal feed. The cellulosic shell of the fruit is a source for fuel. The kernel is a supplement for food products (e.g. edible nuts, peanut-butter like product). The crude Balanites oil is a source for edible vegetable oil or otherwise use in other industries (e.g. soap making). The kernel-cake, after expressing the oil, is a source of protein and carbohydrates for animal feed, See Fig. 4.

Figure 4

Intermmediate Products from Balanites Fruit



4.1 Processing Balanites mesocarp for fermentation products and steroidal sapogenins

Balanites mesocarp, which forms 28 - 33 per cent of the whole fruit, is a rich source of fermentable sugars : 56.65 per cent w/w , and a considerable protein content 5.56 per cent w/w , in addition to Vitamin C and some minerals. These valuable nutritional constituents of the Balanites mesocarp, makes the fruit a commercially attractive commodity.

In markets of West Africa, the Balanites fruit is considered as an article of commerce [13]. The fruit mesocarp is sucked by school children up to an extent of 15 - 20 fruits per day. In areas where the Balanites tree is abundant, goats and other ruminants graze on the mesocarp of this fruit. No toxicity has ever been reported, though a soft stool has been experienced when larger amounts are consumed. The fruit has also been reported to possess anthelmintic and laxative effects [4, 12]. The Balanites mesocarp also contains steroidal saponins : up to 8 per cent w/w , which could be the factor inducing soft stool (i.e. laxative effect). These saponins on hydrolysis yield steroidal sapogenins.

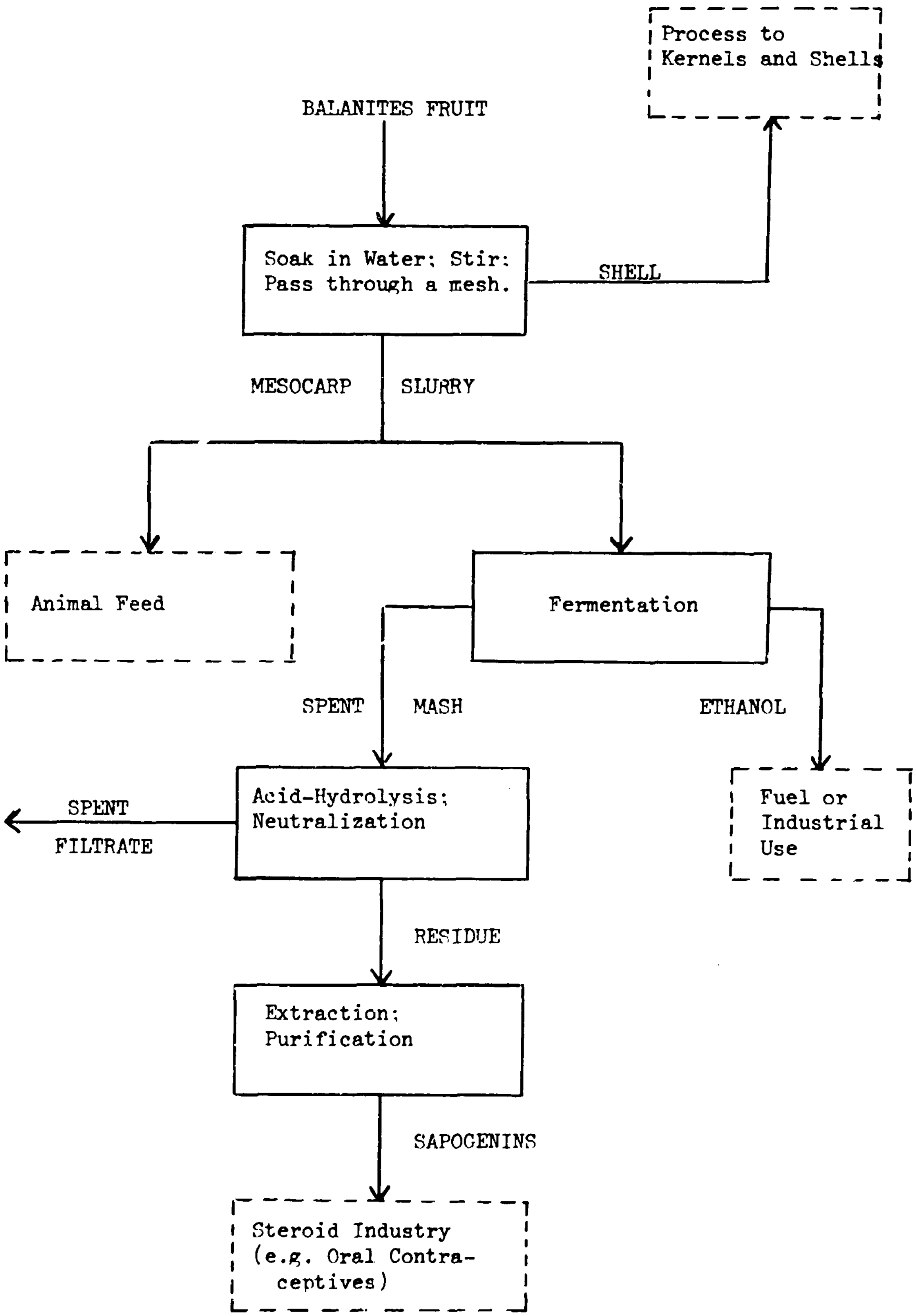
It is still questionable whether Balanites fruit mesocarp can be used for direct human consumption. It is recommended that more extensive biochemical studies and toxicity test are to be done before introducing the Balanites mesocarp as a food product.

Nevertheless, Balanites mesocarp is best utilized for the production of fermentation products and steroidal sapogenins , see Fig. 4.1.

It is known that some animals, such as goats and camels, graze on Balanites mesocarp. Recenlty, biological tests on ruminants revealed that the Balanites mesocarp has no gross toxicity. The above two evidence would give light on possible utilization of Balanites mesocarp for animal feed, particularly, in view of the promising results obtained from feeding trials with Balanites kernel-cake, see Section 5.1. This would certainly extend the scope of the mesocarp utilization: i.e. for animal feed as well as for fermentation products.

Figure 4.1

Flow Diagram for Processing Balanites Fruit's Mesocarp



4.1.1 Chemical composition of Balanites mesocarp

Balanites fleshy mesocarp, scrapped off with a sharp knife, was analysed according to the AOCS Standard Methods. The protein content was determined by the kjeldahl method, and fat content by soxhlet extraction. Free reducing sugars were determined by Lane-Enone Method[27] and sucrose by the method of total reducing sugar after mild hydrolysis[31]. Table 4.1.1 presents the proximate chemical constituents of Balanites mesocarp.

Table 4.1.1

Proximate chemical constituents of Balanites mesocarp

Constituent	Per cent w/w
1. Moisture	22.32
2. Ash (sulphated)	4.85
3. Protein (crude)	5.56
4. Fat (crude)	0.10
5. Carbohydrates (total)	65.51
6. Fibre	1.72
7. Vitamin C	0.02
i. Total Reducing Sugars	56.65
ii. Free Reducing Sguars (glucose + fructose)	56.08
iii. Sucrose	0.57

4.1.2. Production of ethanol by fermentation process

The mesocarp slurry (a rich source of fermentable sugars) is diluted to 12 per cent sugar, ammonium salts are added and the slurry is adjusted to pH 4.5-5.

The adjusted slurry is then sterilized, cooled and inoculated with culture of Saccharomyces cerevisiae. The slurry is allowed to ferment at 25°C under anaerobic conditions. The alcohol produced is distilled from the fermented mash and further passed through a rectifying coloumn for production of industrial ethyl alcohol -yield ≃ 10 per cent w/w of the whole fruit . The spent liquor after distillation of alcohol is reserved for the production of steroidal sapogenins, Section 4.1.3. Ethanol such produced is used as an industrial solvent or a raw material for chemicals, on further purification it is used as a fuel alcohol.

4.1.3 Production of steroidal sapogenins

The spent liquor left after distillation of ethyl alcohol, see Section 4.1.2, is a rich source of steroidal saponins which are not affected by the previous fermentation process. Steroidal saponins are glycosides composed of steroidal moiety linked by glycosidic linkage to sugar molecules. upon hydrolysis these saponins split to a steroidal sapogenin called diosgenin and its isomer yamogenin in addition to sugar molecules : glucose, xylose and rhamnose. These steroidal sapogenins are freely soluble in chloroform and slightly soluble in other organic solvents such as petroleum spirit.

The spent liquor is hydrolysed by boiling with two normal Hydrochloric acid at ≃ 100°C for 2 hours[8]. This reaction splits the steroidal Saponin (glycoside) into two : Sapogenin and sugar moiety. The acid hydrolysate is neutralized with ten per cent ammonium hydroxide solution followed by filtration. The filtrate is disposed and the residue is dried for overnight at 60°C. The dried residue is extracted with petroleum spirit of low boiling point. The petrol extract is evaporated to dryness to yield crude sapogenins : 2 to 4 per cent w/w of fresh mesocarp . The crude sapogenins are further purified by crystallisation from 85 per cent methanol to yield pure Yamogenin/Diosgenin in the ratio 3 : 1. These are drug-precursors for the pharmaceutical steroid industry , including oral contraceptives .

The yield of total sapogenins was determined by densitometric thin layer chromatography using a standard diosgenin[7].

4.2. Processing of Balanites kernel to food products

In some rural areas of Sudan and other African countries, debittered Balanites kernels at the village scale are consumed as a food product. In West Sudan, the kernel cake is also consumed as a food product and the expressed oil in cooking food. When the Balanites kernel cake was tested on rats, no gross toxicity was observed[9]. The Balanites kernel is a rich source of oil and protein, but the presence of steroidal saponins imparts a very bitter taste to the kernel rendering it unagreeable for edible purpose when raw. Processing trials were thus carried out to debitter the Balanites kernel and render it edible.

More than 50 kilograms of whole Balanites kernels, obtained from the Blue Nile Area in Sudan, at a price of 0.30 LS per kilogram were debittered by leaching with water at 60°C for 48 hours. The debittered kernels were then roasted and salted to offer an alternative food supplement. However, other products such as peanut butter like product or nuts incorporated into food or sweet recipe would very likely find acceptability. The debittering process could become more economic if the bitter principle (Steroidal saponins) is recovered from the extractives.

4.2.1. Debittering of Balanites kernels

Balanites kernels weighing 0.9 gram as an average individual and measuring 0.8 cm in diameter and 2.1 cm in length, were used for the debittering process. The oil content of these kernels was in the range 53 - 56 per cent w/w, protein 27 - 29 per cent w/w and a moisture content of 2 - 4 per cent w/w.

The Balanites kernels are soaked in water in the ratio 1:20, the temperature is maintained at 60°C, the kernels are stirred occassionally, changing the water every eight hours. After 48 hours the extracted kernels are removed and dried at 60°C for 24 hours. The disappearence of the yellow tint from the water extract is a clear indication for completion of the debittering process.

Decreasing the ratio of water to kernel would increase debittering time. Reducing the kernel size: $\simeq$ 0.2 cm, would not markedly decrease the debittering time. Comminution of the kernel : particle size $\simeq$ 0.01 cm, would not be recommended for food production since most of the oil and protein shall be lost during the process . Subjecting whole Balanites kernels to steam at 97.5°C up to 3 hours would result in over-roasting of the kernels without compelte debittering. Boiling whole kernels with water for 16 hours would result in a debittered product, but over-cooked. Boiling with aqueous alcohol is not recommended for a food product, unless the main object is to extract steroidal saponins. Table 4.2.1 presents some informative data on the different procedures for debittering Balanites kernels and some chemical constituents of the resultant product.

Table 4.2.1.

Some data on debittered Balanites kernels

Debittering Procedure	Debittering Time	Condition of product	Moisture content	Oil content	Protein content
1. Whole kernels soaked in water at 60°C	48 hours	Just cooked, in good condition	2.3 % w/w	59.9 % w/w	24.5 % w/w
2. Whole kernels boiled in water	16 hours	Over-cooked and brittle	4.0 % w/w	47.8 % w/w	27.1 % w/w
3. Whole kernels boiled in 50 % Ethanol	9 hours	Partially cooked, in good condition	2.2 % w/w	39.4 % w/w	33.2 % w/w
4. Untreated kernels	---	Fresh	2.4 % w/w	54.0 % w/w	24.8 % w/w

4.2.2. Food products from Balanites kernels

The debittered Balanites kernels were then roasted using the Batch Method[48]. The kernels are rotated in a round-bottom flask placed over a heating mantle where the temperature is controlled at 130 - 140°C for 25 - 30 minutes. The roasted kernels are then cooled by means of a stream of air and salted with 5 per cent w/w sodium chloride solution. The roasted salted kernels are then dried for four hours at 60°C. They developed a bright brown colour with a taste similar to most of the commercial edible nuts, but with a comparatively higher protein and oil contents.

Halva was also prepared[17] from debittered Balanites kernels. However, such Halva lacked the characteristic fibrous and friable textures of commercial Halva produced from sesame seeds.

4.3. Processing of crude Balanites oil

Balanites oil is composed mainly of triglycerides with small quantities of diglycerides, phytosterols, sterol esters and tocopherols. It has a high autoxidative stability as compared to other oils[30] (e.g. sunflower and olive oil). In general, Balanites oil is suitable for refining to edible oil as well as for processing to other industrial products (e.g. soap). Table 2.4.1. presents the comparative fatty acids composition of some vegetable oils including Balanites oil.

4.3.1. Processing of curde Balanites oil for edible purpose (refining)

After reaching the optimum conditions [2,40] required, crude Balanites oil was refined using the Continuous Cuastic Soda Method, see Figure 4.3.1. The crude oil is heated at 80 - 90°C, allowed to flow through a proportionometer at the rate of 42 kg/min, ultimately mixing for a short time with measured quantities of lye solution of 10' Baumé, at a rate of 2.2 Kg/min. The mixture is then allowed to flow to a battery of continuous centrifugal separators by which the oil is separated as a light effluent from the heavy soap stock. The separated oil is washed continuously with hot water to remove the soap. The moisture is removed by a continuous flash vaccum drier. The neutralized oil such obtained is then bleached by the Open-Tank Batch Method. The oil is heated to 110-120°C under agitation for 20 minutes to ensure complete drying: 4% w/w bleaching acid activated clay is added and agitation is continued for another ten minutes. The hot slurry is filtered immediately using vaccum filters. The material balance for the whole process is represented in Table 4.3.1.

