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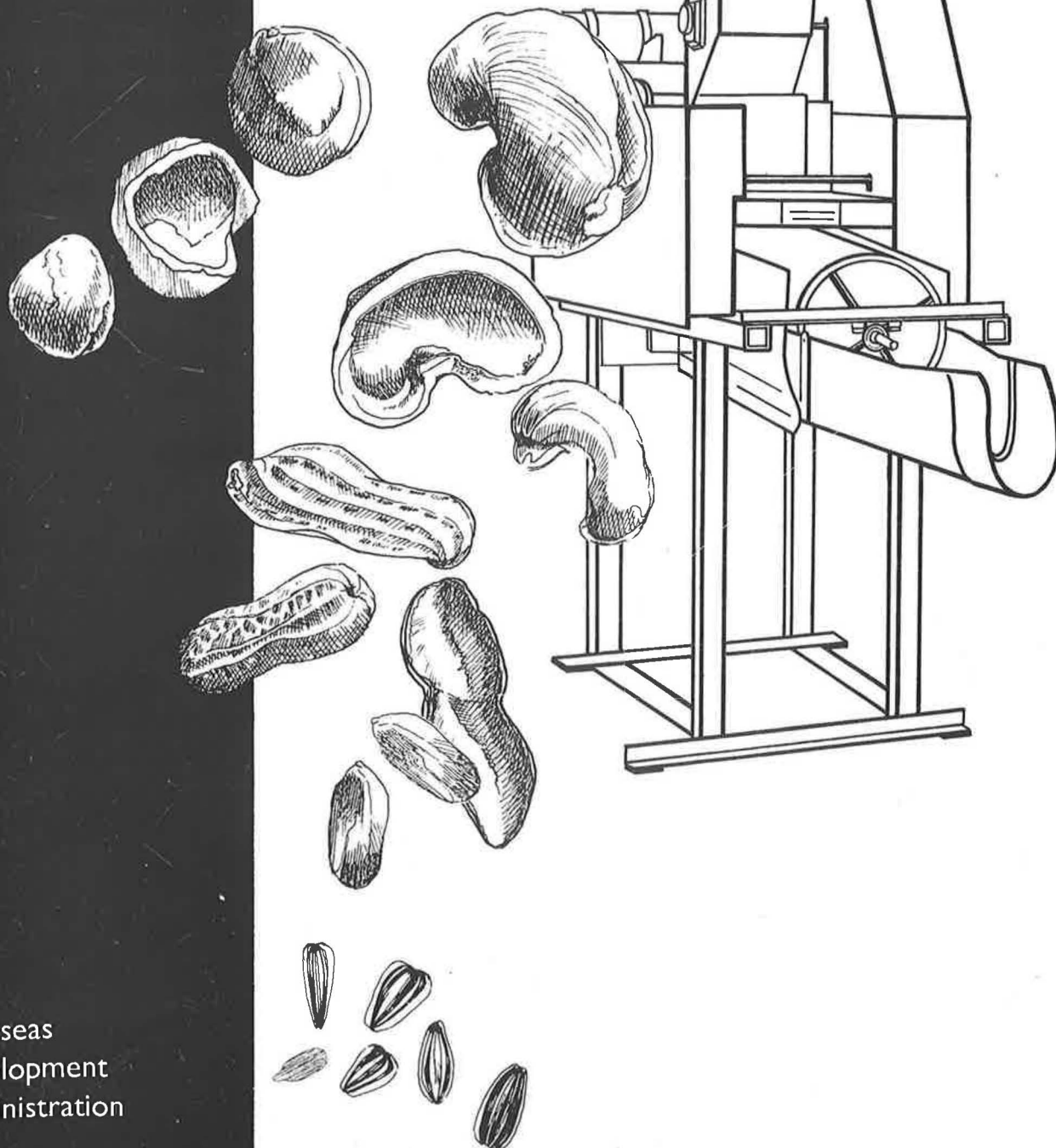
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DECORTICATION OF TROPICAL OILSEEDS AND EDIBLE NUTS

Bulletin No. 42



NATURAL RESOURCES INSTITUTE

BULLETIN No. 42

DECORTICATION OF TROPICAL OILSEEDS AND EDIBLE NUTS

G. S. PINSON, D. J. MELVILLE and D. R. S. COX

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The Natural Resources Institute (NRI) is the scientific arm of Britain's Overseas Development Administration. NRI's principal aim is to increase the productivity of renewable natural resources in developing countries through the application of science and technology. Its areas of expertise are resource assessment and farming systems, integrated pest management, and food science and crop utilization.

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Summaries

SUMMARY

This publication describes NRI experience in the recovery of seven different 'seed kernels' of tropical origin: balanites nuts, cashew nuts, coconuts, cottonseeds, groundnuts, macadamia nuts and sunflower seeds. It includes the decortication and related operations for specific nuts and oilseeds for human food, as well as the by-products which may have other uses. The structure of the seeds and their implication for decortication are discussed and general descriptions of the typical decortication techniques are included. The effect of crop and processing variables on the efficiency of the operation and the recovery of products is also covered. This publication does not cover decortication processes that are applied to husk, bark or fibre crops resulting in some form of fibre product (e.g. sisal and hemp) without any direct connection to the seeds of a plant.

RESUME

Cette publication décrit l'expérience du NRI quant à la récupération de sept fruits et amandes différents d'origine tropicale: arachides, graines de cotonnier, graines de tournesol, noix balanites, noix d'acajou, noix de coco et noix du Queensland (*Macadamia ternifolia*). Elle couvre de décortiquage et les opérations connexes pour des exemples spécifiques d'amandes et de graines oléagineuses destinées à l'alimentation humaine, ainsi que les sous-produits qui peuvent avoir d'autres usages. La structure des graines et leurs implications pour le décortiquage sont examinées et des descriptions générales des techniques typiques de décortiquage sont fournies. L'effet des éléments variables de la culture et du traitement sur l'efficacité de l'opération et la récupération du produit est également décrit. Cette publication ne couvre pas les procédés de décortiquage qui sont appliqués pour les récoltes de coque, d'écorce ou de fibre qui fournissent différentes formes de produits fibreux (par exemple, le sisal et le chanvre) qui n'ont aucun rapport direct avec les graines d'une plante.

RESUMEN

En esta publicación se describe la experiencia del NRI por cuanto respecta a la recuperación de siete distintas 'semillas' de origen tropical: anacardos, 'Balanite', cacahuets, cocos, macadamias, semillas de algodón y semillas de girasol, abarcando el descascarillado y operaciones relacionadas para semillas y nueces específicas utilizadas para consumo humano, junto con subproductos que pudieran tener otros usos. También se estudia la estructura de las semillas y sus consecuencias sobre el descascarillado, además de presentar descripciones generales sobre técnicas típicas de descascarillado. La publicación abarca asimismo el impacto de las distintas variables de cultivo y elaboración sobre la eficiencia de la operación y sobre la recuperación del producto. Quedan fuera del alcance de esta publicación aquellos procesos de descascarillado aplicables a cultivos con cáscara, corteza o fibra, que resultan en cierto tipo de producto fibroso (tal como el sisal y el cáñamo), que no posee una conexión directa con las semillas de una planta.

Introduction

GENERAL

There are often many botanical similarities between food crops but the processes required to recover the product are varied and are usually quite specific to the crop involved. Different varieties of the same crop may respond differently to a particular operation and some crops may require several operations, including decortication. Conversely, the same machine may find use, with variable efficiency, on a range of crops. Tropical oilseeds and edible nuts are important crops and are used widely for human consumption; the by-products also have a variety of uses. Their decortication is necessary to remove the outer layers which previously provided physical protection to the kernel and to achieve the economic recovery of primary and secondary products.

To prepare the crop for decortication it is sometimes necessary to grade it. Winnowing, sieving and air separation of shell may also be required to recover the products fully. A general description of these complementary processes is given in Section 3 (see p.16). and where applicable these operations are discussed under the specific nut or oilseed commodity in Section 4 (see p.19).

DEFINITION OF TERMS

The word *decorticate* comes from the Latin verb *decorticare* derived by adding the prefix *de* (meaning to be rid off) to the noun *Cortex*. The cortex refers to the outer layer of a botanical or anatomical object, often specifically to a layer which lies just beneath the very outer surface, and to general features such as bark, husk, shell or rind.

The verb to decorticate is generally used in two principal ways: firstly to describe a general process in which a nut or oilseed is 'cracked open' and the kernel recovered, and secondly to an individual stage in a processing operation in which an enveloping layer or hard shell is removed or separated prior to a more involved recovery process. The associated noun *decorticator* is applied to any machine which executes this type of process. Use of machines with this informal name is often the reason for the widespread use of the verb.

Words such as *dehusking*, *husking*, *cracking*, *splitting*, *popping* and *shelling* are also used in different parts of the world to describe decortication operations. In order to avoid over-repetitive use of some of the key words in this document, it has been found convenient to allow a free use of other words with broadly, though not exactly, the same meaning.

Seed structure and decortication products

SEED STRUCTURE AND IMPLICATION FOR DECORTICATION

Nuts or seeds are part of the fruit of a flowering plant or tree. Fruits occur in two general groups: fleshy or dry. These are illustrated in Figures 1 and 2 and show the major physical features which might be encountered during decortication processes. Few fruits will have these exact structures, but most conform to one or other general patterns.

Figure 1 illustrates a typical fleshy tree fruit. This broad classification includes 'drupes', for example, plums, apricots, peaches, olives, palm fruits, coconuts, walnuts and almonds. Figure 2 illustrates a typical dry fruit in which the kernel is surrounded by a thin shell, for example, acorns, beechnuts, hazelnuts and sunflower seeds.