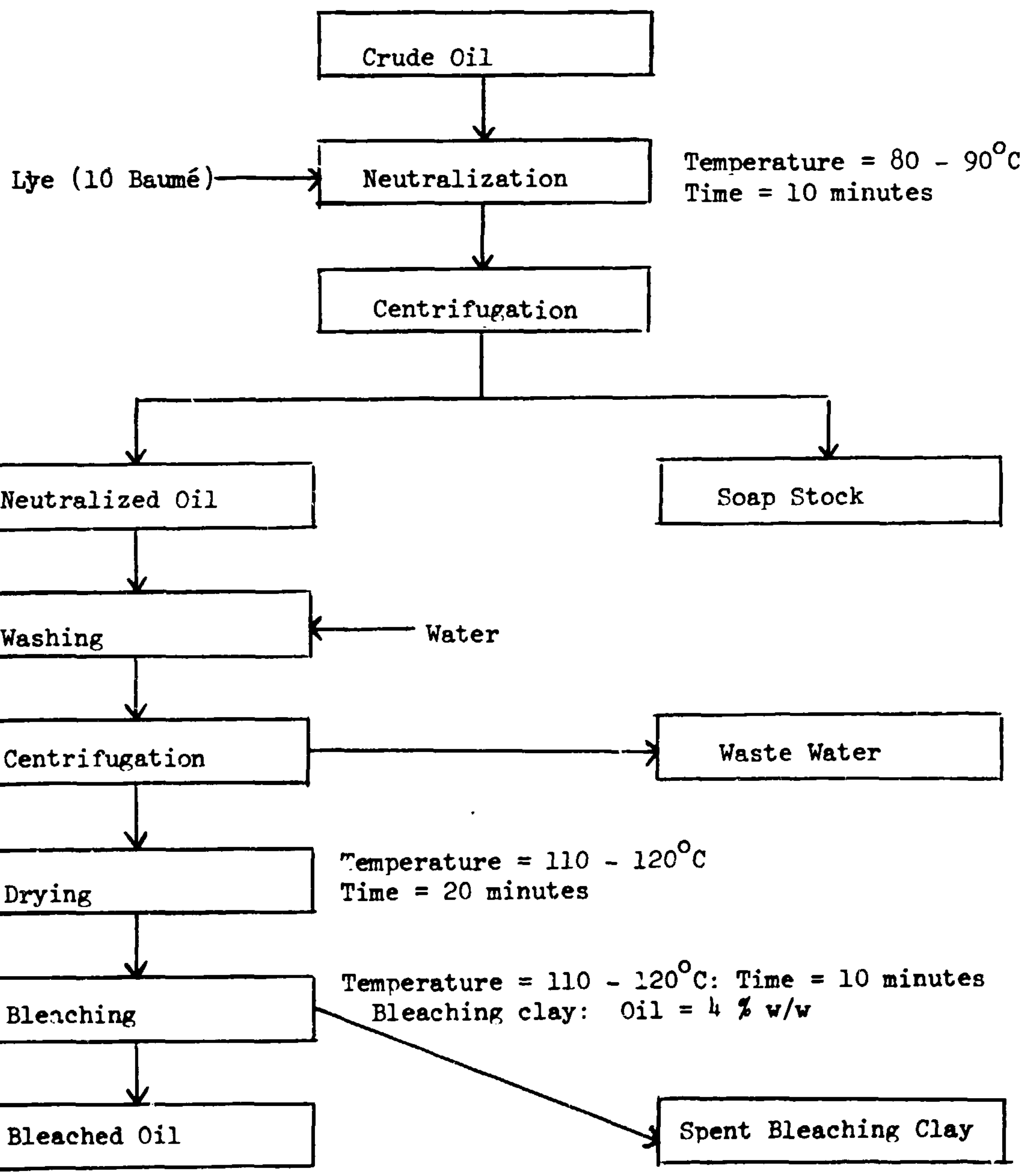
Table 4.3.1

Material balance of refining crude balanites oil

a.	Material Balance of Neutralization:		
	Quantity of crude oil used (Kg)	=	273.0
	Quantity of oil refined (Kg)	=	260.0
	Loss of neutralization (Kg)	=	13.0
	Percentage loss of neutralization (% w/w)	=	4.8
b.	Material Balance of Bleaching:		
	Quantity of refined oil (Kg)	=	260.0
	Quantity of bleached oil (Kg)	=	251.7
	Loss of bleaching (Kg)	=	8.3
	Percentage loss of bleaching (% w/w)	=	3.2
c.	Overall Material Balance of Refining:		
	Quantity of crude oil used (Kg)	=	273.0
	Quantity of bleached oil obtained (Kg)	=	251.7
	Loss of refining (Kg)	=	21.3
	Percentage loss of refining (% w/w)	=	7.8

Figure 4.3.1

Flow Diagram for Balanites Oil Refining



4.3.1.1 Physico - chemical properties of refined Balanites oil

Table 4.3.1.1 presents the physico-chemical properties of refined Balanites oil as obtained in Section 4.3.1. Standard limits for commercial edible oils are also presented in this table. The oil was tested for presence of steroidal saponins and free steroidal sapogenins using thin-layer chromatogrophy and applying antimony trichlorid colouring reagent for detection.[1]

As seen in Table 4.3.1.1 refined Balanites oil lie within the recommended standards of the International Codex for common edible oils: however, Balanites oil acid value was found exceptionally lower than that of the other edible oils. The oil was also found free of saponins and free sapogenins.

4.3.2. Processing of crude Balanites oil for soap production

Laundry soap was produced from crude Balanites oil using the semi-boil method: caustic soda is added to a blend of Balanites oil and tallow, the mixture is heated up to 40 - 50°C making use of the following formula:

Balanites Oil	(% w/w)	68.75
Tallow	(% w/w)	12.50
Caustic soda (37' Baume)	(% w/w)	12.50
Silicates and other additives	(% w/w)	6.25

Soaps are grouped according to the main fatty acid constituents of the oil (fat) used for soap production. The soap made from Balanites oil would belong to the group of oleic-linoleic soaps which are characterized by good foaming and detergency property, but lacks the firmness property. To improve this firmness property, tallow was blended with Balanites oil.

Table 4.3.1.1

Recommended international codex standards for some edible oils as compared with analytical data obtained for Balanites oil

Characteristic of oil	Balanites kernel	Soyabean	Sesame seed	Peanut	Cotton seed	Sunflower
1. Specific gravity (25°/25°C)	0.918	0.917-0.921	0.914-0.919	0.910-0.915	0.916-0.918	0.915-0.919
2. Refractive indes (25°C)	1.471	1.470-1.476	1.470-1.474	1.467-1.470	1.468-1.472	1.472-1.474
3. Iodine number	98	120 - 141	104 - 120	80 - 106	99 - 119	110 - 143
4. Saponification number	189	189 - 195	187 - 195	187- 196	189- 198	188 - 194
5. Unsaponifiable matter (w %)	1.2	< 1.5	< 2.0	< 1.0	< 1.5	< 1.5
6. Steroidal saponins	Negative	---	---	---	---	---
7. Free steroidal sapogenins	Negative	---	---	---	---	---

4.3.2.1 Properties of Balanites oil soap

Balanites oil soap solution of 0.05 % w/w in water at 25°C was found to posses a profuse lathering action, both in soft and hard waters, indicating a good detergency action. The Balanites oil soap solution of 0.8 % w/w in water, was found stable when refluxed with concetrated sulphuric acid up to 1 per cent w/w H_2SO_4 or with Sodium hydroxide up to 21.6 % w/w NaOH. Balanites oil soap solution of 0.1 % w/w in water, gave a clear solution with alkali up to 2.7 % w/w sodium hydroxide.

4.4 Production of Saponins from Balanites kernel cake

Steroidal saponins are glycosidic compounds which are readily soluble in water or aqueous alcohols. They are present in both Balanites Mesocarp and Kernel. However, their production from the mesocarp is not economically feasible.

After the mechanical pressing of Balanites kernel to oil and kernel-cake the saponins are left unaffected in the kernel-cake from which they were extracted. The saponin-free kernel cake was still a high nutritional source for animal feed.

4.4.1 Preliminary trials on extraction of steroidal saponins from Balanites kernel-cake

In experimental trials for the extraction of steroidal saponins from Balanites kernel-cake special consideration was given to preserve the nutritional value of the cake in view of using it for animal feed.

Extraction of these saponins with water was annulled due to the fact that water would extract a good part of the nutrative component (protein): and would render the drying process of the saponin extract and residual cake rather economically unfeasible. High frothing of water saponin extract would also present a problem in the processing.

Some preliminary tests for the extraction of saponins from Balanites kernel-cake were carried out using different alcohol concentrations. Coarsely powdered Balanites kernel-cake (20 grams) is refluxed with 200 mls of solvent alcohol in a 500 ml round-bottom quick-fit flask for three hours: the refluxed material is filtered and the residue (kernel-cake) is subjected to chemical analysis for oil and protein contents.

Table 4.4.1 shows the chemical composition of residual Balanites kernel-cake after refluxing with various alcohol solvents. Both 90 per cent Ethanol and 90 per cent Methanol were found suitable for extraction of the saponins while reserving the main nutrative constituents of the kernel-cake.

4.4.2. Production of steroidal saponins from Balanites kernel-cake

Ground Balanites kernel-cake is placed in a percolator, soaked with 90 per cent Ethanol and left to stand overnight at room temperature. The soaked cake is then percolated with enough 90 per cent Ethanol until the effluent is colourless indicating the exhaustion of the saponins which have a distinct yellow colour. The alcoholic extract is concentrated by evaporation under vacuum at 50°C and then extracted with low-boiling petroleum spirit to free it from residual oil. The petrol-extracted alcoholic concentrate (crude saponin extract) is then dried to yield crude saponins.

The optimum conditions found for spray drying the crude saponin extract of viscosity 2.64 were as follows: flow rate of extract at 41.9 ml/min with inlet temperature of 190°C and outlet temperature of 101°C while the automizer speed was 120 r.p.s. (rotation per second).

A total dry crude saponin residue of 6.5 per cent w/w from the starting kernel cake was obtained. This residue was yellowish amorphous hygroscopic powder which melted at 86°C and was estimated to contain approximately 30 per cent w/w pure steroidal saponins.

Table 4.4.2 presents the data obtained after spray drying aliquots of one litre of crude saponin extracts with variation in viscosity.

Table 4.4.1

Chemical composition of Balanites kenrel-cake after refluxing with various aqueous alcohols for three hours

Refluxed Balanites Kernel-cake	Oil content % w/w	Protein content % w/w	Saponin Concentration
1. Ethanol 50 % w/w	11.2	39.52	+
2. Ethanol 70 % w/w	10.2	47.36	+
3. Ethanol 90 % w/w	4.1	54.54	+
4. Methanol 90% w/w	5.9	52.80	+
5. Untreated	11.6	47.70	+++++

Table 4.4.2

Data obtained after spray-drying one-litre aliquots of crude saponin extracts with variable viscosity

Aliquot Sample	Viscosity	Weight of Residue (gramme)	Moisture Content (% w/w)	Melting Point °C	Texture
A	2.60	118.8	1.2	88	Slightly sticky
B	2.64	139.1	1.4	86	Amorphous
C	2.67	112.9	1.1	85	Amorphous
D	2.97	119.8	1.2	92	Lumpy and rather granular

Chapter 5

UTILIZATION OF BALANITES FRUIT PROCESSED PRODUCTS

The Balanites fruit has been proved to be of multi-purpose potential. The various industrial products which can be produced from this fruit would support different industries:

1. Food Industry (Edible Balanites Kernels and Oil):
2. Animal Feed Industry (Balanites Kernel Cake and Mesocarp):
3. Drug Industry (Sapogenins and Saponins):
4. Fermentation Industry (Ethanol):
5. Other Industries (Soap).

5.1. Utilization of Balanites kernel-cake

Balanites kernel-cake as produced by the mechanical pressing of Balanites kernels, See section 3.3, was subjected to trials on both poultry and animal feed. Balanites kernel-cake pretreated with 90 per cent ethanol to extract the steroidal saponins see Section 4.4, was also tested for poultry feed. Such cake from which most of the saponin has been removed, is referred to as Treated Balanties kernel-meal ; it is still a rich protein source.

5.1.1 Trials on poultry feed and egg production

Balanites kernel cake or treated Balanites kernel-meal was added to regular chick mash, growers, or layer's rations in different inclusion rates to substitute, partially, the commercial oil-seed cakes conventionally used. Substitution was made in such a way as to end-up with nearly the same crude protein content of these feeds, which is required for the normal growth and egg production in poultry.

The aim of these trials was to study the effect of Balanites kernel-cake on the weight gain in chicks and growers and on egg production in layer hens, in view of the utilization of Balanites kernel-cake for poultry feed.

5.1.1.1 Preliminary trials on weight gain

Preliminary feeding trials on one-day old male chicks were experimented : One hundred tetrabred male chicks of average weight 35.7 to 38.6 grams per chick were divided into four groups of 25 chick each. Each group was fed on a different inclusion rate of Balanites kernel cake: one of the groups being a control group, was fed on regular feed ration.

Using high inclusion rates (25.0 % w/w) of Balanites kernel-cake for the partial replacement of cotton, sesame and groundnut cakes have induced adverse effect on weight gain in chicks and caused mortality up to 32 per cent of the experimented chicks.

Lower inclusion rates of Balanites kernel cake were tested on one-day old chicks of average weight 35.7 grams per chick:

Group A was fed on 7.5 per cent w/w replaced Balanites kernel cake to end up with a ration of total crude protein (tcp) = 19.75 % w/w;

Group B was fed on 12.5 per cent w/w replaced Balanites kernel cake to end up with a ration of tcp = 19.85 per cent w/w;

Group C was fed on 15.0 per cent w/w replaced Balanites kernel cake to end up with a ration of tcp = 19.90 per cent w/w;

Control Group was fed on regular chick mash without inclusion of Balanites kernel cake, tcp = 19.75 % w/w;

Each group of chicks was weighed every week and the average increase in weight per chick of each group was recorded the percentage mortality was also recorded, See Table 5.1.1.1.a.

Inclusion rates of treated Balanites kernel-meal were tested on three groups of one day-old chicks of average weight 38.6 grams/chick.

Group A was fed on 10 per cent w/w replaced treated Balanites kernel meal (tcp = 19.78 % w/w);

Group B was fed on 15 per cent w/w replaced treated Balanites kernel-meal (tcp = 19.93 per cent w/w).

Control Group was fed on regular chick ration without Balanites kernel-meal (tcp = 19.75 per cent w/w).

See Table 5.1.1.1.b.

Table 5.1.1.1.a

Average total weight gain and total mortality of chicks fed on inclusion rates of Balanites kernel-cake (A=7.5: B=12.5: C=15.0% w/w).