Figure 1
Fleshy fruit

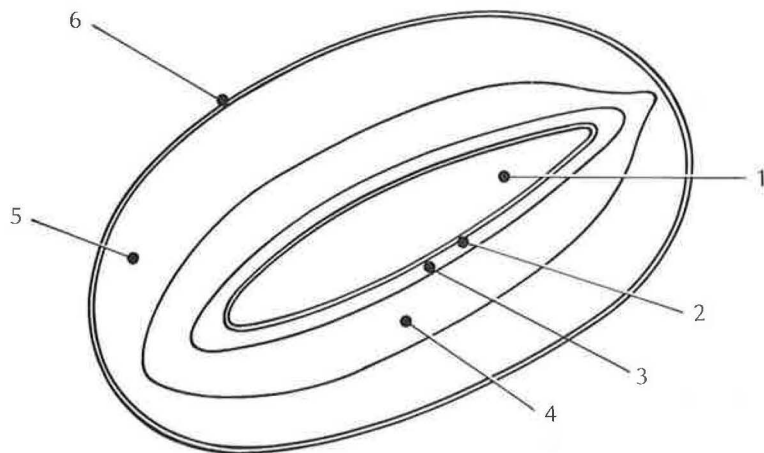
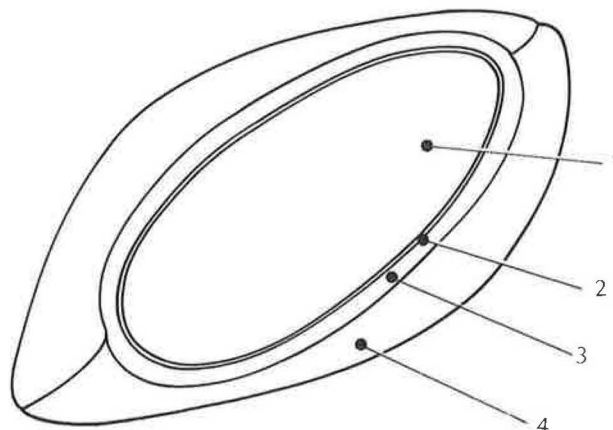


Figure 2
Dry fruit

- 1 Kernel
- 2 Kernel skin
- 3 Cavity
- 4 Hard shell
- 5 Outer husk
- 6 Outer covering



Kernel

The kernels of the nuts or seeds – the regenerative element that the outer layers serve to protect – contain nutritive material; they usually constitute the primary recovery product. The kernels are valuable as foods, supplying protein and oil. However they are very delicate, and will often split, break up or be damaged during an inefficient decortication operation.

Kernel skin

The thin kernel skin of the nut or seed – the **testa** – closely surrounds the kernel (for example, groundnut and cashew nut). It remains closely attached to the kernel and it may loosen easily, for example on drying of the kernel.

Cavity

The cavity occurs as the fruit or nut dries out.

Hard shell

The hard shell of the nut or seed provides substantial physical protection around the more delicate kernel structure. It is hard, of variable thickness, and often reinforced with a fibrous matrix which must be 'cracked' in a decortication operation. The basis of this process is to open up the shell in an efficient and controlled manner to recover as much kernel as possible. It is usually desirable to minimize the proportion of broken or improperly decorticated kernels. These two requirements tend to be in conflict with one another when setting operational parameters.

Outer husk

The nature of the outer husk layer of the nut or seed varies considerably. It may contain a soft wet or oily material (for example mango, oil palm fruit, cashew nut, walnut, etc.), or it may be predominantly fibrous (for example, coconut). The outer husk areas usually contain important secondary products. Removal of fibrous layers is usually a mechanical operation known as '**Dehusking**'. If oil is removed from an oil-rich fruit pulp as a primary product (for example, oil palm and olive) this would leave the kernel as a secondary product. If a layer is wet and no valuable oil is present, removal is often achieved by rotting or fermentation.

Outer covering

The outer covering is usually a thin flexible membrane providing a waterproof covering around the nut or seed, offering it some form of physical protection once it has been separated from the growing plant. It is often removed in the same process as the layer below.

DECORTICATION PRODUCTS

Decortication products are:

- (i) whole or kernel pieces for confectionery foods;
- (ii) kernel material for oil extraction feedstock and animal feed production; and
- (iii) fibres, husks and shell for use as solid fuel, charcoal manufacture and sometimes as fillers for animal feeds.

The markets for products (i) and (ii) are largely unrelated.

In the first case, (i), it is usually important to comply with strict kernel quality requirements. Substantial price variations apply to quality grades and a premium is usually paid for clean, undamaged kernels as opposed to broken

or degraded fragments. The variety of crop that is used for this purpose is carefully selected primarily for financial reasons, consumer appeal and processing efficiency. In throughput terms, decortication is carried out on a small or medium scale, reflecting the close attention that must be paid to kernel quality.

In the second case, (ii), the need for undamaged kernels is of lesser importance, the requirement being to release as much kernel material as possible so as to maximize oil yields. The actual crop variety used as feed is usually of a type selected specifically for oil extraction, containing a large proportion of oil with the required chemical characteristics. The process is normally carried out on a large scale, reflecting the industrial nature of this type of operation.

The third type of by-products recovered, (iii), depend upon the nature of the original nut; usually they are fibres from the husk and solid fuel from any hard shell material. Smaller nuts do not normally provide fibres of sufficient length to be of much commercial value. Some special oils, fillers and components for animal feeds can also be recovered.

Shells produced in a process are likely to be burned as fuel directly, although the availability of larger quantities of shell make the production of charcoal progressively more attractive. The value of any charcoal produced from the shell depends upon the density of the shell and upon any special qualities the resulting charcoal might possess. For the charcoal to be of maximum value the shell should be free of contaminants.

Decortication techniques and processing parameters

TRADITIONAL METHODS

Traditional methods of decortication are usually manual operations using simple tools. Continued use of such methods implies the existence of suitable labour with the right skills and costs; the absence of machinery which could achieve equivalent results; and the continuing demand for an expensive, hand-shelled product.

There are two distinct kinds of operation to be considered. Firstly, those involving nuts which can be processed individually, such as coconuts, and small complex nuts such as cashew, which can be processed by hand; and secondly those consisting of small, less valuable nuts which, unless there is a ready supply of low-cost labour, can only be processed economically in bulk using specialized machinery.

Items in the first group require dextrous handling and are well suited to manual decortication. Manual methods are suitable both at a farm level for a small-scale producer or collector and on a large-scale plantation where suitable labour is available. Lacking the dexterity of the human hand, any machinery designed to carry out the same operation is likely to be relatively complex. The purchase of such equipment will represent a significant investment since a greater scale of operation is required to make the mechanized process financially viable.

Items in the second group will require large-scale production but relatively simple machinery. Depending upon the nature of the nuts, the operation would tend to have high productivity at the expense of some loss of whole kernel extraction efficiency.

There are two basic mechanical effects that can be used to open the shell of a nut; the shock caused by an impact against a hard object, or the application of direct mechanical pressure to crush, cut or shear through the shell. For manual methods, such actions can be provided by knives, hammers, simple presses, etc.

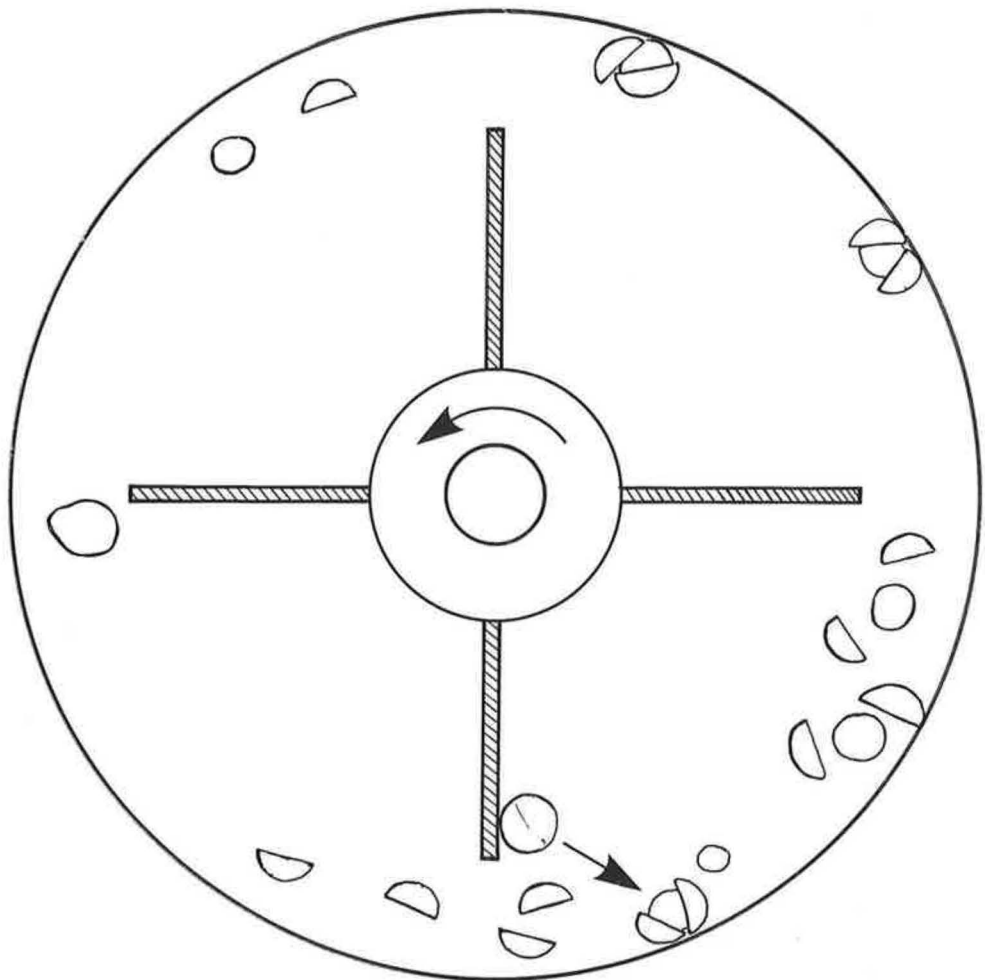
A number of mechanical decortication machine techniques are described in the following sections.

CENTRIFUGAL IMPACT DECORTICATORS

If the physical nature of the shell is suitable – brittle and not substantially reinforced by any fibrous matrix – then decortication can often be achieved by subjecting the nut to a simple impact of controlled minimal intensity. For this to be successful, the kernel must first have dried sufficiently to have become fully released from the inside surface of the shell, but without becoming too dry or brittle. The kernel must itself be strong enough to remain intact during this impact.

In centrifugal impact decorticators, nuts are fed into a rotating impeller assembly consisting of two discs that are separated by a number of radial vanes. By driving the impeller around at an appropriate speed, these vanes impart radial acceleration to the nuts. They are then discharged towards a peripheral target against which they impact and break open (see Figure 3). Detailed mechanical design of the impeller and target are important for optimum performance. The severity of the subsequent impact is determined by the impeller speed which must be high enough to fracture the shell, but not so high as to cause excessive damage to the kernel.