Week	Av. total weight gain , grams per chick				Percentage total mortality			
	Group A	Group B	Group C	Control	Group A	Group B	Group C	Control
1	11.6	15.8	12.4	10.8	-	-	-	-
2	27.7	33.6	23.6	29.1	-	-	-	-
3	46.4	51.8	50.2	50.7	-	-	-	4
4	82.0	79.3	62.5	82.4	-	-	-	4

Table 5.1.1.1.b

Average total weight gain and total mortality of chicks fed on treated Balanites kernel-meal (A=10: B=15 % w/w)

Week	Av. total weight gain . grams/chick			Percentage total mortality		
	Group A	Group B	Control	Group A	Group B	Control
1	6.6	7.4	6.2	4	4	4
2	17.9	16.4	14.9	4	4	4
3	38.0	34.1	31.8	12	12	4
4	57.1	54.1	52.3	12	12	12

From the above trials, it appears that an inclusion of 7.5 per cent w/w Balanites kernel cake or 10 per cent w/w treated Balanites kernel-meal, would give nearly the same response in weight gain of one day-old chicks as obtained by the conventional chick mash.

5.1.1.2 Preliminary trials on egg production

Preliminary trials of feeding Balanites kernel-cake and its effect on egg production was experimented on Hisex Layer Hens. The hens were divided into four groups as follows:

Group A was fed on layer's ration containing 7.5 per cent w/w Balanites kernel cake (Bkc).

Group B was fed on layer's ration containing 10.0 per cent w/w (Bkc).

Group C was fed on layer's ration containing 12.5 per cent w/w (Bkc).

Control Group was fed on regular layer's ration without inclusion of Balanites kernel cake.

Egg production was followed for four weeks and results were recorded in Table. 5.1.1.2.a. The nutrative composition of the rations used and also their chemical analysis are presented in Table 5.1.1.2.b.

Table 5.1.1.2.a

Egg production of layer's hens receiving different inclusion rates of Balanites kernel-cake (A=7.5: B=10.0: C = 12.5 % w/w)

Group	Inclusion rate of Bkc % w/w	Number of hens (unit)	Total egg production (unit)	Average egg production (%)	Total mortality (units)
A	7.5	16	82	20.2	3
B	10.0	16	70	16.7	2
C	12.5	16	57	14.5	4
Control	-	16	103	26.8	4

Table 5.1.1.2.b

Nutrative composition and chemical analysis of four different layer's rations

I. Nutrative composition (percentage w/w)

Composition	Group A	Group B	Group C	Control
Dura	55.5	55.5	55.5	55.5
Groundnut cake	10.5	9.0	7.0	13.0
Cottonseed cake	3.0	3.0	2.5	5.0
Sesame cake	9.0	8.0	8.0	14.0
Wheat bran	9.0	9.0	9.0	7.0
Shell	3.5	3.5	3.5	3.5
Vitamins	1.5	1.5	1.5	1.5
Salt	0.5	0.5	0.5	0.5
Balanites cake	7.5	10.0	12.5	-

II. Chemical analysis (percentage w/w)

Constituent	Group A	Group B	Group C	Control
Crude protein	22.40	20.38	20.38	20.54
Crude fat	5.22	5.36	5.44	4.60
Crude fibre	4.86	4.49	4.38	4.43

It is obvious that there is a decrease in egg production in treatments receiving Balanites kernel-cake; however, there is no prominent toxic effect noticed among these treatments.

The experimental layer hens were then mixed and divided randomnly into three groups, each of 15 hen. All groups were kept on a regular layer's ration. After ten days another trial was conducted as follows:

Group A **was fed** on Ration containing 7.5 per cent w/w Balanites kernel cake.

Group B was fed on Ration containing 7.5 per cent w/w treated-Balanites kernel meal.

Group C was fed on regular layer's ration without inclusion of Balanites kernel meal or cake.

Egg production was followed for two weeks: the results are presented in Table 5.1.1.2.C.

Table 5.1.1.2.C.

Egg production of layer hens receiving different treatments of 7.5 % w/w Balanites kernel meal /cake

Group	Treatment	No.of hens	Total eggs (unit)	Percentage egg prod.	Total mortality
A	Untreated cake	15	31	14.8	--
B	Treated (meal)	15	44	21.1	--
Control	No inclusion	15	92	48.4	1

5.1.1.3 Final poultry feeding and egg production trial

Based upon the preliminary trials on poultry feeding and egg production, the final poultry feeding and egg proudction trial was set up as follows:

Sixty female-chicks, (Tetrabred) of one-day old weighing 37.4 grams in average per chick, were divided into three groups each of 20 chick·

Group A was fed on ration containing 7.5 per cent w/w Balanites kernel cake (Bkc).

Group B was fed on ration containing 7.5 per cent w/w treated Bkc (meal).

Control group was fed on regular ration containing no inclusion of Balanites kernel meal or cake.

One day old chicks were fed on chick-mash, see Table 5.1.1.3.a. When the chicks are two months old, the ration was changed in composition to suit Grower's ration. When the growers are four months old, the ration was changed to Layer's ration, see Table 5.1.1.3.b.

The average weight gain of chicks was followed from day one until the sixth week, see Table 5.1.1.3.c. The average weight gain of growers was followed from the first month of age until they are seven months old, see Table 5.1.1.3.d. The average egg production of layer hens (pullets) was recorded during the last four weeks of the experiment i.e. seventh month, see Table 5.1.1.3.e.

5.1.1.4 Results on poultry feed and egg production

From the above trials it can be concluded that 7.5 per cent w/w inclusion of both treated and untreated Balanites kernel cake would replace 9.5 per cent w/w of other oil-seeds cakes: cotton, groundnut, sesame, in poultry feed. This inclusion would give more gain in weight as obtained by feeds containing the other oil seeds cakes. At this inclusion rate, i.e. 7.5 per cent w/w, Balanites kernel cake was found to have an adverse effect on egg production

Figure 5.1.1.4 presents the effect of 7.5 % w/w inclusion rate Balanites kernel-cake and treated Balanites kernel-meal, compared with 9.5 % w/w of other oil-seed cakes.

Table 5.1.1.3.a

Chick's mash nutrative composition

Nutrient	Composition % w/w Group A	Group B	Control
Dura	55.5	55.5	55.5
Groundnut cake	10.5	10.5	13.0
Cottonseed cake	3.0	3.0	5.0
Sesame cake	9.0	9.0	14.0
Balanites kernel cake	7.5	-	-
Treated Balanites kernel meal	-	7.5	-
Wheat bran	12.0	12.0	10.0
Shell	1.0	1.0	1.0
Vitamins/minerals	1.0	1.0	1.0
Salt	0.5	0.5	0.5

Table 5.1.1.3.b

Layer's ration nutrative composition

Nutrient	Group A	Composition % w/w Group B	Control
Dura	55.5	55.5	55.5
Groundnut cake	10.5	10.5	13.0
Cotton seed cake	3.0	3.0	5.0
Sesame cake	9.0	9.0	14.0
Balanites kernel cake	7.5	-	-
Treated Balanites kernel meal	-	7.5	-
Wheat bran	9.0	9.0	7.0
Shell	3.5	3.5	3.5
Vitamins/minerals	1.5	1.5	1.5
Salt	0.5	0.5	0.5

Table 5.1.1.3.c

Average weight gain of chicks in grams

Week	Group A	Group B	Control
One	62.0 ± 6.0	73.0 ± 6.1	63.0 ± 7.3
Two	84.0 ± 5.6	90.0 ± 5.9	84.5 ± 8.1
Three	98.3 ± 7.2	104.4 ± 9.6	98.8 ± 6.2
Four	121.0 ± 9.3	130.0 ± 11.2	123.5 ± 6.9
Five	154.0 ± 8.6	158.0 ± 7.9	154.0 ± 10.3
Six	182.0 ± 12.1	194.2 ± 15.2	184.0 ± 14.5

Table 5.1.1.3.d

Average weight gain of growers/pullets in grams

Month	Group A	Group B	Control
One	121.1 ± 13.1	130.7 ± 11.7	123.1 ± 10.9
Two	335.7 ± 22.4	332.5 ± 31.8	310.2 ± 27.6
Three	720.9 ± 68.1	712.3 ± 76.1	682.5 ± 79.6
Four	1215.3 ± 142.2	1214.1 ±123.8	1143.3 ± 125.8
Five	1519.2 ± 131.7	1515.2 ±142.6	1430.7 ± 151.3
Six	1780.2 ± 190.2	1711.6 ±193.7	1625.8 ± 179.2
Seven	1943.5 ± 167.8	1878.3 ±149.2	1714.7 ± 193.7

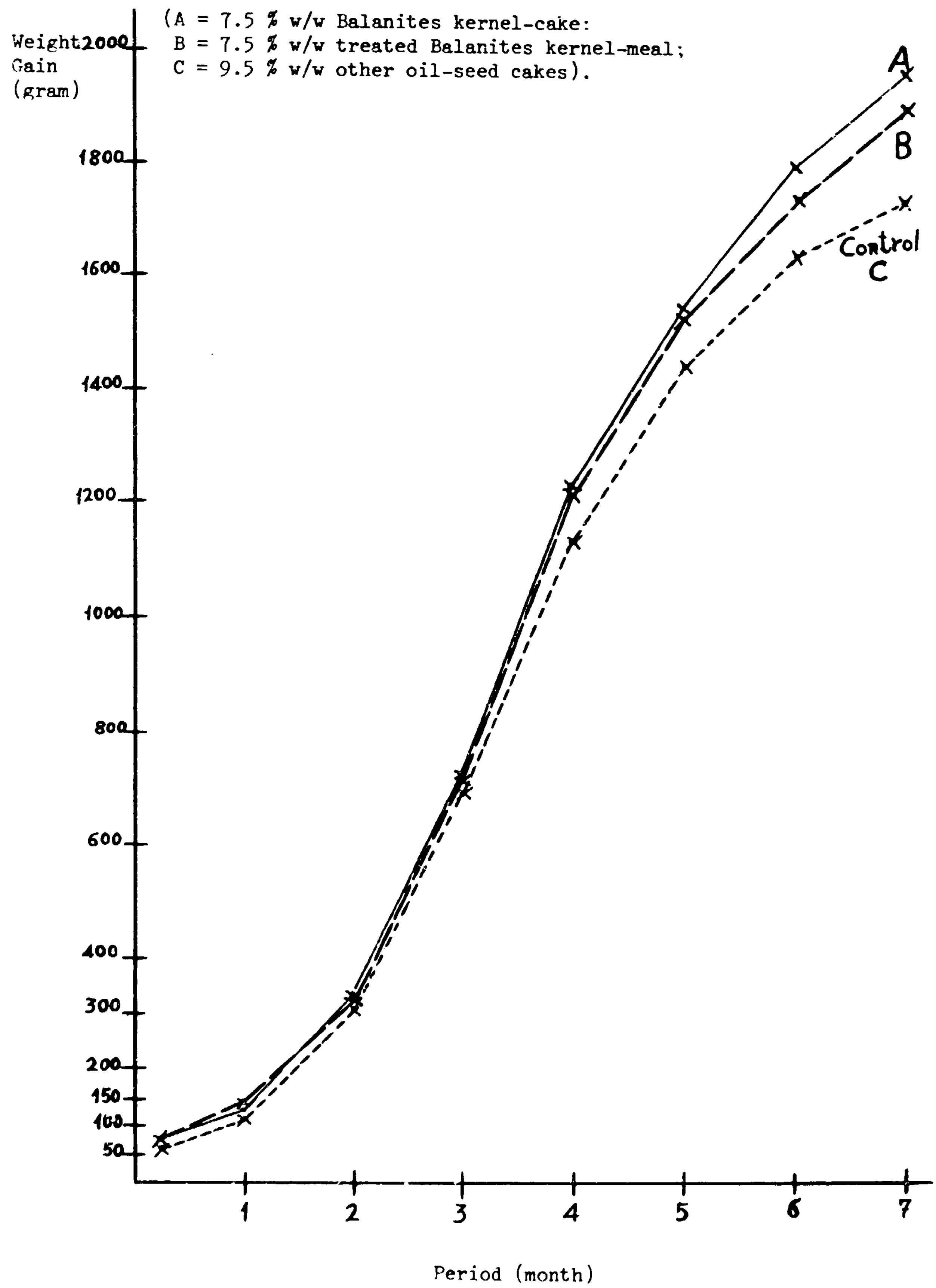
Table 5.1.1.3.e

Percentage egg production of pullets

Group	Inclusion of Balanites kernel cake % w/w	Percentage Egg production
A	7.5 (untreated)	21.0
B	7.5 (treated)	26.7
Control	----	45.0

Figure 5.1.1.4

Effect of Balanites Kernel-Cake on Poultry Weight-Gain



5.1.2 Trials on animal feed

Balanites kernel cake was added to animal feed rations in replacement of cottonseed cake to determine the effect of Balanites kernel cake on weight gain and consequently its utilization for animal feed.

Two groups (A and B) of 11 desert sheep in each group were used for the experimental trials. The lambs live-weight at the start of the experiment was 20.2 ± 4.1 and 20.1 ± 3.4 kilogrammes for groups A and B respectively.

5.1.2.1 Preliminary trials on animal feed

During the first three weeks preliminary period the two groups of lambs (A and B) were fed ad libitum on a ration of 60 % w/w straw (sorghum species) and 40 per cent w/w concentrates for one week followed by two weeks feeding on 40 per cent w/w straw and 60 per cent w/w concentrates, See Table 5.1.2.1. The gradual increase of the concentrates in the rations from 40 to 60 per cent during the preliminary period was arranged to avoid any digestive disturbance.

For the purpose of excluding the possible toxicity of Balanites cake a pilot experiment was conducted with three groups of sheep of two animals each. The sheeps were fed for three weeks on rations containing 5,10 and 20 per cent Balanites cake. During this period, the animals were weighed twice a week and feed in-take was recorded.

Table 5.1.2.1

Animal feeds offered during the preliminary period

Ingredient	Percentage rations 1st week	last two weeks
Straw	60	40
Molasses	10	10
Cottonseed cake	20	30
Sorghum	9	19
Salt	1	1

5.1.2.2. Final feeding trials on animal feed

At the end of the preliminary period lambs of group A continued feeding on the same ration of the preliminary period. Lambs of group B were fed on ration containing 20 per cent w/w Balanites kernel cake Table 5.1.2.2.a. shows rations fed to group A and B.

Table 5.1.2.2.a

Percentage ingredients of rations A and B for animal feed

Ingredient	Ration A	Ration B
Straw	40	50
Molasses	10	10
Balanites kernel cake	-	20
Cotton seed cake	30	-
Sorghum	19	19
Salt	1	1

Table 5.1.2.2.b presents the proximate chemical analysis of the above experimental rations.

Table 5.1.2.2.b

Proximate analysis of the experimental rations, % w/w, for animal feed

Feed ingredient	Dry Matter	Ash	Crude Protein	Crude Fibre	Ether Extract
Abu 70 (Straw)	86.3	7.2	2.1	44.8	0.8
Balanites cake	95.9	6.5	36.8	5.9	15.9
Cottonseed cake	92.4	5.9	28.0	23.6	6.3
Sorghum	91.6	2.0	14.0	4.7	3.2
Ration A	90.0	6.8	11.9	24.2	5.4
Ration B	89.8	8.1	12.3	24.7	5.8

5.1.2.3 Results of animal feeding trials

Results of the pilot experiment showed that feeding of Balanites kernel cake at the level of 5, 10 and 20 per cent w/w of the ration, did not stimulate any digestive disturbance of the experimented animals. No adverse effect on feed in-take or growth performance of the animals was observed. Table 5.1.2.3.a. shows the average live-weight changes and feed in-take of the three groups of sheep. Table 5.1.2.3.b shows the live-weight changes of group A and B during the three preliminary weeks and the first seven weeks of introduction of Balanites kernel cake in the ration of group B, See Figure 5.1.2.3.

Table 5.1.2.3.a

Feed in-take and growth performance of experimented animals during the pilot experiment

Feed in-take and growth performance	Group 1	Group 2	Group 3
Level of Balanites cake % w/w	5	10	20
Feed in-take kg/day	1.8	1.8	1.8
Initial live weight kg	41.0	37.3	35.0
Final live weight kg	41.5	38.8	36.3

Table 5.1.2.3.b

Average weekly live-weight changes in kilogrammes of experimented sheep

Week	Group A (cottonseed cake)	Group B (Balanites cake)
1	20.6 ± 4.0	20.4 ± 4.0
2	21.4 ± 4.4	21.4 ± 4.4
3	21.8 ± 4.8	22.4 ± 4.5
4	22.7 ± 5.0	23.3 ± 4.5
5	23.8 ± 3.2	24.3 ± 4.3
6	25.0 ± 5.7	25.5 ± 4.3
7	25.9 ± 5.9	27.0 ± 5.0
8	27.7 ± 6.3	29.0 ± 5.0
9	30.3 ± 6.9	31.1 ± 5.2
10	31.4 ± 7.2	33.0 ± 5.2

The average feed in-take of group A and B is about 1.8 kg per animal. The growth performance of group B is insignificantly ($p = 0.5$) higher than that of group A. This suports a good evidence for the higher quality of protein content of Balanites kernel cake for feeding ruminants, considering that 20 % w/w of Balanites kernel cake has replaced 30 per cent w/w of cotton seed cake.

The palatability of rations containing Balanites kernel cake are acceptable to sheep the same as other conventional feeds. There is no difference in taste between the meat of lambs fed on rations containing Balanites kernel cake and that of those receiving cotton seed cake.

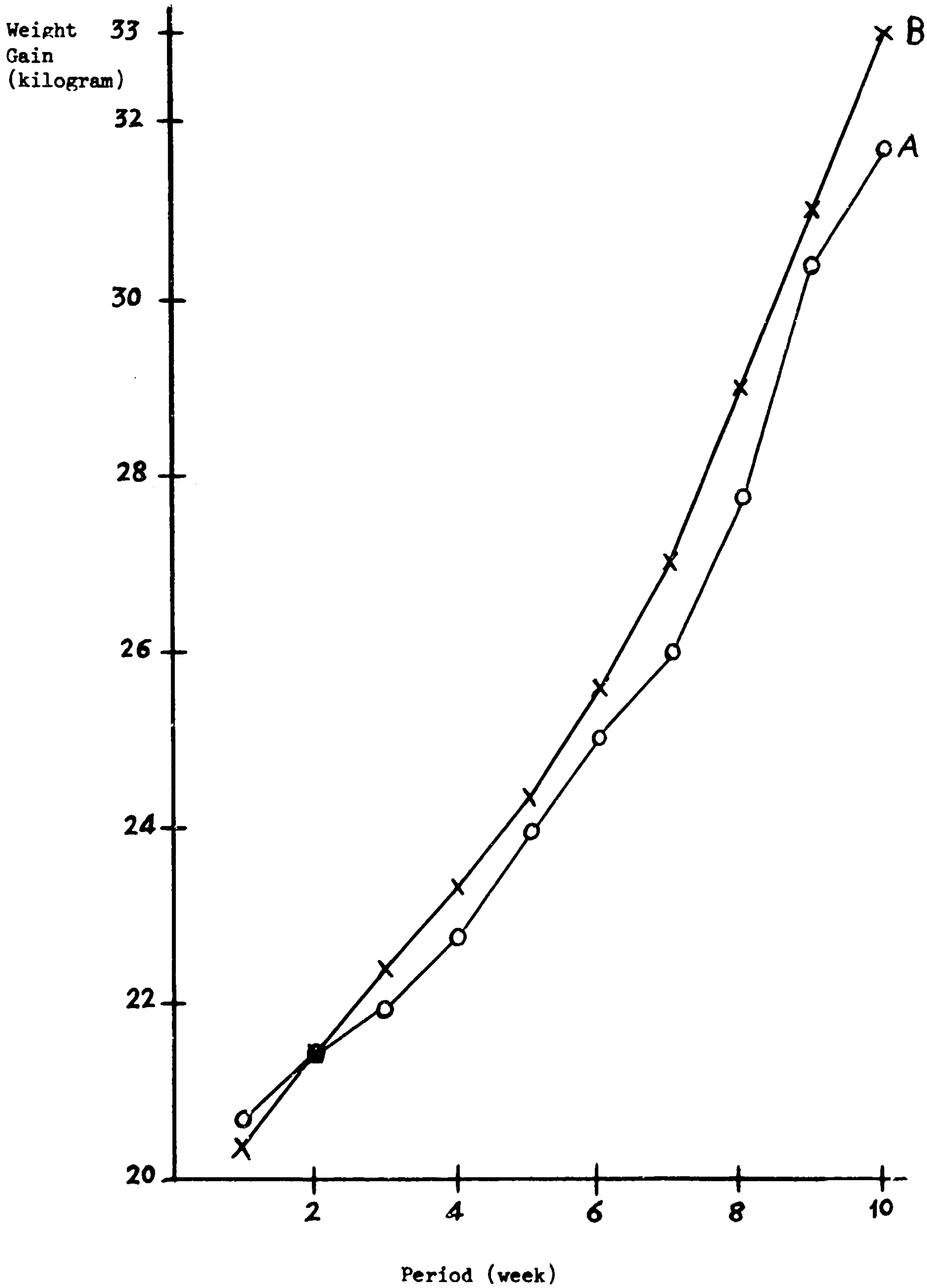
5.2 Biological testing of Balanites steroidal saponins

Crude Balanites steroidal saponins were tested for some biological activities in view of their future utilization by the Pharmaceutical Industry. The crude saponins as obtained in Section 4.4 were considered as a by-product of the Balanites kernel cake: their utilization would make the processing of Balanites fruit more economic.

Figure 5.1.2.3

Effect of Balanites Kernel-Cake on Sheep Live-Weight Gain

(A = 30 % w/w Cottonseed cake; B = 20 % Balanites Kernel- Cake)



Balanites crude saponin was experimented for its effect on blood sugar and in the control of Schistosomiasis. The saponin was also tested for gastrointestinal function and its lethal dose (LD 100) **was determined**.

5.2.1 Effect of Balanites saponins on blood sugar level

Wistar rats weighing 200 - 250 grams or white New Zealand rabbits weighing 1.5 - 2 kg were used as experimental animals. Rabbits were fasted for 24 hours before the start of the experiment, blood samples were collected before and after drug administration considering precautions stated by Varley, 1969 (45).

A solution of crude saponin dissolved in water for injection was injected intraperitoneal (I.P.) in doses of 40, 80 and 160 mg/kg. in rats, and doses 80, 160 and 320 mg/kg in rabbits. Blood samples were collected two hours after injection ; basal blood glucose and that after administration of the saponin was determined using the alkaline copper reduction method of Asatoor and King, 1954 (5).

Table 5.2.1.a. shows the effect of different doses of Balanites Saponin on rat blood sugar level and Table 5.2.1.b shows the effect on rabbit blood sugar level.

Table 5.2.1.a

Effect of Balanites Saponin on rat blood sugar

Dose (I.P.) mg/kg	Blood sugar level mg/100 ml		Percentage
	Basal	2hours after inj.	Change
40	97.0	69.6	- 28.3
80	78.25	52.6	- 33.9
160	65.4	151.0	+130.9

Table 5.2.1.b

Effect of Balanites saponin on rabbit blood sugar

Dose (I.P.) mg/kg	Blood sugar level mg/100 ml Basal	2 hrs.after injection	Percentage Change
80	67.6	72.2	+ 6.8
160	103.7	75.0	- 34.3
320	56.9	214.0	+274.0

The saponin induced hyperglycaemia (increase in blood sugar level) may be due to increased release of glucagon [42]. In this connexion, it should be recalled that the hypoglycaemic (cause decrease in blood sugar) agent, Tolbutamide, besides stimulating insulin release, is also shown to enhance glucagon release [35].

However, the results of these experiments direct the attention of the potential capability of Balanites saponin to affect blood sugar level.

5.2.2 Effect of Balanites saponin on gastro-intestinal function

Four white New Zealand rabbits, each weighing 1.5 - 2.0 kg were placed each in a metabolic cage. Both food and water were made available ad libitum. To one of the rabbits 0.5 g saponin (in water solution) per kg body weight was administered by lavage: 1.0 g/kg and 2.0 g/kg were also administered similarly to the second and third rabbit respectively. The fourth rabbit was used as a control and to which distilled water in a volume equivalent to that administered to each of the other three was administered similarly. All the rabbits were observed during a period of 10 hours.

Table 5.2.2 shows the weight of faeces and their consistency, 10 hours after treatment. The table shows that a dose of 1 g/kg is very effective in increasing the weight of faeces excreted and changing their consistency from the solid nature to the semi-solid form. A dose of 2 g/kg induced excretion of both semi-solid faeces and fluid, i.e. clear cathartic effect.

Table 5.2.2

Effect of Balanites saponin on weight and consistency of faeces

Dose of saponin (g/kg)	Weight of faeces (g/rabbit)	Consistency
0	20	Solid
0.5	24	Solid
1.0	46	Semi-solid
2.0	48	Semi-solid to fluid

The above table clearly demonstrates that Balanites saponin possesses a clear purgative effect in a dose of 1 g/kg. This is changed to a chathartic effect on higher doses. See Figure 5.2.2.

The effective purgative dose of crude Balanites Saponin (1 g/kg) is far above the effective hypoglycaemic dose found in Section 5.2.1 which is 80 - 160 mg/kg. This shows a wide range of safety at the level of hypoglycaemic effect.

5.2.3 Lethal dose (LD_{100}) of Balanites Saponin

White Wistar rats each weighing 200 - 250 g or White New Zealand rabbits each weighing 1.5 to 2.0 kg were injected with Saponin solution intraperitoneal at various dose levels. The dose that kills all the experimented animals was determined as the Lethal Dose (LD_{100}).

Table 5.2.3 shows that 15.7 grammes Saponin per kilogramme body weight is required to kill all the rats under experiment, whereas a lower dose of 5.0 g/kg is required to kill the rabbits under experiment. This lethal dose (LD 100) is also far above the effective hypoglycaemic dose found in Section 5.2.1 which is 80 - 160 mg/kg.

Figure 5.2.2

Effect of Balanites Saponin on Weight of Rabbit Faeces, after 10 hours of administration

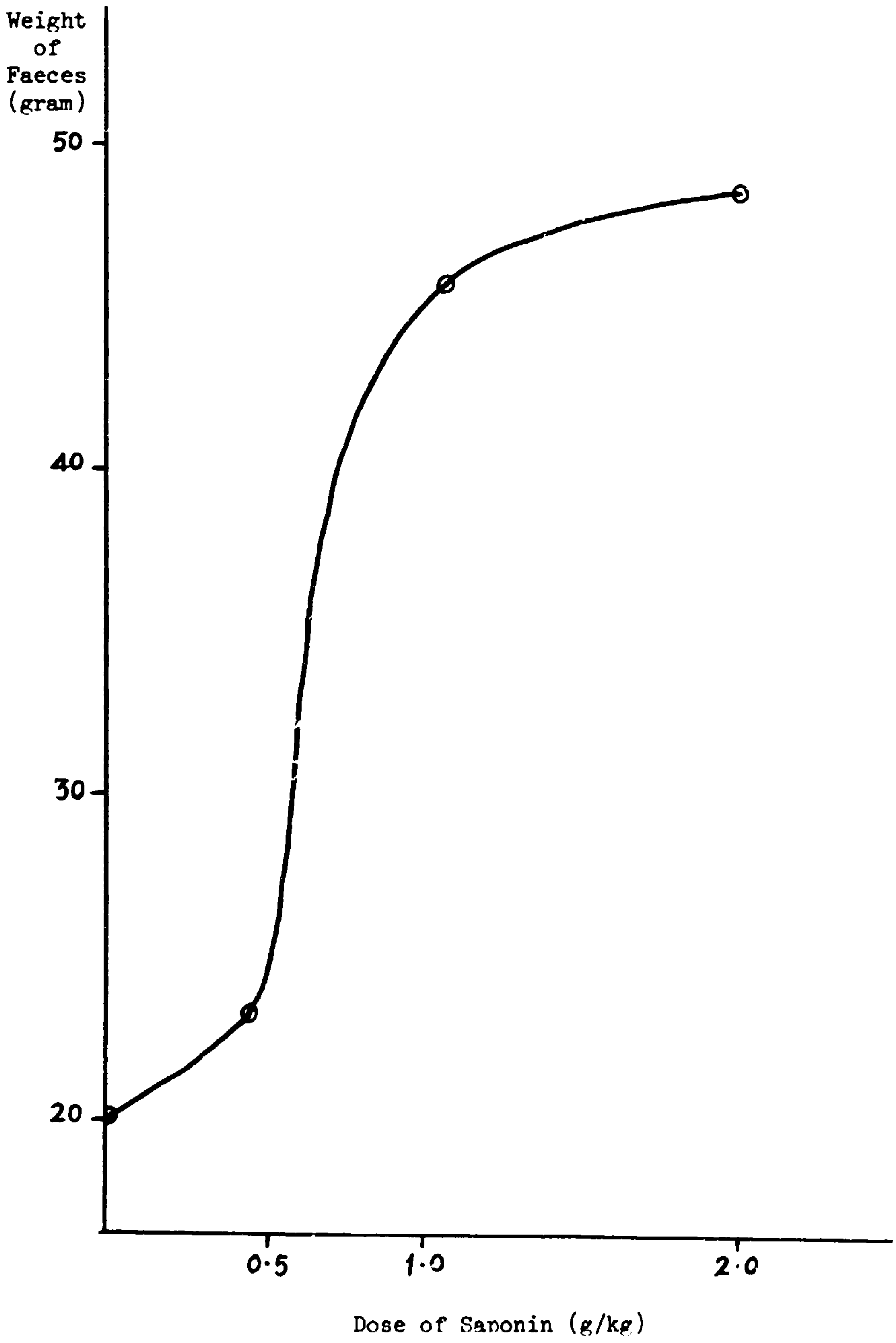


Table 5.2.3

Lethal Dose (LD 100) of Balanites saponins in rats and rabbits

Animal	LD 100
Rat	15.7 g/kg
Rabbit	5.0 g/kg

5.2.4 Balanites saponins effect on schistosomiasis

Chemical molluscicides are of great use in controlling Schistosomiasis - a common parasitic desease affecting man and live stock in most of the tropics of Africa, the Middle East and South-East Asia. According to WHO estimates, approximately 250 million people suffer from this disease and more than 600 million people are living in areas where Schistosomiasis is endemic.