Figure 3
Centrifugal impact decorticator

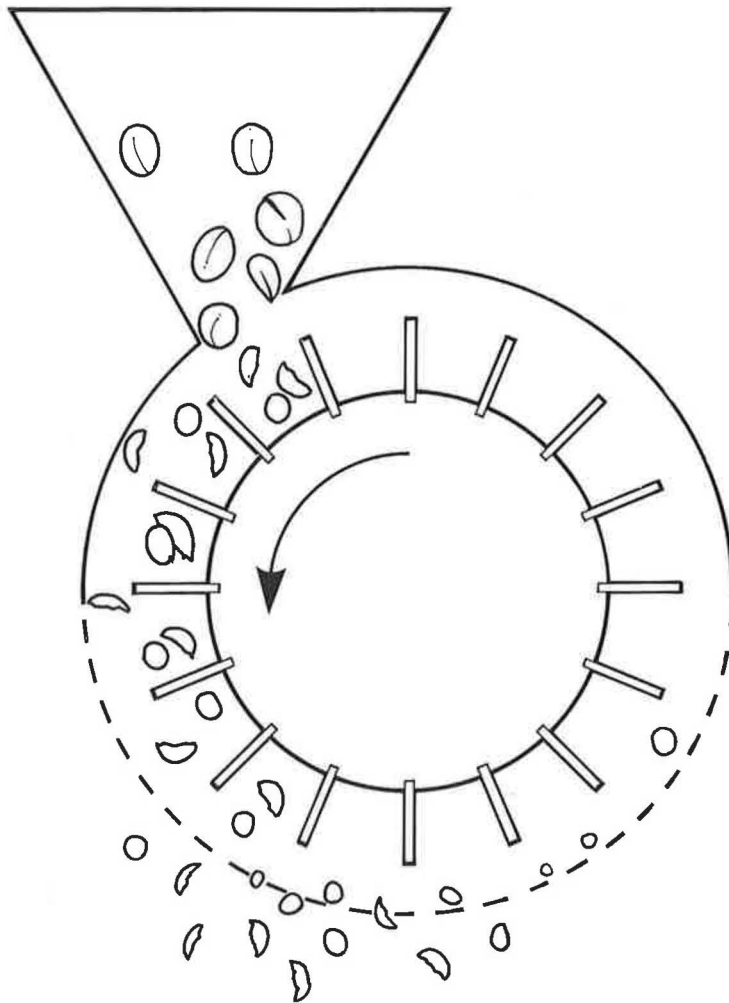


The removal of dust by air extraction is possible at this stage. All of the discharged material requires further processing to separate the shell from the kernels and recycle any undecorticated nuts for cracking. More complex grading methods allow further separation of whole and broken kernels.

PEG AND DRUM DECORTICATORS

One of the simplest methods of breaking open weak-shelled nuts is to bring a stream of them into contact with rapidly rotating projections fixed to the curved surface of a drum or rotor (see Figure 4). This action is not necessarily as violent as that from simple impact methods, but it can produce successful results on softer shells when the rotor speed is reduced. By confining the flow about the drum with a liner and a screen, these projections strike the nuts and eventually break the shells and release the kernels, allowing only shell fragments and released kernels to pass to the discharge.

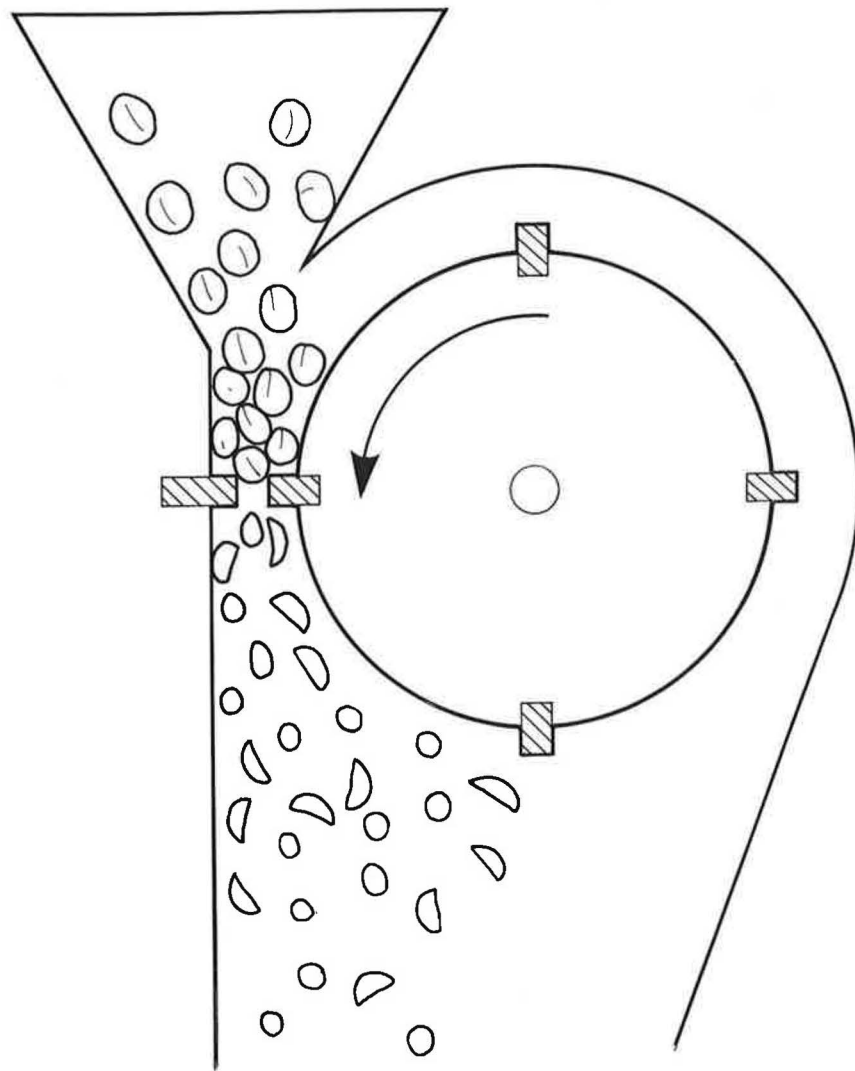
Figure 4
Peg and drum decorticator



BAR AND DRUM DECORTICATORS

For nuts whose shells cannot be made to shatter easily (either because of excessive toughness or because of some reinforcement by fibrous components) a more positive means of breaking open the shell is required. Bar and drum, (see Figure 5) or knife decorticators, with longitudinal bars or blades rotating against fixed edges at a pre-set clearance, have the potential to trap nuts for an instant and to make a positive cut into the shell without necessarily penetrating through to the kernel.

Figure 5
Bar and drum decorticator



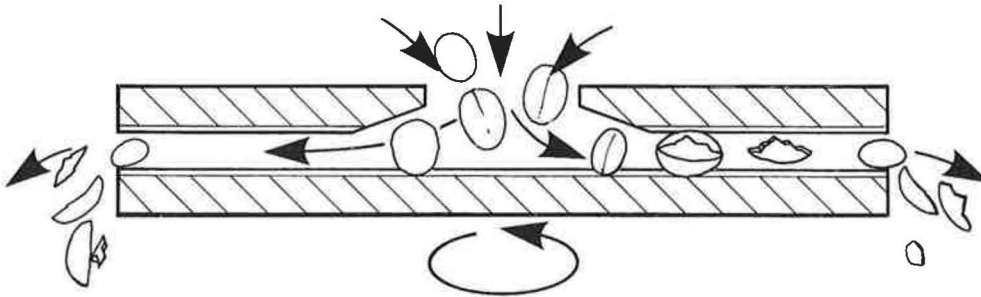
Many shells, because of their individual structures, exhibit zones or planes of relative weakness or strength. It is preferable to align the nut during decortication so that the working elements of the machine can attack the weaknesses, rather than the inappropriate areas of strength. However with the violent circulation around a rapidly spinning rotor, it is difficult to maintain comprehensive alignment. The choice of the correct speed of rotation is not as important as achieving the most appropriate setting of the gap between rotor and stator blades. This gap is changed by adjustment of the stationary blade and is governed by the size of the nut, or more particularly, by a dimension which reflects the typical shape of the nut and the size variation within the particular batch. Too wide a gap will result in insufficient penetration of the shells and a high level of undecorticated nuts. Too close a gap will lead to excessive damage to the kernels. Any substantial size variation within the nut feed will result in a loss in decortivating efficiency making some form of prior size batching or grading necessary.

DISC DECORTICATORS

Parallel gap disc decorticators

When a shell is relatively soft or will not cleave open readily, the nut may not be suited to the relatively violent techniques previously described. Items which have an approximately circular section or which can be made to roll easily, may only require a light pressing and rubbing action to break the shells. This effect can be achieved by feeding a stream of nuts into the gap between a stationary and a coaxially rotating disc (see Figure 6).

Figure 6
Parallel gap disc decorticator

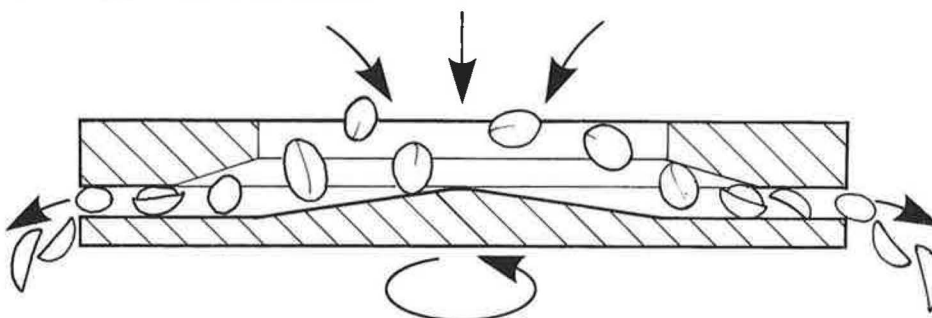


The discs are set to have a rigidly maintained parallel gap so size grading of the feed may become necessary. The surfaces of the discs are roughened or grooved to provide necessary edges that will help in the removal of the shells. The working surfaces may have to be hard-faced to reduce abrasion and any damage caused by stones or tramp metal which may inadvertently enter with the feed. The nature of the breaking action is critically affected by changing the rotational speed of the disc.

Tapered gap disc decorticators

Very delicate kernels often require a still softer action for efficient shelling, even to the point of requiring hand shelling. The tapered gap method is a variation of the parallel gap approach and allows the shell to be progressively weakened in a slowly tightening nip (see Figure 7).

Figure 7
Tapered gap disc decorticator



In this type of device, the working surfaces are machined so that the gap between the discs narrows as the diameter increases. Thus nuts are drawn in by the rotating action of the lower disc and are then rolled, pinched, weakened and shelled as they progress outwards. The angle of the taper is chosen so that the gap at the central inlet can be made slightly larger than the individual whole nut, while at the same time the outlet gap can be only slightly larger than the kernel to minimize the chances of crushing damage. Important factors are the shape of the taper, the speed of rotation and the surface texture of the disc (material, hardness, friction, roughness and durability).

RECIPROCATING ACTION DECORTICATORS

The previous sections on disc decorticators describe techniques which use a rotating and crushing action. An adaptation of this type of action, using a manually applied reciprocating, rather than a rotary action, is particularly suitable for use with inexpensive hand-operated groundnut decorticing machines. The technique of reciprocating action can also be applied effectively using motor driven decorticators.

Nuts are fed between two parallel assemblies, for example between an operating shoe and a fixed screen (see Figure 8). The nuts move against the projections and recesses on these assemblies and the shell is progressively removed. The upper assembly is moved to and fro, separating the kernel and shell fragments which fall through the screen.

Figure 8
Reciprocating action decorticator



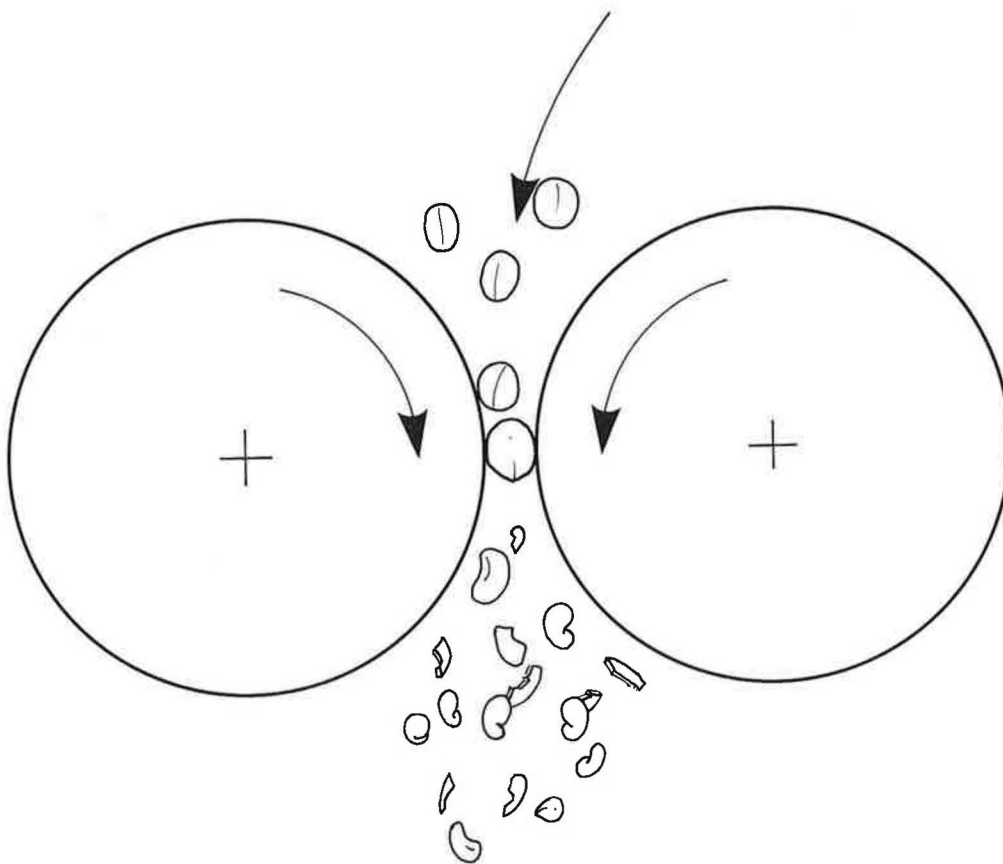
Operation of this type of machine is more fully described in Section 4 (see p.25).

OTHER METHODS OF DECORTICATION

A number of decortication techniques, usually suitable for small grains, involve the use of abrasive techniques to wear away thin outer layers rather than to remove them in discrete pieces. Effective use of such techniques is restricted mainly to cereal and legume grains because the level of oil in the powdered bran should be low. Otherwise there is a risk that any knives, abrasives or even the inside of the machine itself, will choke from a build-up of the compacted bran removed from the grain.

The use of two contra-rotating parallel cylinders, set horizontally, is another simple technique for obtaining a convergence in which to crush the brittle shells of suitable nuts (see Figure 9). This method is often used on a large scale as one stage in an integrated oil extraction operation.

Figure 9
Parallel cylinder decorticator



PROCESSING PARAMETERS

A number of quantitative terms are used to describe the physical nature of nuts and the efficiency of any processing operation. There are no universal standards for expressing these parameters, but the formulae set out below provide a guide. In most instances, weight is the most convenient form of measurement.

- (i) The **kernel to whole nut percentage** describes the relative proportion of the kernel to the original nut. This percentage varies widely between: different types of nut; different varieties of the same type; and individual nuts in a batch. The relationship can be expressed as:—

$$\frac{\text{average weight of recovered kernel}}{\text{average weight of whole nut input}} \times 100\%$$

The higher this percentage the higher the potential yield of kernel in proportion to the whole nut as determined by its physical nature.

The average weight of recovered kernel is the average weight of a sample of kernel recovered after manual decortication.

The average weight of whole nut input is the average weight of the sample prior to manual decortication.

- (ii) The **kernel recovery efficiency** (decortication efficiency) for the particular nut type can be expressed as:

$$\frac{\text{weight of all recovered kernel}}{\text{weight of potential kernel material}} \times 100\%$$

This figure should approach 100% for an efficient operation

The weight of all recovered kernel includes all kernel (whole and broken) recovered after machine decortication.

The weight of potential kernel material is estimated from the kernel to whole nut percentage derived in (i) above.

- (iii) The **proportion of whole kernel** can be expressed as:

$$\frac{\text{weight of recovered whole kernel}}{\text{weight of all recovered kernel}} \times 100\%$$

This figure should approach 100% for an efficient operation.

The weight of recovered whole kernel is the weight of undamaged kernel recovered after machine decortication.

The weight of all recovered kernel includes all kernel (whole and broken) recovered after machine decortication.

- (iv) The **proportion of broken kernel**, (or broken kernel subdivided into, for example, damaged and shrivelled) can be expressed as:

$$\frac{\text{weight of particular substandard kernel}}{\text{weight of all recovered kernel}} \times 100\%$$

This figure should approach 0% for an efficient operation.

The weight of substandard kernel is the broken or damaged or shrivelled kernel after machine decortication.

The weight of all recovered kernel includes all kernel (whole and broken) recovered after machine decortication.

- (v) The **proportion of undecorticated nuts** can be expressed as:

$$\frac{\text{weight of nuts remaining undecorticated}}{\text{weight of original whole nut input}} \times 100\%$$

This figure should approach 0% for an efficient operation.

The weight of the nuts remaining undecorticated includes all nuts after machine decortication still with their shell intact or with the shell partially split but in which the kernel has not yet been released.

The weight of the original whole nut input is the weight of the sample prior to machine decortication.

- (vi) The **kernel fraction recovery** as a percentage of whole nut input can be expressed as:

$$\frac{\text{weight of recovered whole kernel}}{\text{weight of original whole nut input}} \times 100\%$$

This figure increases with improved machine settings.

The weight of the recovered whole kernel is the undamaged kernel recovered after machine decortication.

The weight of the original whole nut input is the weight of the sample prior to machine decortication

This formula can be used in experiments as a guide to the effect on whole kernel recovery caused by adjustments to machine settings, provided all other parameters remain unchanged.

- (vii) The **total recovery percentage** describes the mass balance of input material to output material and can be expressed as:

$$\frac{\text{weight of all recovered products}}{\text{weight of original whole nut input}} \times 100\%$$

This figure should approach 100% for an effective experiment.

The weight of all recovered products includes dust, shell, whole and broken kernels.

The weight of the original whole nut input is the weight of the sample prior to machine decortication.

For an example of results (i), (iii), (vi) and (vii) from sunflower seed decorticator trials see Table 1.

Table 1**Results of sunflower seed decorticator trials**
(by Beaumont in Bangladesh 1978)

Decorticator type	Feed rate lb/hour (kg)	Seed moisture content (%)	Seed oil content (%)	Kernel to whole nut (%)	Kernel fraction recovery (%)	Proportion of whole kernel (%)	Total recovery (%)
Disc mill with standard discs	15 (6.8)	7.0	38.1	70.0	79.4	81.7	92.7
Disc mill with disc made in Bangladesh	18 (8.2)	8.6	37.8	69.5	78.0	82.0	92.2
Bar mill with wooden rotor and stator quadrant	53 (24.0)	7.6	38.3	70.4	76.6	82.5	92.1
Bar mill with metal rotor and stator quadrant	40 (18.1)	7.6	38.1	70.0	77.8	83.2	92.5
Engine-powered unit, Bangladesh seed	118 (53.5)	7.6	39.3	72.3	76.8	90.1	95.8
Engine-powered unit, imported seed	120 (54.4)	9.2	45.1	83.8	75.0	99.5	92.4

The effect of processing variables

It will be apparent from Section 2, *Decortication techniques and processing parameters*, that much care must be taken in selecting the precise method of decortication that will be suitable for coping with the individual properties of one type of nut. Once machinery is installed, it must be set up carefully to operate efficiently over an extended period, and to maintain this efficiency despite some variation in the feed material.

The following general aspects should be considered:

- **the nature of the input material:** the physical quality and maturity of the crop processed;
- **botanical variety of the input material:** the effect of different crop varieties;
- **moisture content:** the effect of drying;
- **machinery settings:** the effect of setting on efficiency and damage; and
- **complementary processes:** separation and grading.

THE NATURE OF THE INPUT MATERIAL

Where possible, control must be exercised over the actual quality of the raw material supplied to a process. The input material needs to be adequately dried, cleaned and free from contamination by dirt, stones, field rubbish and other extraneous material. In many instances it may be possible to use additional machinery, such as cleaners and graders. Any attempts at improvement may however be impractical if, for example, lengthy delays have already caused irreversible adverse changes to the crop. Therefore it is necessary to be selective in the purchasing of supplies.

BOTANICAL VARIETY OF THE INPUT MATERIAL

In many instances the supply of raw material may come from existing stands of unimproved natural varieties or from stands with little varietal consistency. On the other hand, as newly cultivated areas are generally planted with varieties selected as being optimum for local conditions, suitability for efficient decortication may not be the prime criterion and the resulting crop may not be ideally matched to the machinery available. The range of variations which might affect decortication is substantial and the following general features may have some effect:

- general shape and size of the kernels and shell/nuts;
- strength of the kernels and shell/nuts;
- strength of any internal bonds; and
- the proportion of available kernel.

Any of the above factors is likely to require a slightly different approach to effective decortication. In the simplest case, a minor adjustment to a machine setting might be necessary, but in extreme cases, it may not be possible to obtain satisfactory results. Replacement of the entire process might be required.

MOISTURE CONTENT

On separation from the tree, the moisture content of the nut is invariably high. In this condition there are no internal voids; the kernel is difficult to remove intact and the kernel is readily damaged by the decortication action. The nut itself is often surrounded by a skin and layers of mucilage which also contain very high levels of moisture. When stored in bulk without air circulation, the presence of this moisture will promote deterioration and encourage external microbial growth. For prolonged storage and processing, this outer layer of mucilage should be removed before drying the entire nut to a safe moisture level. As far as decortication itself is concerned, correct drying can have two useful effects:

- (i) drying tends to make the outer layers relatively brittle and toughens the kernels.
- (ii) drying tends to cause a substantial amount of internal shrinkage, thus opening up any fissure weaknesses and breaking surface bonds between layers.