Some workers have reported on the effectiveness of Balanites fruit extracts on the control of Schistosoma snails (Molluscicidal activity). Crude Balanites saponin was tested for its molluscicidal activity in view of replacing some of the already known chemical molluscicides, and consequently for its utilization by the pharmaceutical industry.

5.2.4.1 Effect of Balanites saponins on schistosoma snails

To test the effect of Balanites crude saponins on schistosoma snails. two adult species of snails were used, namely Bulinus truncatus and Biomphlaria pfeifferi. Screening tests were carried out according to the method recommended by WHO[47].

Different concentrations of the crude saponins were prepared for testing their molluscicidal activity in the above mentioned snails. Saponin concentration was expressed in terms of parts per million (ppm) of the original fruit material, See Table 5.2.4.1.

Table 5.2.4.1

Molluscicidal activity of Balanites saponins

Concentration of Saponin (ppm)		Percentage mortality of snails	
Mesocarp	Kernel	Bulinus truncatus	Biomphlaria pfeifferi
1.56	3.0	-	-
2.3	4.5	-	40
3.0	6.0	40	40
3.8	7.5	40	80
4.5	9.0	80	100
5.3	10.5	80	100
6.0	12.0	80	100
6.8	13.5	100	100
7.5	15.0	100	100

As seen in the above table, Balanites saponins showed high molluscicidal activity against Biomphlaria pfeifferi: LD 100 = 9.0 ppm of the whole kernel; and against Bulinus truncatus :LD 100 = 6.8 ppm of mesocarp or 13.5 ppm of kernel. The WHO recommendation for plant material with economic molluscicidal activity are those up to 75 ppm. This indicates that Balanites fruit saponins are highly active as molluscicides.

5.3 Roasted Balanites kernels as food products

Balanites roasted kernels as processed in Sections 4.2.1 and 4.2.2, were studied for acceptability as a human food product by the Sudanese consumer.

A questionnaire based on 'new product development strategy[26] was designed, See Figure 5.3 . The roasted Balanites kernels were distributed to visitors of "The Development and Progress Exhibition" held in Khartoum on the Occasion of the 11th Anniversary of the May Revolution, together with the designed questionnaire.

Of the 3,000 distributed questionnaires, 2507 were received back duly filled. It is then concluded that the Balanites product is tasteful with a good smell and high quality.

5.4 Refined Balanites oil for use in food

Balanites oil is known for long as being used in food at the rural level in Sudan. To assure the suitability of refined Balanites oil for use in food, some tests on its frying properties were carried out and the oil was also market analysed.

5.4.1 Frying properties of refined Balanites oil

Balanites oil remained stable, as compared to sunflower and olive oils when heated at a high temperature: 200°C ± 10°C, for a long period : 1 hour.

The smoking point of Balanites oil was found to be 233 - 235°C which was higher than that of cotton seed and peanut oils, see Table 5.4.1. This seems to be attributed to the low free fatty acid content of Balanites oil.

Table 5.4.1

Comparative smoke point and free fatty acid of some edible oils

Fat	Smoke point(°C)	Free Fatty Acid (% w/w as oleic)
Steamed rendered fat	189	0.33
Continuous processed lard	215	0.11
Cotton seed oil	229	0.12
Balanites oil	233	0.02

A comparative frying experiment was carried out using refined Balanites oil. refined cottonseed and peanut oils. The number of times a frying oil can be used before foaming was determined; considering the end point when enough foam covers the fried product and persists for more than five minutes. It was found that each of the above three oils can be used for three times before starting to foam.

Figure 5.3

Questionnaire for Consumer's Acceptability on the Roasted Balanites Kernels

1. Sex (Male , Female) Age.....
2. Occupation ....
3. Everheard of Balanites kernel (Damlouge) product:

   Yes , No
4. What is your opinion of the provided product:
   a) Taste (Tasteful : Tasty : Otherwise ....
   b) Smell .... c) Texture ....
   d) Quality (High : Good · Acceptable ·
   Unacceptable : State why ....

5. Do you prefer it for similar products (e.g. peanuts)
   Yes : No .

6. What price you recommend for provided sample which weighs 25 grammes:-
   £S
7. Any other comments? ....
   ....
   ....

5.4.2. Test market of refined Balanites oil

The Hedonic test questionnaire was carried out for both refined Balanites oil and refined cotton seed oil. Table 5.4.2 shows the consumers judgement on the above two oils when used for frying fish and potato chips.

Table 5.4.2

Hedonic test :consumers judgement on Balanites and cottonseed oils used for frying fish and potato chips

Judgement	Frying oil	
	Balanites oil	Cottonseed oil
Like very much	35 %	30 %
Like	34 %	34 %
Moderately like	19 %	25 %
Cannot determine	3 %	2 %
Like below moderate	2 %	2 %
Unlike	7 %	7 %

5.5 Use of crude Balanites oil for soap production

Crude Balanites oil was used in production of laundry soap, see Section 4.3.2 The soap produced had a profuse lathering action and good detergency properties,(see Section 4.3.2.1).

Balanites laundry soap was found satisfactory between 80 per cent of the assessors who stated that the soap was of good detergency and foaming properties.

Chapter 6

ECONOMIC ASPECTS OF BALANITES FRUIT PROCESSING

6.1 Market potential of Balanites mesocarp

The Balanites mesocarp which forms 28 - 33 per cent w/w of the whole Balanites fruit. is considered to form a big potential for the fermentation and steroid industries, and to some extent for animal feed. Of the 400,000 tonnes Balanites fruits available annually in Sudan, about 120,000 tonnes of mesocarp can be exploited for the above industries. Balanites mesocarp would find market in either of the following utilities:

a) Direct utilization in animal and poultry feed·
b) Fermentation and Steroid industries.

6.1.1 Direct utilization of Balanites mesocarp

Balanites mesocarp can be fed directly to animals and poultry as a rich source of carbohydrate content ;65 per cent w/w , in addition to protein supplement; 5.5 per cent w/w. It can be incorporated into ready-mixed feeds or sprayed on roughages or grain mixtures fed to animals or poultry. The sweet taste of mesocarp makes the animal feed more palatable and induces the stock to eat roughage of poor quality. Up to 40 per cent w/w Balanites mesocarp can be incorporated into cattle fatening ration.

Cane sugar molasses has been reported to give favourable results when incorporated into cattle rations. The following ration utilized by Cleasby [10] gave a live weight gain of about one kilogramme per head per day.

Molasses	40 % w/w
Corn and yellow meal	35 % w/w
Bagasse pith	12 % w/w
Nut oil cake	8 % w/w
Urea	2 % w/w
Minerals, vitamins and trace elements	3 % w/w

For poultry feed up to 10 per cent in layers ration and 5 per cent in chicks ration has been successfully utilized using the following formula:

Ingredients	kg/1,000 kg feed	
	chick ration	layer ration
Yellow maize	500	400
Other cereals and by-products	75 - 85	75 - 85
Oil cakes (groundnut, cotton seed)	230 - 240	210 - 230
Animal protein (mainly fish meal)	35 - 45	45 - 55
Mineral additives	15 - 20	110 - 120
Vitamins and trace elements	3 - 4	3 - 4
Sugar	0 - 50	30 - 50
Molasses	0 - 5	0 - 10

6.1.2 Balanites mesocarp for fermentation and steroid industries

Balanites mesocarp when properly diluted and fermented will yield mainly ethyl alcohol and carbon dioxide, in addition to other products such as fusel oil, glycerol and succinic acid. Diosgenin (a steroidal sapogenin) is recovered from the fermented mash after the distillation of alcohol and hydrolysis of the steroidal saponin. The remaining spent mash is evaporated to a total of 60 per cent w/w solids, referred to as slops, and is used for animal feed.

When 120,000 tonnes of Balanites mesocarp are fermented, more than 27,000 tonnes of ethanol are produced. 15,000 tonnes carbon dioxide, 1,200 tonnes diosgenin, 25,000 tonnes animal feed and 120 tonnes fusel oil.

6.1.2.1 Ethanol and its utility

The production of alcohol fuels from sacchariferous raw materials is becoming of a world wide interest as being a contribution to the solution of shortages in liquid energy. The use of ethanol as gasoline additive for improving the octane number, is continuously increasing. The use of ethanol as a solvent in industry and chemical laboratories is also increasing. The economic production of chemicals such as acetaldehyde and acetic acid from ethanol rather from ethylene is not inconceivable in the vicinity of the coming few years.

The demand for ethanol in industry exceeds 250 million gallons a year, and the alcohol fuel market is now about 100 million gallons annually. It is estimated that about five million imperial gallons of ethanol can be produced annually from Balanites mesocarp. This is estimated on the basis of Balanites mesocarp containing 56 % w/w fermentable sugars i.e. 120,000 x 56/100 = 67,200 tonnes sugars. This would theoretically yield 48 per cent alcohol i.e. 32,256 tonnes. Assuming that 85 per cent alcohol recovery then alcohol yield is 27,500 tonnes. This is equivalent to 27,500 x 1000 (kg) x 0.79 (litres)/4.5 imp. gal. = approximately five million imperial gallons.

Ethanol (ethyl alcohol or grain alcohol) has many uses, the most important of which are the following:

a - As a Fuel:
  i. for small stoves where smokeless and odourless combustion is desired;
  ii. for alcohol lamps as a source of light;
  iii. as a power source where absolute alcohol is mixed with petrol.

b - For General Utility: as antiseptic in hospitals and as a multi-purpose organic compound in laboratories.

c - As a Solvent: for dyes, nitrocellulose, lacquers and enamels, drugs and chemicals

d - As a Raw Material: in chemical processes.

According to 1980 estimates[28] ethanol was mainly used as follows:

Intermediates, acetaldehyde vinegar	43 % w/w
Cosmetics and pharmaceuticals	28 % w/w
Cleaning preparations and solvents	16 % w/w
Coatings	13 % w/w

The dramatic rise in the cost of gasoline has led developing countries to study the replacement of gasoline by a mixture of alcohol and gasoline as a fuel in automotive engines. As indicated by a road test[3], methanol and ethanol would be more economic than unleaded gasoline as shown from the following data.

	Urban driving		Highway driving	
	km/10^6 kj	km/litre	km/10^6 kj	km/litre
Unleaded gasoline	240	(7.513)	290	(9.078)
Ethanol	281	(6.182)	330	(7.260)
Methanol	290	(4.573)	345	(5.440)

Some data on the main characteristics of Ethanol/Gasoline mixtures[3] is represented below:

Item	Unit	Ethanol/gasoline mixture composition 0/100 E/G	10/90 E/G	20/80 E/G	30/70 E/G	100/0 E/G
Lower calorific value	kj/kg	42.680	41,050	39,430	37,350	26,800
Density at 15.5°C	kj/l	0.7335	0.7375	0.7448	0.7519	0.7439
Volumetric expansion	%	0	0.24	0	0	0
Octane index	-	95	96.7	98.3	100	106
Indicative fuel consumption	1/100 km	9.0	8.9	9.2	10.3	12.3

E = Ethanol

G = Gasoline

6.1.2.2 Diosgenin and the steroid industry

Steroid drugs come second after antibiotics in the world prescribed medicine[11]. The major steroid drugs are the corticosteroids, contraceptives, sex hormones and anabolic agents. These are produced mainly by partial synthesis from plant steroids: however, production of steroid drugs is also achieved by total synthesis and to a lesser extent through extraction from natural sources, e.g. animal organs . Plant steroids nowadays form the most important group of pharmaceutical raw materials derived from higher plants.

Before 1975, diosgenin was the predominant raw plant steroid for the production of steroid drugs by partial synthesis, see Table 6.1.2.2.1 . But later, following the Mexican events and consequent rise of diosgenin price to US$ 140 per kilogramme, multinationals started to shift for use of plant sterols and microbial degradation. Nevertheless it is still possible for diosgenin to come back and dominate the steroid market provided it is offered at a low price with constant supply.

The total steroid consumption has been regularly increasing, see Table 6.1.2.2.2; it reached up to 2,100 tonnes, equivalent diosgenin, in 1980. It is estimated that Balanites diosgenin potential in Sudan would cover half of the world demand : 1,200 tonnes, at a price as low as US$ 30 per kilogramme. This is based on the minimum content of diosgenin in Balanites mesocarp : 2 % w/w . Thus 120,000 tonnes mesocarp will give 2,400 tonnes diosgenin, assuming 50 % is recovered, i.e. 1,200 tons.

The prices of diosgenin over the last few years have been fluctuating, see Table 6.1.2.2.3 . This might be attributed to the unstable availability of diosgenin in the steroid market.

Figure 6.1.2.2.1 represents the world production of total steroids (1963 - 1976). Figure 6.1.2.2.2 shows the increasing world consumption of the major drugsteroids (1963 - 1980). Figure 6.1.2.2.3 reflects the fluctuating world prices for chinese diosgenin over the years 1976 - 82.