The outer shell is often intended to protect the seed (kernel) by inhibiting moisture transfer from the centre. If practical, some form of intermediate decortication or husk removal will speed preparatory drying. As this takes place, the kernel will shrink, become tougher and will often break free from the shell interior allowing it to rattle. Continued drying of the kernel to excess, particularly at high temperatures, will not only degrade germination properties, damaging taste and flavour, but will make the kernel excessively fragile and cause it to break easily during further processing.

MACHINE SETTINGS

The descriptions of the various types of machine techniques given in Section 2 indicate where machine adjustments are possible and necessary. As a general rule, the more aggressive the settings, the greater will be the proportion of nuts which will be both shelled and damaged. Conversely, a gentle setting will shell fewer nuts but produce fewer broken kernels. Thus there is, in setting up the machinery, a compromise to be achieved between efficiency and the level of damage. In practice, greater financial income can be obtained by the use of tighter settings at higher capacities, at the expense of only a slightly higher production of broken kernels.

COMPLEMENTARY PROCESSES

In the previous discussion of decortication methods, mention has been made of complementary processes which need to be carried out before (for example, size and density grading), during (for example, dust removal) and after (for example, shell removal and kernel grading), the operation of decortication itself.

Size grading

If the nuts are approximately spherical in shape, accurate size grading can be achieved by simple reciprocating screens or rotating drums. As the shape of the nuts becomes less spherical, the same type of machine will provide a progressively less accurate grading, and more specialized machinery may be required.

Density grading

In situations where simple size grading does not achieve the required results, it may be appropriate to separate the stream of feed material into fractions based upon relative density. Although this type of process is more appropriate to nuts with light shells and to the grading of the kernels, it may be needed to meet higher quality requirements.

Dust removal

In a small scale or rural situation, winnowing in circulating air will be sufficient to separate dust and light material from the heavier kernels and any remaining nuts. On a larger mechanized scale, the use of a simple suction extraction device consisting of a centrifugal fan and a cyclone (to collect the dust) will be appropriate.

Shell removal

Although removal of shell by air buoyant extraction is normally sufficient, in many cases there may still be excess shell present in the kernel stream. Alternative methods such as sieving, flotation in water or brine or even gravity tables may have to be used.

Kernel grading

In small-scale enterprises, it would be normal to separate the various grades of kernels by hand. Unshelled nuts requiring further shelling can also be recovered in this way. These grading operations are likely to be more tedious and time consuming than the shelling process itself and special machinery, usually of the types already described, is needed as the scale of operation increases.

Section 4

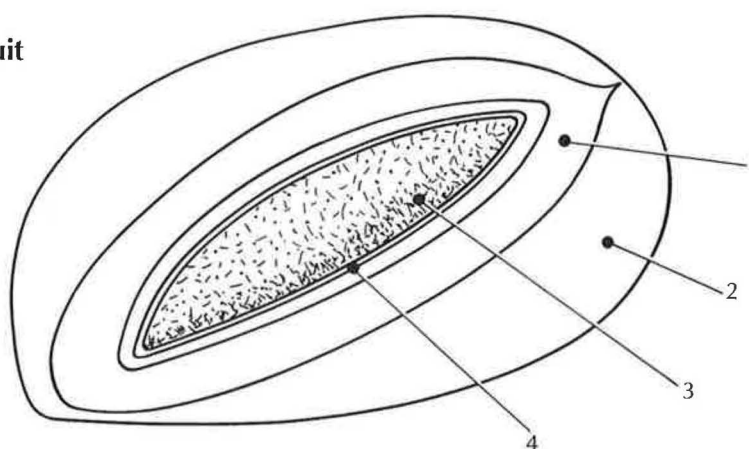
Discussion, by commodity, of decortication operations

This section describes, by commodity, details of the application of some of the decortication techniques described in Section 2, and includes descriptions of other processing operations required by particular crops.

BALANITES NUTS (*BALANITES AEGYPTIACA*)

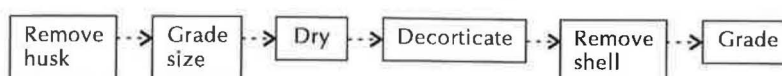
Balanites aegyptiaca is also known as desert date, lalob tree and soap berry tree. Balanites was regarded as the balm of Biblical verse, which accounts for another name, Jericho balsam. The balanites tree grows in abundance in the wide tropical belt of Africa, extending from Tanzania to the Côte d'Ivoire and also in the drier areas of Northern Africa where it is presently an under-used resource. It is not cultivated and the nuts, as collected from the wild, are used only occasionally for human consumption or animal feed. A major inhibition to the development of this crop is the lack of mechanical means for decortication. The decorticated kernels may be exploited on a larger scale for oil extraction, animal feeds or as a source of various minor chemicals. The shell also has potential as a fuel or source of charcoal (see Figure 10).

Figure 10
Balanites fruit



The shell (1) is both hard and thick and is contained within a soft, moist, husk (2). The shell has substantial fibrous reinforcement which makes it strong and difficult to crack open. The positioning of these fibres however does not produce a comprehensive strengthening and some planes of relative weakness occur along the length of the shell. The kernel (3) is small in weight, relative to the whole nut and in contrast to the shell is soft and easily damaged. It is closely surrounded by a thin testa (4).

Process flow



Decortication

There are a number of different types of balanites nuts. The principal difference between them is in the relative size and shape of the shell and kernel. Typically, the kernel makes up only 20% of the weight of the whole nut, a percentage that may often be much less.

The first operation to be carried out is the removal of the outer husk. This covering does not remain fresh for long after removal from the tree and can be readily removed by a simple rotting procedure. The nuts are then dried slowly allowing the internal moisture to migrate from the centre, to release the kernel/shell bond gradually.

Before decortication the nuts are size graded preferably using a drum grader with bar screens. A bar mill device as described in Section 2 (see p. 8) may be used to break open the nuts. Recycling of undecorticated nuts is an essential feature of the process. Nuts are fed in from the side position so that they roll about their long axis as they enter the area between the fixed and rotating bars. In this orientation there is a good chance that the line of the cut will be aligned along one of the lines of weakness. A prototype mechanical decorticator is being developed for field trials.

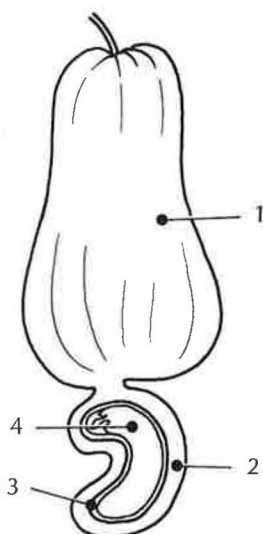
A large proportion of the kernels will be fully released, but many nuts will still be closed or partly open. All the material is passed to the next stage where flat reciprocating sieves separate out the whole and broken kernels, whole or partly decorticated nuts and any fibre or dusty material. The separation will not be precise and there will be some material in the wrong stream, for example shell splinters mixed with kernels and kernel lost with shell.

Careful control of the processes will minimise this effect but a second and different separation stage using air buoyancy is recommended.

CASHEW NUTS (*ANACARDIUM OCCIDENTALE*)

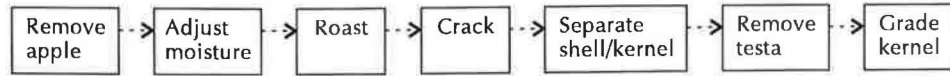
The cashew fruit is unusual in comparison with other tree nuts since the nut is outside the fruit (see Figure 11). The primary products of cashew nuts are the kernels which have a high value as confectionery nuts. Cashew nut shell liquid (CNSL) is an important industrial raw material for resin manufacture and the shells can be burned to provide heat for the decortication operation. If it is collected before rotting, the cashew apple can be consumed as a fruit, or used for beverages, chutneys and alcoholic drinks.

Figure 11
Cashew fruit



The cashew apple (1), an edible false fruit, is attached to the externally borne nut by a stem. The shell of the nut (2) is leathery and not brittle in the raw state, and contains a thick, vesicant oil – cashew nut shell liquid (CNSL) – within a sponge-like interior. A thin testa skin (3) surrounds the kernel (4) and keeps it separated from the inside of the shell.

Process flow



Decortication

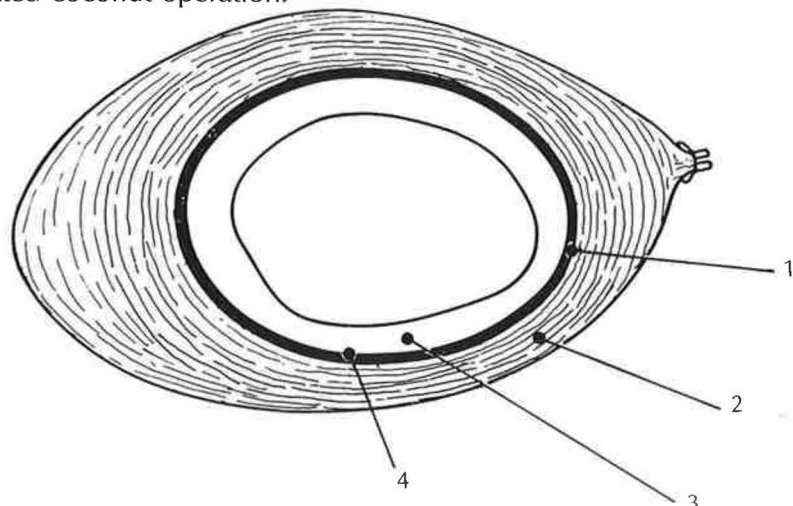
Traditionally, decortication has been a labour-intensive operation, carried out by hand using simple equipment. The nuts are roasted on a steel plate or grid over an open fire until the nut shell is brittle and can be opened with a small hammer or simple mechanical pedal-operated device. During this phase the CNSL is burnt off producing a pungent black smoke. A development of this method involves roasting the nuts in a rotating drum over a fire fuelled by nut shell. In recent years mechanical plant has become available, resulting in a sharp increase in processing capacity. The main technical problems are the removal of the shell, avoidance of CNSL contamination and the removal of the testa. Generally in these large-scale commercial systems the nuts are cleaned, graded and then conditioned to the appropriate moisture content prior to roasting in a CNSL bath to extract most of the CNSL from the shells and to make them brittle. The nut is put through a centrifugal impact decorticator described in Section 2 (see p. 6), after which the kernel and shell are separated. The kernels are dried, graded and the testa is removed prior to storage or sale. The mechanical plant has the advantage over traditional methods of higher throughput and minimization of health hazards arising from the continual handling of CNSL-contaminated nuts (with the resultant damage over a long term to hands and fingers from the vesicant oil), but has the disadvantage of a lower output of whole kernels.

Extended proving trials of a prototype small scale processing plant have been under way in Zambia. The plant has a throughput of approximately 100 kg/h and uses the dry roasting technique.

COCONUTS (COCOS NUCIFERA)

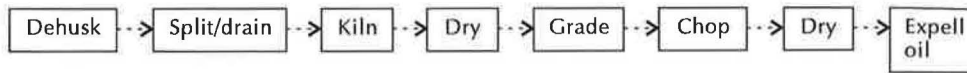
The coconut is important for the oil that can be extracted from the dried kernel known as ‘copra’. Desiccated coconut is also a major product from the kernel, whilst fibres from the husk and charcoal made from the shell are by-products. The decortication of the coconut includes the traditional copra operation and the desiccated coconut operation.

Figure 12
Coconut



The shell (1) of the kernel is surrounded by a thick fibrous husk (2) which is removed by dehusking. The flesh of the kernel (3) is a thick layer attached to the inner wall of the shell by the testa (4).

Process flow (traditional copra)



Decortication

Although attempts have been made to mechanize the dehusking and decortication for coconut production, all of the world production is processed by hand at present, even on large-scale plantations.

Copra

The coconut is dehusked manually using a sharp blade or spike embedded in the ground. The husk is impaled onto the spike and torn from the shell by a twisting action; the nut is then split into halves with a machete and the flesh is removed after it has been shrunk by drying. In some coconut-growing countries where the industry is not commercially developed, the complete coconut (husk, shell and kernel) is cut in half with an axe or a knife in one operation. The flesh is then removed by scooping it out immediately.

Attempts to mechanize the dehusking operation have been made with patents described since 1929. No records of their performance in the field exist. In the early 1970s, because of shortages of labour reported in some developing countries, a machine was designed which mechanized dehusking by presenting the coconut to a set of 6 blades, 4 of which were wedged open during the cycle removing the husk. Prototype trials in St Lucia indicated the potential of this machine but further development is required to remove residual fibre or 'beard' remaining and to accommodate coconut hybrid size variability. As labour prices rise, regional interest in mechanized dehusking is likely to increase.

Desiccated coconut

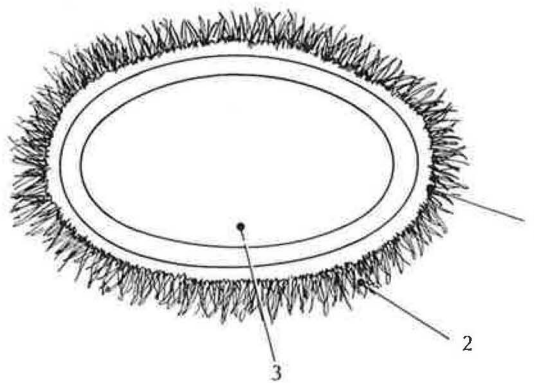
In the production of desiccated coconut in Sri Lanka, for example, the coconut is decorticated by an operator holding the kernel in one hand and skilfully 'hatchet' the shell away from the kernel.

The difficulty in mechanical decortication is because of the firm attachment of the kernel and testa to the inner shell. One method of releasing the kernel is to subject the shell to hydraulic pressure.

COTTONSEEDS (*GOSSYPIUM HIRSUTUM*)

The seeds from the cotton plant are a by-product of cotton fibre production. They are removed, with the fibres attached, when the cotton crop is picked. The cotton fibres are separated from the seeds in the ginning process. The kernels are used for oil extraction and the remaining cake is processed to make high-protein animal feed. The presence of the toxin gossypol in most common varieties of the seed inhibits its direct use for human food, as well as limiting its use in animal feeds.

Figure 13
Cottonseed



The seeds (1) have short fibres called linters (2) attached to their external surface which surround the kernel (3).

Process flow

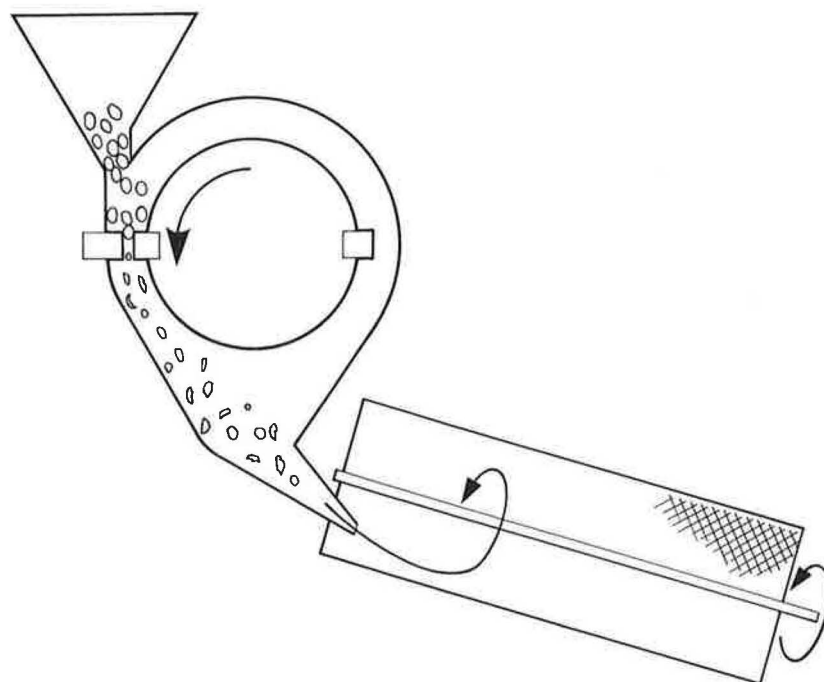


Decortication

Recovered kernels from gossypol-free cottonseed varieties have potential as a nutritious human food. The main processing operation is to open the seed without first having to remove the linter coating.

A machine developed for this operation uses a bar mill system of decortication as described in Section 2 (see p. 8). With the linters still attached, the seeds will not flow freely under gravity and must be positively driven into the machinery. Thus the feed hopper is carefully designed to prevent bridging and a rotary feeder is provided at the base to ensure a continuous flow of seeds into the decorticator (see Figure 14).

Figure 14
Bar mill decorticator for cottonseed



This machine will readily open up the seeds in a single pass without crushing the kernels provided the bars are kept sharp.

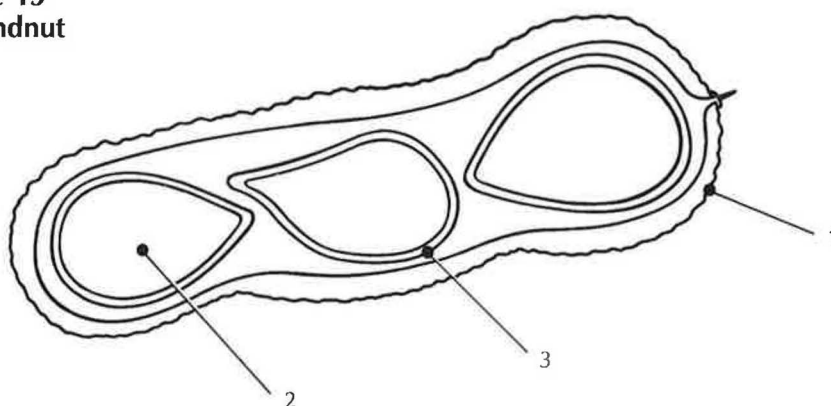
A special rotating screen system is required for this machine that both separates the resulting lintered hulls and grades the kernels into the required quality fraction. The nature of the process requires constant attention to moisture content control.

GROUNDNUTS (*ARACHIS HYPOGAEA*)

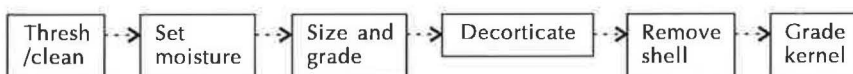
The groundnut (peanut) is cultivated as a primary product either for oil extraction or for confectionery. The discarded shell is of little major use, although it can be used as a low grade fuel. Attempts have been made to utilize the shell in building products with limited success. A groundnut is illustrated in Figure 15.

The shell (1) is soft and friable when dry and surrounds the several kernels (2), each of which has a thin testa skin (3).

Figure 15
Groundnut



Process flow



Decortication

Simple decortication of many varieties of groundnut is not normally difficult because of the brittle nature of the shell and the uniformity and strength of the kernels. However, popular varieties with soft and irregular kernels present substantial problems in maintaining acceptable levels of decortication efficiency.

In the simplest case, a drum, fitted with small projections and rotating in a simple screened enclosure, will be effective for many varieties which have strong kernels. However the stresses set up by this random decortication action can be sufficient to cause an excessive proportion of the total kernels to split.

The kernel sizes are not closely related to the external size of the nut. Irregularities in the supply of the nuts can be dealt with by prior size grading, but it may be difficult to establish a workable machine setting for each size grade that will allow an acceptable balance to be achieved between the production of broken and whole kernels. In these circumstances, a more tolerant and softer action can be set by reducing the speed of rotation of the projections and increasing the clearance between the projections and the screen.

Hand shelling, which produces low levels of broken kernels, uses low cost labour at the point of production and is a practical operation where the crop

is relatively small and of exceptional value. Small, manually operated farm-level machines are used with varieties which have strong kernels and they substantially improve productivity.

Typically, these may be the reciprocating machines referred to in Section 2 (see p. 11). The most common machine using this method is a bowl-like unit in which the upper assembly is worked to-and-fro by hand and the kernels and shell fragments fall through holes in a wire or sheet metal screen (see Figure 16).

In simple form, the decortication efficiency of the machine may not be very high and so improvements have been introduced in order to reduce the unnecessary damage done to the kernels while they remain in the bowl. The *Rural Technology Guide No. 4* describes a feeder unit which can be built onto the top of the machine which minimizes the dwell time of the kernels thus reducing breakages, and is shown in Figure 17.

By buffering the main bulk of the nuts in the top hopper and delivering only a controlled flow, the quantity of nuts in the bowl is reduced to those which are actually in the process of being shelled. Manual effort is thus much reduced and shelling is more rapid and efficient.

The type of machine described above has two drawbacks which inhibit its use in remote areas.

- (i) It is really only suitable for manufacture in a moderately well-equipped engineering workshop.
- (ii) The kernel recovery efficiency is low with some delicate varieties.