Table 6.1.2.2.1

World production of steroids, tonnes diosgenin equivelent and (%)

Steroid	1963	1968	1973	1974	1975	1976
Diosgenin (Mexico)	375(75)	500(50)	570(42)	600(43)	550(36)	400(25)
Other Sapogenins	40(8)	210(21)	290(22)	200(14)	215(14)	230(14)
Stigmasterol	60(12)	150(15)	280(21)	350(25)	385(26)	460(28)
Sitosterol	--	--	--	--	70(5)	165(10)
Cholesterol	5(1)	10(1)	--	--	--	30(2)
Bile Acids	20(4)	50(5)	50(4)	90(6.5)	123(8)	156(10)
Total Synthesis	--	80(8)	150(11)	160(11.5)	170(11)	180(11)
Total	500	1000	1340	1400	1513	1621

Table 6.1.2.2.2

World consumption of drug steroids, tonnes diosgenin equivalent and (%)

Year	Corticosteroids	Contraceptives	Sex Hormones	Spiranolactone	Total
1963	275(55)	91(18)	86(17)	48(10)	500
1968	629(63)	195(19.5)	116(11.5)	60(6)	1000
1973	844(63)	200(15)	131(10)	165(12)	1340
1976	1025(63)	235(15)	162(10)	199(12)	1621
1977	1096(63)	252(14.5)	169(10)	218(12.5)	1735
1978	1141(62.5)	266(14.5)	176(9.5)	247(13.5)	1830
1979	1224(62.5)	280(14)	183(9.5)	273(14)	1960
1980	1295(62)	295(14)	190(9)	320(15)	2100

Table 6.1.2.2.3

Latest prices for Chinese diosgenin in US$/kg

Year	Price	Year	Price
January 1976	140	January 1979	30
April 1977	125	May 1980	20-25
December 1977	50	January 1981	20-30
August 1978	55	June 1982	40-45

Figure 6.1.2.2.1

World Production of Total Steroids

(1963-1976)

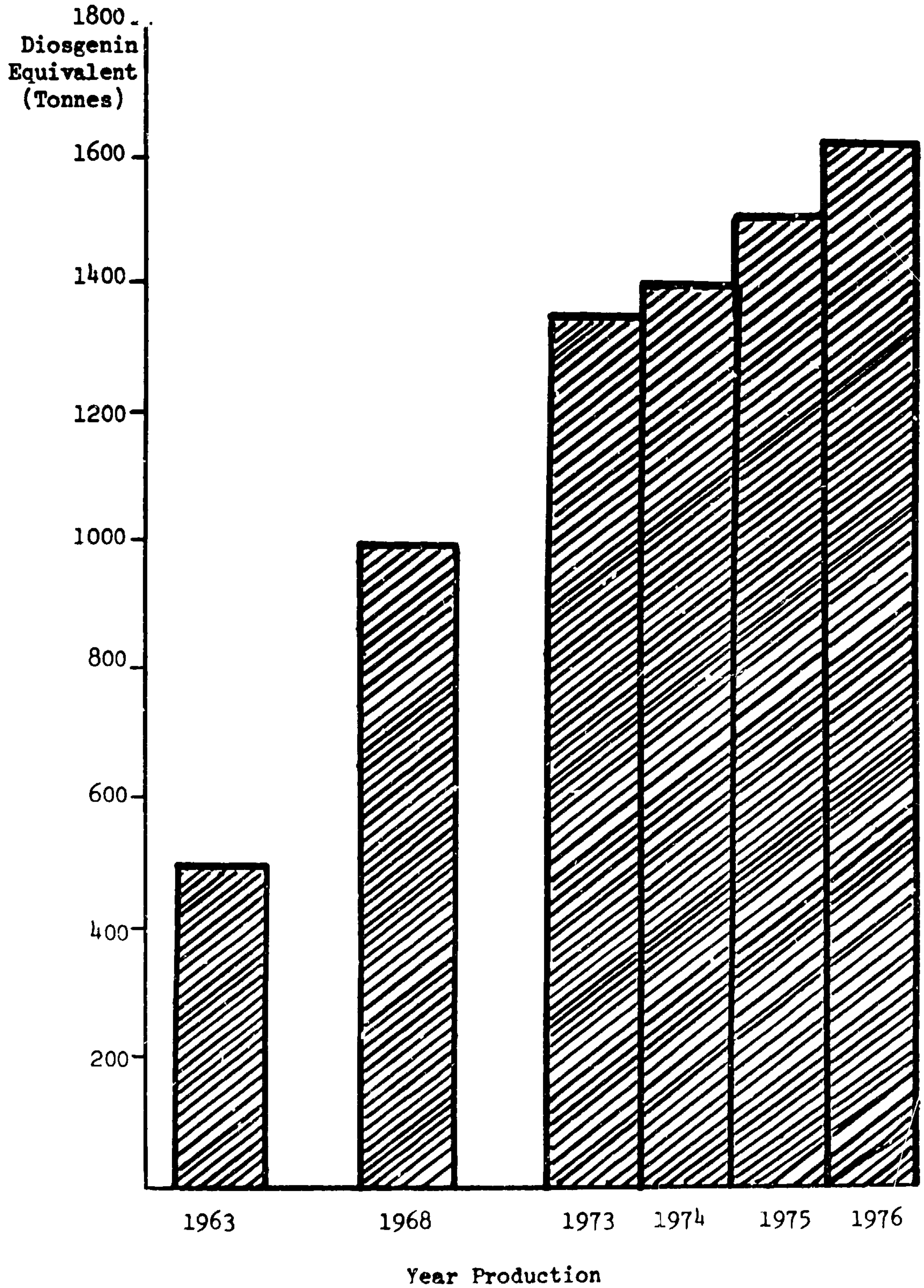


Figure 6.1.2.2.2

World Consumption of Major Drug Steroids
(1963-1980)

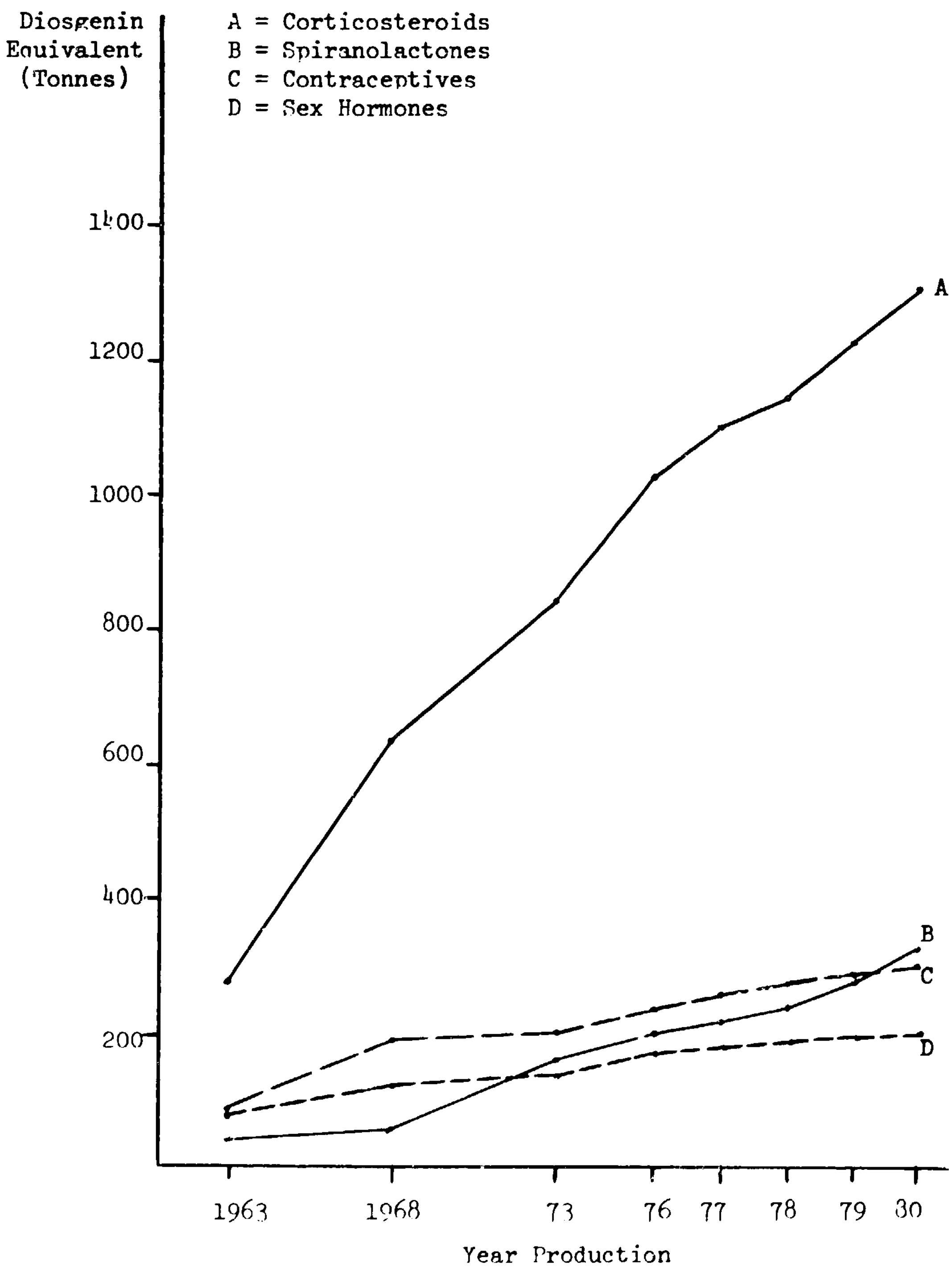
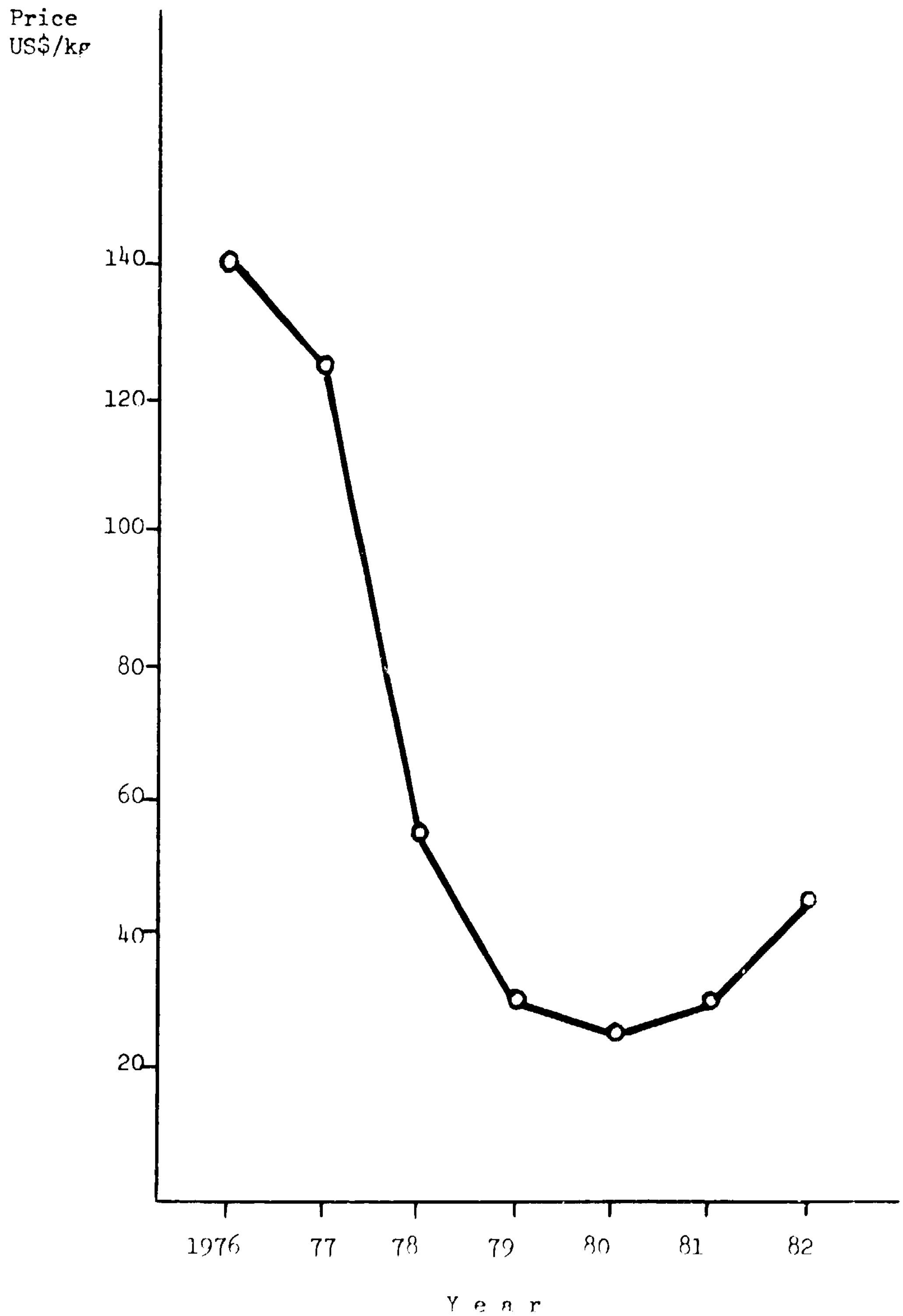


Figure 6.1.2.2.3

World Prices for Chinese Diosgenin

(1976-1982)



6.1.2.3. Carbon dioxide

It is estimated that 160 kilogrammes of carbon dioxide are produced from each 1000 kilogrammes Balanites mesocarp, and that 80 per cent of the produced carbon dioxide is recovered. This would give a yield of (120,000 x 160 x 80/1000 x 100), i.e. 15,360 tonnes carbon dioxide. This is then compressed to condensed carbon dioxide which is used extensively in carbonated beverages, fire extinguishers and in food preservatives.

6.1.2.4. Fusel oil

These are higher alcohols with boiling point of 90-150°C which are collected in the rectification coloumn and consists mainly of amyl and iso-amyl alcohols. It is used as a lacquer solvent. It is estimated that the yield of fusel oil from Balanites mesocarp is 0.1 per cent i.e. (120,000 x 0.1/100) = 120 tonnes.

6.1.2.5 Slop (or stillage)

It is estimated that the slop produced is 9 to 10 times ethanol production i.e. about 250,000 tonnes and this slop contains about 6 - 7 per cent w/w solids. Reducing the volume to 60 per cent w/w solids would yield about 25,000 tonnes feed suitable at an inclusion rate of 20 per cent w/w in animals and 15 per cent w/w in poultry.

6.2 Market potential of Balanites shell

Balanites shell forms about 50 per cent w/w of the whole fruit. It is estimated that 200.000 tonnes of Balanites shell would be available annually in the Sudan. Using Balanites shell as a fuel production of charcoal or otherwise for particle board, would certainly increase the revenue from processing Balanites fruit. It is worth to mention here that excess Balanites mesocarp slurry can be utilized as a binding agent in the production of charcoal blocks.