Figure 16
Hand-operated reciprocating action groundnut decorticator

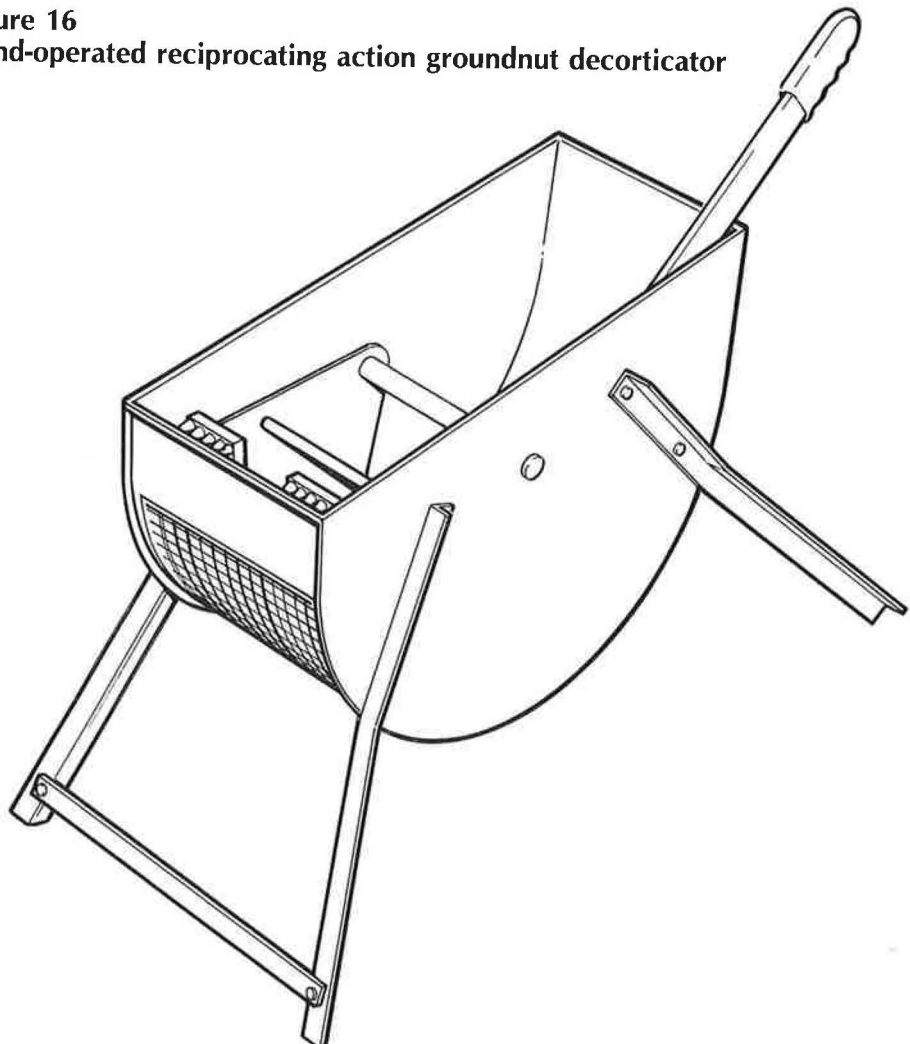
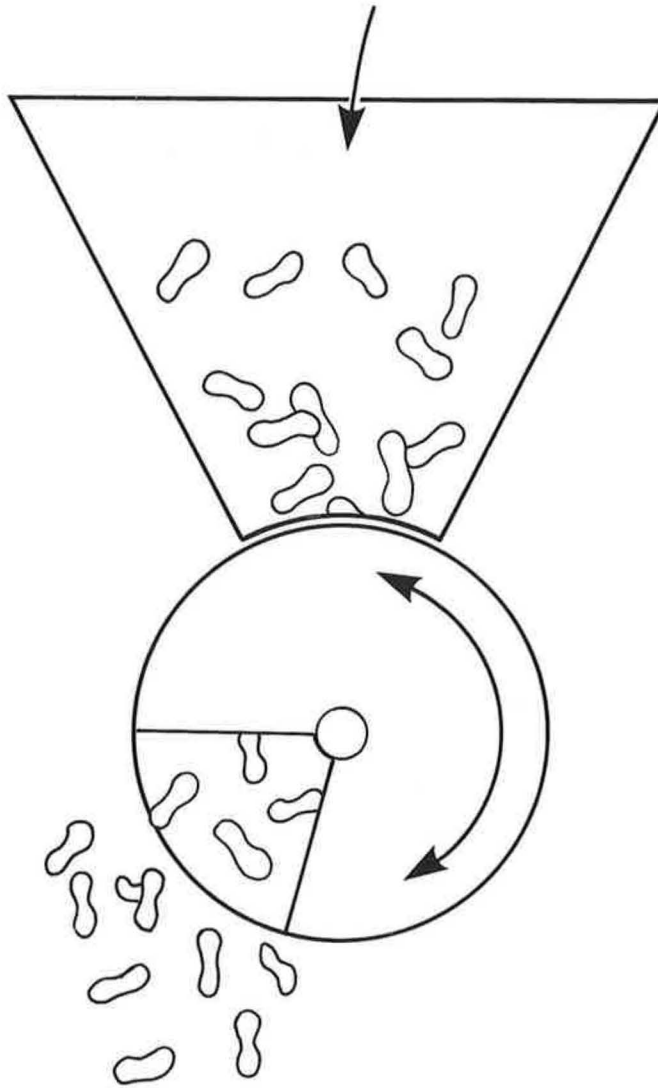
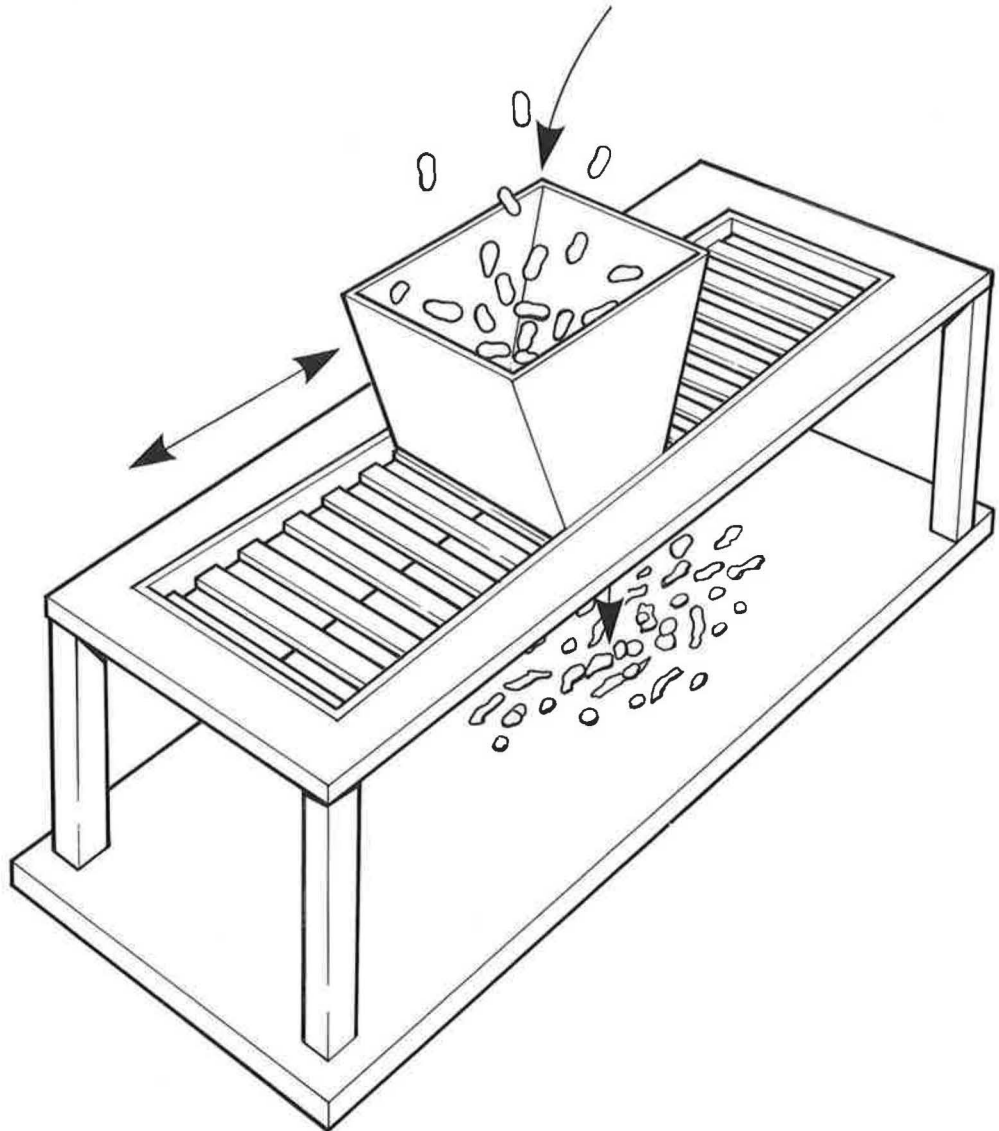


Figure 17
Feeder unit for groundnut decorticator



In such remote areas, manual shelling might be most appropriate. However a device has been developed, called the sliding action groundnut decorticator (see Figure 18) which uses a similar action to the reciprocating decorticator thus addressing the problems (i) and (ii) mentioned on p. 25.

Figure 18
Sliding action groundnut decorticator



The device can be constructed from wood by local carpenters. Use of wood facilitates more appropriate shaping of the components which make a crucial contribution to the efficiency of the machine. In addition, the design allows the working parts to be more flexible and thus to absorb some of the mechanical pressures which might otherwise damage the kernels.

There are other approaches to assisting the speed of hand shelling.

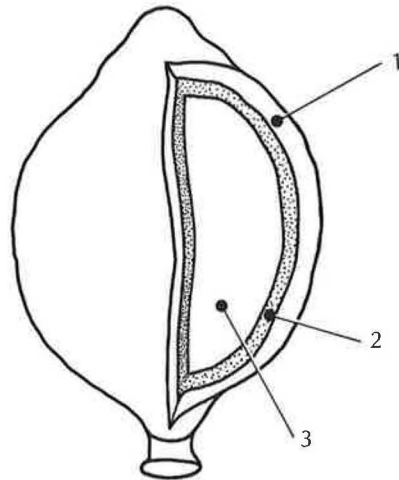
Attempts have been made to perfect a machine which does not attempt complete decortication, but merely crushes the shell slightly, rendering it much easier to open by hand. Shelling in this traditional way not only results in fewer broken, but also means that grading and cleaning are carried out at the same time. This does not happen with machine shelling since the shell and kernels remain mixed together. Without special machinery to relieve the tedium, a substantial amount of time is needed to pick through a heap of kernels by hand. To rectify this situation, more devices, such as winnowers and graders, may be required to maintain a balanced operation.

Powered devices using the disc principle described in Section 2 (see p. 10) can be used on a small scale with delicate nuts. This method, being sensitive to nut size, requires accurate size grading, but by processing discrete size batches, it is possible to obtain better results than might be obtained with simpler powered machinery.