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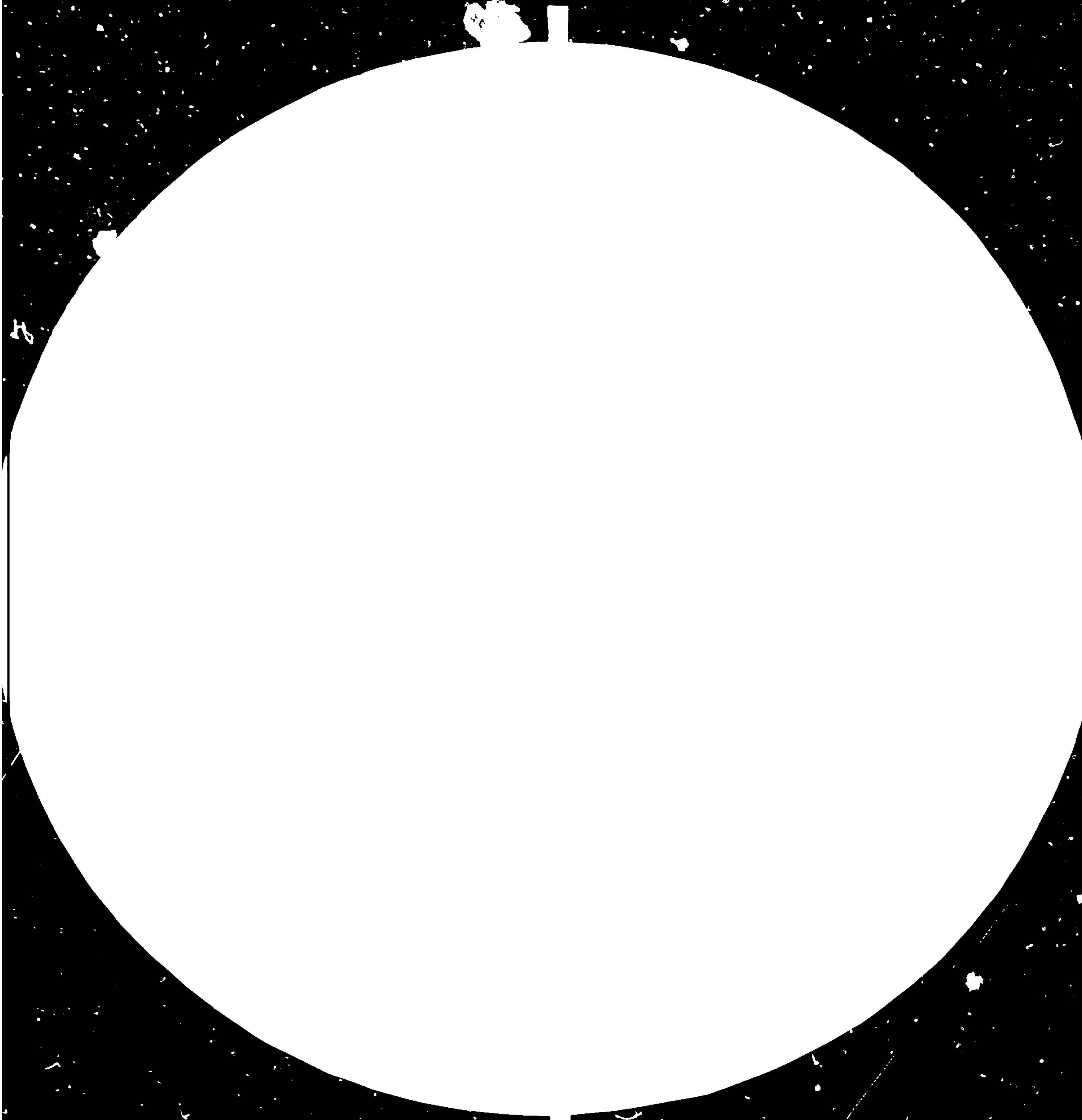
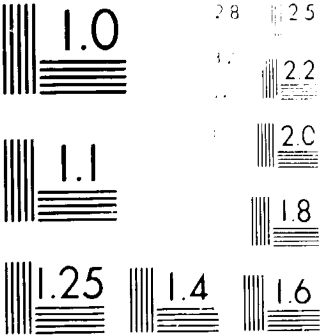



1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

Considering Balanites shell as a source for fuel, it is assumed that the calorific value of Balanites shell is nearly half the calorific value of fuel oil which costs about US$ 200 per tonne. Then one tonne of Balanites shell would be equivalent to US$ 100. For production of charcoal: current price in Sudan is US$120 per tonne , assuming that 50 per cent charcoal is recovered from Balanites shell, then one tonne Balanites shell would yield half a tonne charcoal equivalent to US$ 60. This will end up with a value of: US$100 x 200,000, i.e. US$ 20,000,000 for Balanites shell potential on a higher rate, and :US$ 60 x 200,000 i.e. US$ 12.000.000 on a lower rate. However, if activated charcoal is to be produced, then a higher value is predictable.

6.3 Market potential of Balanites kernel

The Balanites kernel forms about 8 - 12 per cent w/w of the whole fruit, assuming ten per cent w/w in average . This would give a kernel potential of :400.000 x 10/100 =40,000 tonnes annually in Sudan. From previous experimental results, see Table 3.3.2.2 , the crude oil recovery from Balanites kernel is 36.5 per cent w/w which comes down to 34 per cent w/w on refining, considering 7.8 per cent w/w refining losses, see Table 4.3.1: the cake recovery from the kernel is sixty per cent w/w, see Table 3.3.2.2. This indicates an annual potential of: 40,000 x 34/100 i.e. 13.600 tonnes refined oil and: 40,000 x 60/100 i.e. 24,000 tonnes of kernel cake. Current prices in Sudan are US$ 700 - 1,000 for one tonne of refined sesame/peanut oil and US$ 170 - 200 for one tonne groundnut cake. Based on the lower rate prices, a revenue of :13,600 x US$ 700 i.e. US$ 9,520,000 from Balanites refined oil and: 24,000 x US$ 170 i.e. US$ 4,080,000 from Balanites kernel cake is expected.

6.3.1. World Production of Oil Seeds (16,43,44)

The world production of major oil-seeds is continuously increasing showing the persistent demand for oil-seeds and their products. Table 6.3.1 presents the world production of major oi-seeds from the year 1970 - 1981. Figure 6.3.1 represents the world total production of major oil-seeds over the last fifteen years :1965-1980 . However, oil seed prices have remained relatively constant. Soyabeans was at £ 134.2/tonne in 1976 and £ 131.7/tonne in 1980 : According to Frank Fehr and Company Limited, London 1980.

In Sudan, the major oil-seeds production was nearly constant over the last five years ,see Figure 6.3.1.a. . The total oil-seeds production, in fact, is slightly decreasing, see Figure 6.3.1.b . However, there has been plans for the enlargement of oil-seeds production in the Sudan.

Table 6.3.1

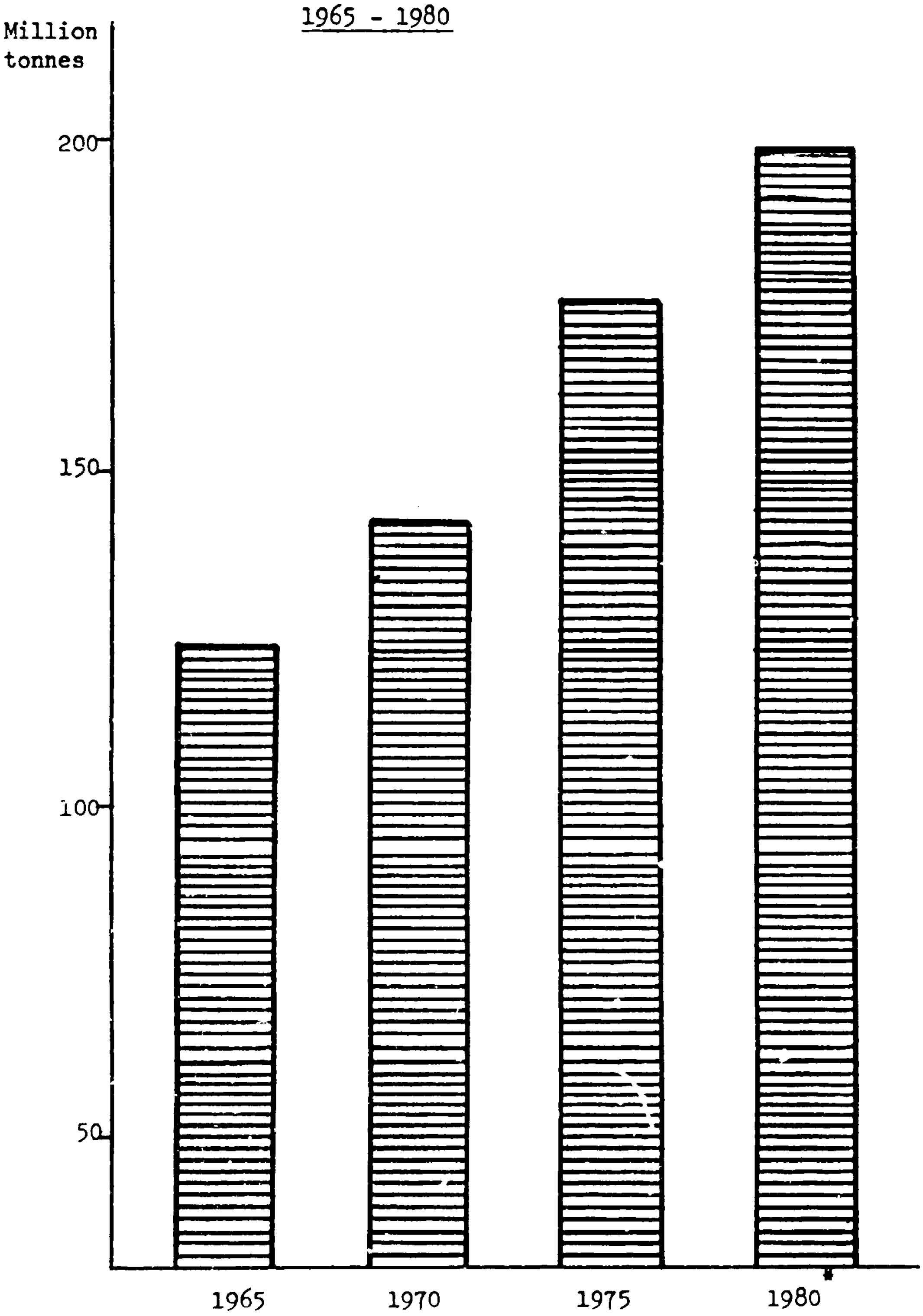
World Production of Major Oil-Seeds in Million Tonnes (1970-1981)

	1970	1975	1979	1980	1981
Soyabeans	46.5	68.4	89.0	80.9	87.9
Groundnuts	18.4	19.1	18.3	17.1	19.4
Sunflower	9.9	9.6	15.3	13.5	13.8
Rapeseed	6.7	8.1	10.5	10.6	12.1
Sesame	2.2	2.0	2.0	1.8	2.0
Safflower	0.7	1.0	1.0	0.9	0.9
Cottonseed	22.2	23.0	26.8	27.0	29.0
Coconut	26.3	29.6	34.0	35.2	36.7
Palm kernel	1.2	1.5	1.7	1.8	1.9

Figure 6.3.1

World Total Production of Major Oil-Seeds

1965 - 1980



*Average of three years: 1979 - 1980 - 1981.

Figure 6.3.1.a

Major Oil-Seeds Production in Sudan

(1977 - 1981)

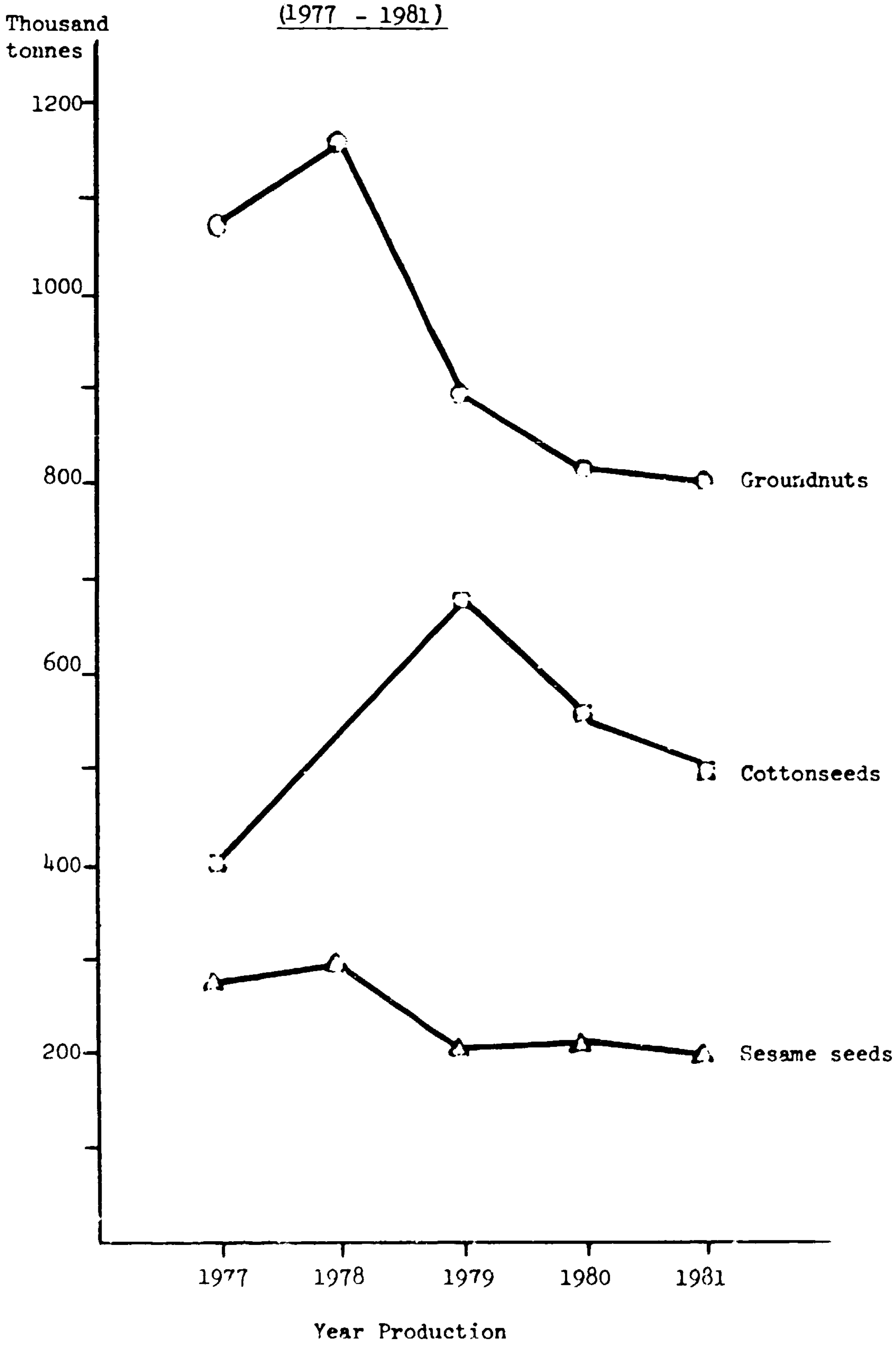
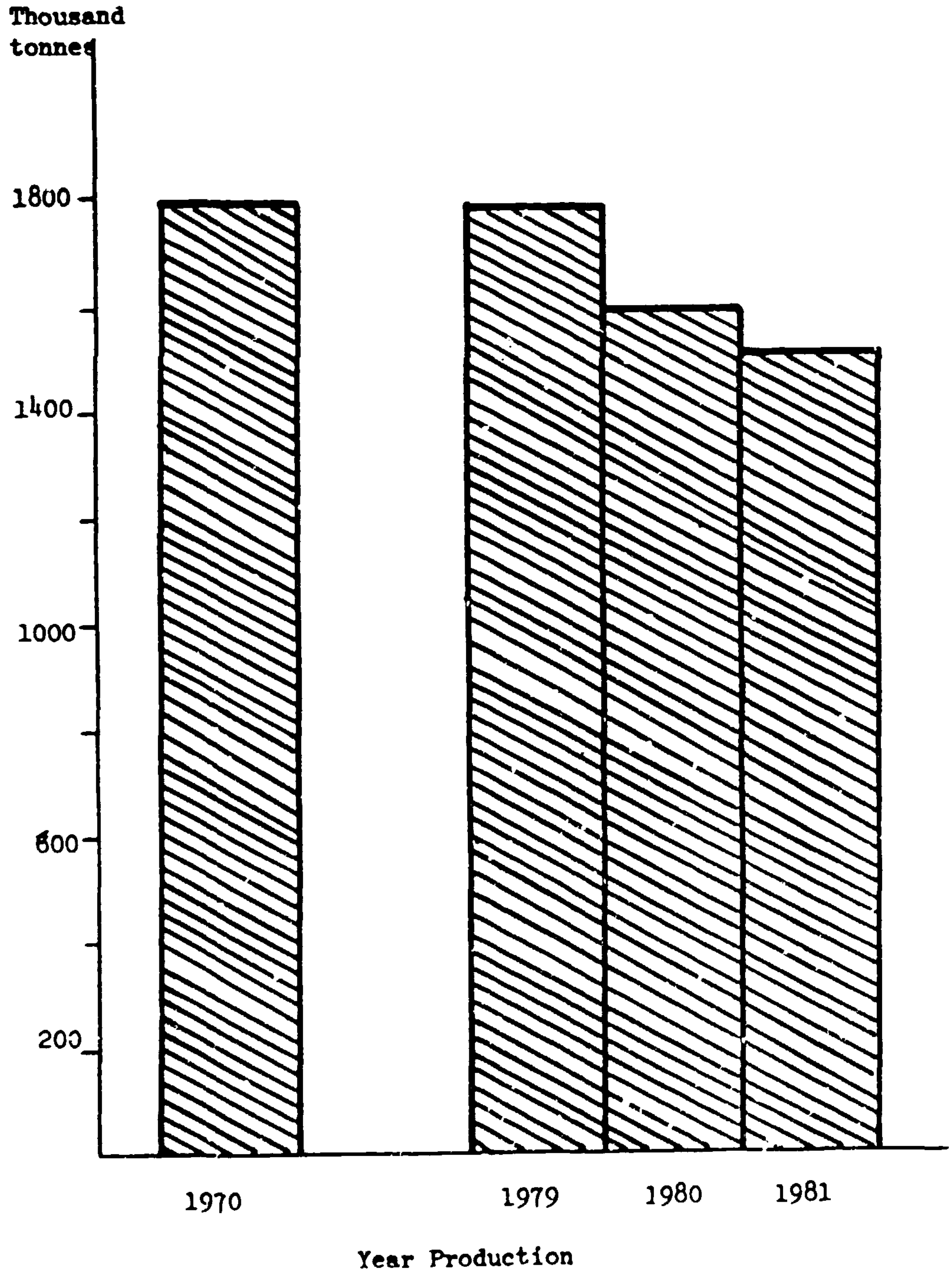


Figure 6.3.1.b

Total Oil-Seeds Production in Sudan

(1970 - 1981)



6.3.2. The world-market for oil-seeds products (16,43,44)

An increase in demand for refined oils is expected due to the continuous development of the margarine, soap and detergent industries where blends of individual fatty-acids are being formulated. The oil-seed cakes industry is acquiring a considerable interest in the field of protein production for human consumption as replacement to animal-protein. Research is continuing for developing protein-products from oil seed cakes to be utilized by different industries, e.g. beverages, flour. As a general view, the demand for oil-seeds products is expected to increase substantially through the coming years. Prices of oil-seeds products are only slightly increasing.

Table 6.3.2. shows the world production of major vegetable-oils. Prices for some vegetable oils and cakes are indicated in Table 6.3.2.a and 6.3.2.b respectively: quoted from Frank Fehr and Company Ltd., London 1980. The latest prices for oil-seeds products are tabluated in Table 6.3.2.c; source: Chemical Market, 23 August 1982.

Table 6.3.2.

World Production of Major Vegetable-Oils
(1978-1980)

Oil	Production in 000' Tonnes		
	1978	1979	1980
Soyabeans	11,803	12,610	13,400
Groundnuts	2,530	2,846	2,600
Sunflower	4,360	4,720	4,900
Cottonseed	3,026	3,000	3,200
Rapeseed	2,822	3,500	3,600
Coconut	2,856	2,550	2,750
Palm kernel	495	568	580
Sesame	610	615	625

Table 6.3.2.a

World Average Prices for Some Vegetable-Oils
(1976-1980)

Oil	Price (£/tonne)				
	1976	1977	1978	1979	1980
Soyabean	264.00	326.49	263.12	357.03	284.44
Groundnut	422.40	544.44	569.29	420.06	590.50
Palm kernel	257.50	348.69	370.37	464.95	345.72

Table 6.3.2.b

World Average Prices for Some Oil-seed Cakes
(1977-1980)

Cake	Price (US$/tonne)			
	1977	1978	1979	1980
Soyabean	204	250	258	362
Cottonseed	184	183	202	245
Groundnut	182	207	224	265

Table 6.3.2.c

Latest World Prices (US$/tonne) for Some Oil-seed Products
(August 1982)

1. Crude Vegetable Oils	
Coconut	515.2
Cottonseed	448.0
Peanut	492.8
Soyabean	403.2
2. Oil-cakes	
Cottonseed	145.0
Peanut	170.0
Soyabean	166.0

6.4 Net value of Balanites fruit products

A Balanites fruit potential of 400,000 tonnes per year in Sudan is expected to give the following gross value after processing:

Component	Yield	Unit price($)	Gross value(US$)
Ethanol	5,000,000 imp.gal.	1.5	7,500,000
Diosgenin	1,200 tonnes	30,000	36,000,000
Carbon dioxide	15,000 tonnes	750	11 250,000
Fusel oil	120 tonnes	720	86,400
Slop	25,000 tonnes	25	625,000
Balanites shell	200,000 tonnes	60	12,000,000
Balanites oil	13,600 tonnes	700	9,520,000
Balanites cake	24,000 tonnes	170	4,080,000
Total gross value			81,061,400

Based on the current Balanites fruit price in Sudan at US$ 3 a sac of 80 kilogrammes fruits, i.e. US$ 37.5/tonne, then 400,000 tonnes fruit cost US$ 15,000,000. Assuming the processing cost is fifty per cent of the total gross value i.e. US$ 40,530,700, the total processing expenditure will be (15,000,000 + 40,530,700) = US$ 55,530,700. This would allow for a net profit of (81,061,400 - 55,530,700) i.e. US$ 25,530,700 annually.

Chapter 7

DISCUSSION AND CONCLUSIONS

This study has outlined the scope of industrial utilization of Balanites fruits for food and feed products, in addition to fermentation by-products and steroidal compounds. The carbohydrate content of the fruit mesocarp offers a rich source for the fermentation industry to produce products such as ethanol and yeast protein: it is also suitable for animal feed. The kernel of the fruit is an alternative source of food products for human consumption, e.g. edible nuts, peanut like butter. This kernel if mechanically pressed would yield about 40 % w/w vegetable oil suitable for edible purpose as well as for other industries, e.g. soap production. The kernel-cake left after pressing the oil, is proved to be of higher quality for animal feed as compared with other conventional oil-seed cakes. The steroidal saponins of the fruit mesocarp when hydrolysed to sapogenins, i.e. Diosgenin/Yamogenin, are of a world-wide commodity as drug precursors for the pharmaceutical steroid industry, e.g. oral contraceptives, corticosteroids and sex hormones. These steroidal saponins have also been proved of high activity in the control of Bilharzia snails, i.e. molluscicidal.

From this study, it is concluded that the following industrial products are of economic value in the process-development of Balanites fruits:

Diosgenin

This is the most valuable product from Balanites fruit :1,200 tonnes ≡ US$ 36,000,000. It is, therefore, necessary to develop this product and find a suitable market for it. The production of steroid intermediates from diosgenin to cover the demand of the Pharmaceutical Steroid industry is very promising. In fact this would support the growing Pharmaceutical Industry in most of the developing countries.

Shell

The Balanites shell is another product which is of economic importance in the utilization of Balanites fruit. It forms fifty per cent of the fruit potential, i.e. 200,000 tonnes ≡ US$ 12,000,000. The bulk of this material can be utilized as a fuel source, locally, in places of production, the rest of it would have a high value as activated charcoal. This would be another commodity for export, besides diosgenin.

Oil

The produced Balanites oil: 13,600 tonnes ≡ US$ 9,520,000, would cover the demand of vegetable oils to the areas of production; this would consequently decrease the quantities of imported edible oils to the Sudan.

Kernel-meal and mesocarp-slop

The kernel-meal : 24,000 tonnes ≡ US$ 4,080,000 , and the mesocarp-slop : 25,000 tonnes ≡ US$ 625,000 , produced from Balanites fruit are good sources of animal feed in the rural areas around the production sites where cattle are grazed mainly on weed and straw with limited protein sources.

Ethanol

The production of ethanol : 5,000,000 imp. gal ≡ US$ 7,500,000, from Balanites mesocarp would cover the shortage of industrial spirit in the perfumery industry and other sectors in Sudan.

Carbon dioxide

An amount of 15,000 tonnes carbon dioxide equivalent to US$ 11,250,000 which is produced by the fermentation process of Balanites mesocarp, would easily find direct local utilization in beverages.

An illustration for the process-development of Balanites fruits was carried out in Sudan, where the fruit potential was estimated as 400,000 tonnes fruits per year. The industrial utilization of this potential is expected to produce industrial products worth eighty millions US dollars, with a yearly net revenue of twenty-five million US dollars.

The guidelines presented in this study for the beneficial utilization of the so far hardly utilized Balanites potential in many developing countries and particularly those situated in the Sahel area may inspire government authorities, industrialists and investors to get engaged in relevant industrialization schemes or sponsor them.

When considering the manifold benefits to be obtained from the industrial utilization of the, in many developing countries indigenous Balanites fruits, the authorities may also keep in mind the important problem of desertification. Instead of cutting Balanites trees for fire wood purposes and by doing so permitting deserts areas to expand into arable land, new Balanites trees should be planted in an organized way. Such forest policy would certainly reduce desert areas in the long run and preserve and expand agricultural land. The Balanites shells necessarily obtained as a by-product from industrial processing operations, will easily replace the fire wood so far obtained from Balanites trees.

The important forest policy issue as outlined above certainly adds considerably to the benefits to be obtained from the setting-up of Balanites processing industries.

In order to adapt relevant industrial Balanites utilization schemes to prevailing local conditions, detailed and comprehensive industrial feasibility studies are to be carried out on a case by case basis prior to investments. UNIDO should be pleased to assist developing countries in their deliverations to this effect.

Chapter 8

RECOMMENDATIONS

8.1 Further development work on Balanites mesocarp

From the present study, it is obvious that Balanites mesocarp forms a great potential for the production of Diosgenin which is the most valuable product of the Balanites fruit. It is also noticed from recent research that better yield of diosgenin can be obtained by the use of enzymes [44], incubation of the plant raw material [45] and more recently through the use of silastic resin and biotransformation [46].

8.1.1 Recommendation:

It is recommended that further development work on *Balanites aegyptiaca* fruit mesocarp would be carried out to increase the yield of diosgenin production, usually obtained through acid hydrolysis, simultaneously with ethanol production.

8.1.2 Procedure:

The following steps are recommended.

8.1.2.1 Preliminary laboratory trials:

a) To find out the effect of enzymes, incubation, mould and other relevant microbes in increasing the yield of diosgenin from Balanites mesocarp. Trials on the use of silastic resins as carriers for enzymes or mould, would be reported in order to define a suitable economic process for diosgenin production.

b) Considering the outcome of 8.1.2.1.a, experimental trials to study the production of ethanol simultaneously with diosgenin is to be carried out to define a preliminary processing of Balanites mesocarp for the maximum production of diosgenin and ethanol.

8.1.2.2 Pilot scale trials:

Based on the findings of 8.1.2.1, a pilot scale plant is to be set in order to study the techno-economic production of diosgenin and ethanol from Balanites fruit mesocarp, adopting most recent techniques.

8.2 Further development work on cracking Balanites seed and separation of intact kernel

A process for cracking Balanites seed and the separation of kernel from shell has been outlined in this study. However, in such process, the kernel is separated as a ground material which is well suitable for processing to oil and oil-seed cake. But this ground kernel would not suit the production of edible nut-like product where the kernel is desired intact.

8.2.1 Recommendation :

It is recommended that the previously outlined process for cracking Balanites seed is to be developed in such a way as to end up with an intact kernel rather than ground kernel. This would make it possible to produce edible nuts of relatively high value.

8.3 A techno-economic feasibility study

This report has highlighted the big role of Balanites fruit in supporting various industries, namely vegetable oil, animal feed, fermentation, pharmaceutical and fuel industries. The necessary information, data and basic experimental work for processing Balanites fruit has been defined in this study.

8.3.1 Recommendation :

It is recommended that a techno-economic feasibility study is to be carried out to study the most economic utilization of the commercial Balanites fruit resources in Sudan, and other developing countries with huge Balanites potential.

8.3.2 Consideration :

Consideration should be given to the following:

a) There are two valuable export commodities namely diosgenin and activated charcoal, these would support the pharmaceutical industry and other chemical industries in the developing countries.

b) Fermentation products such as ethanol and carbon dioxide would support local perfumery and other chemical industries.

c) Vegetable oil and animal feed would self-satisfy most of the areas with Balanites potential in Sudan and other developing countries.

d) The bulk material of the fruit, which is the sehll. would support local industries for fuel. excess is utilized for the more valuable activated charcoal, a valuable commodity for export.

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