MACADAMIA NUTS (*MACADAMIA INTEGRIFOLIA*)

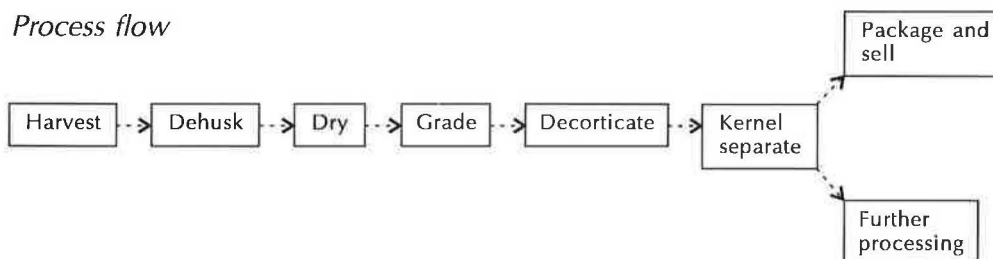
The macadamia nut is renowned for its quality and is claimed to be superior in flavour and texture to any other confectionery nut. The decortication of this nut is difficult because of its hard shell. For these reasons the nut is one of the highest priced processed nuts available. This sub-section describes work carried out on *Macadamia integrifolia*, a round, smooth-shelled nut, as opposed to *Macadamia tetraphylla*, an elliptical, rough-shelled nut.

Figure 19
Macadamia nut



The size range of the nuts is from 10 mm to 28 mm. Harvested nuts are contained within a fleshy husk (1) which ranges in thickness from 4 mm to 6 mm. To prevent deterioration of the nuts the dehusking should take place within 24 hours of collection. After dehusking and drying, decortication removes the shell (2) and exposes the high quality kernel (3).

Process flow



Decortication

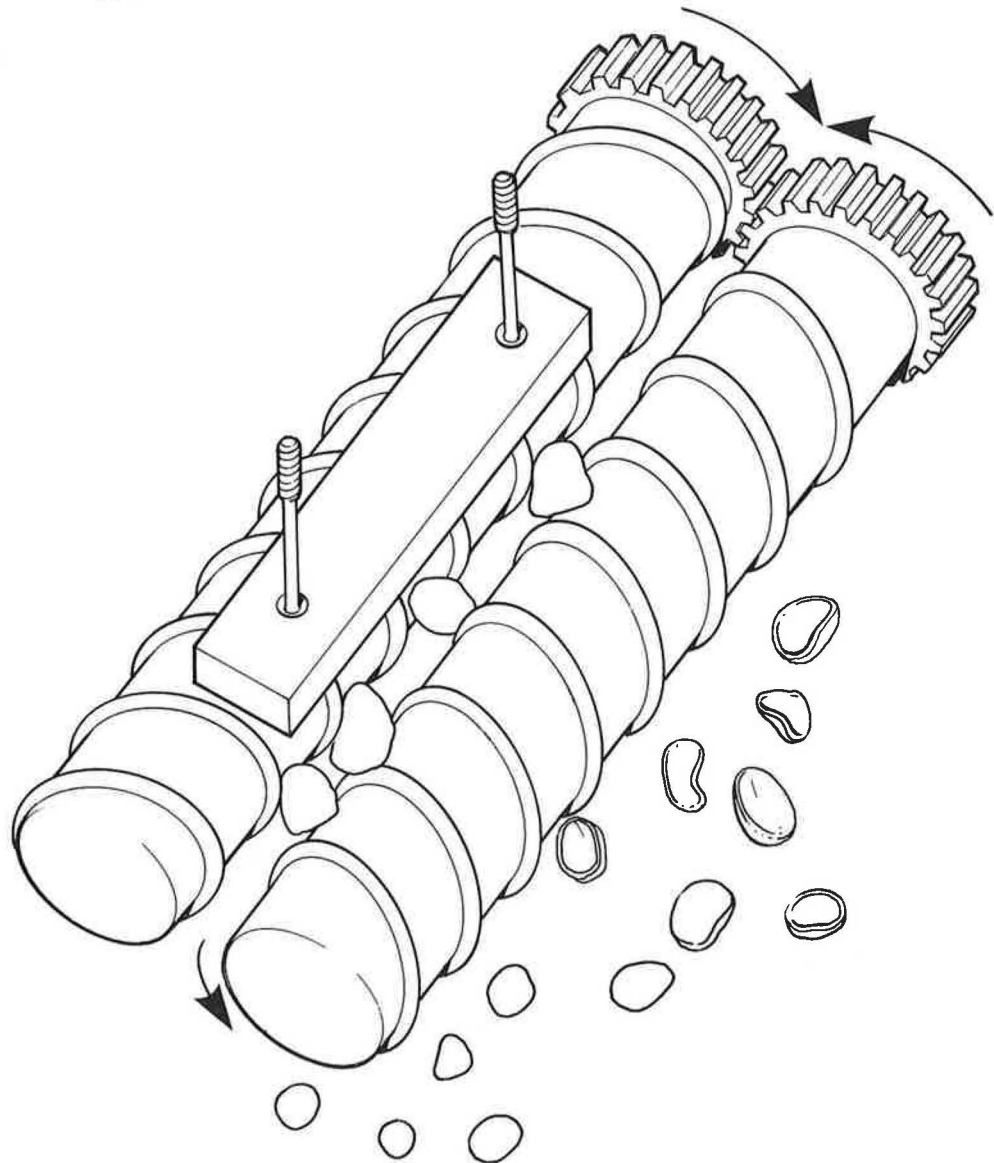
Dehusking

The first processing operation is to dehusk the macadamia nut. One method of achieving this is to pass the nut between a car tyre (driven by an electric motor) and a wooden pressure plate covered in wire mesh. The technique described in Section 2 (see p. 12) using the scroll-type dehusker shown in Figure 20 is also used to dehusk. This dehusker consists of two wide pitched contra-rotating screws to squeeze and hence rupture the husk to release the shell.

In countries where both varieties are grown, a practical method of sorting a mixture of *Macadamia integrifolia* nuts from *Macadamia tetraphylla* nuts after dehusking is to place the nuts on an inclined surface. The smoother-shelled *M. integrifolia* will have less rolling friction and their higher speed will enable the nuts to cross a gap which will swallow the rough shelled *M. tetraphylla*.

Once the nut has been dehusked it will be necessary to dry it to a moisture content of 2.5-4.0% w.b. in two stages. The first stage is usually carried out in the field or on the farm and involves shade drying from about 35% to between 10-12% w.b. The first stage can be carried out in a deep silo, but if too high a temperature is used initially, changes to the composition will reduce the quality. The second stage is carried out in deep bed dryers using air temperatures of 60°C for about 12 hours. The kernel is dry enough for decortication when it detaches from the shell and 'rattles' when the nut is shaken.

Figure 20
Scroll-type dehusker



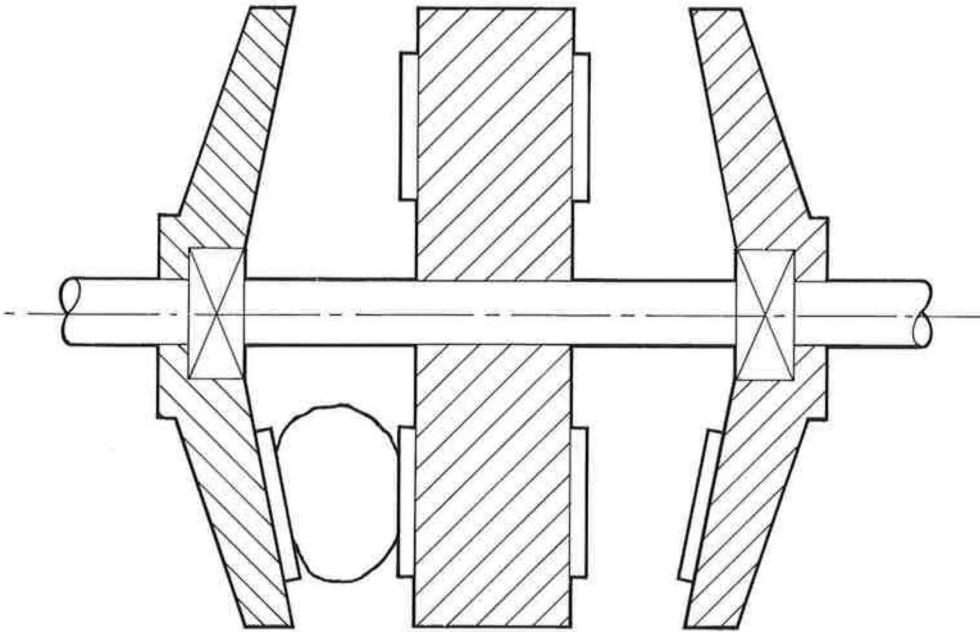
Jaw decorticator

The jaw decorticator works on the principle of the stone crusher. It generates an impulsive compressive force once per cycle which cracks the shell. Because of the dry brittle nature of the shell, the fractured shell springs open, easing the release of the kernel. In this method of decortication it is necessary to grade the size of the nuts before cracking.

Shaw decorticator

The Shaw decorticator is the most widely used decorticator. It consists of a rotating inner disc with a ribbed surface and a stationary outer casing, which is tapered and ribbed. The nut is fed into a cavity and subjected to a shearing action between these two discs. Since the cavity is tapered, nuts of various sizes can be accommodated and pregrading is not required.

Figure 21
Shaw decorticator



Screening

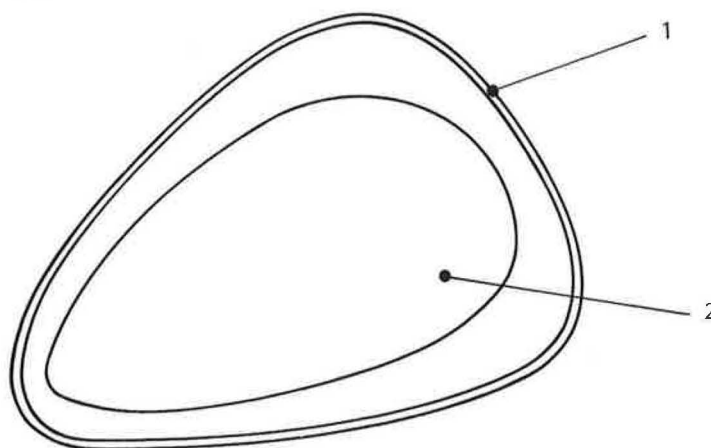
Post-decortication screening is required to return any kernels still trapped in their shell. Various mechanical sorting and sifting devices are used, but the final sorting operations are manual. Time spent on recovering all but the smallest chips is an indication of the value of macadamia nuts. There is a specific market for small chips of macadamia for use in the confectionary trade for decorative purposes.

In wet roasting the oil content of the kernel is important. Low oil content kernels go dark at the temperatures used for roasting. Therefore it is necessary to sort the kernels for oil content using a flotation technique before roasting. In Hawaii the kernels are separated after roasting by a colour sorting machine. A flotation method developed and used in Malawi and Zimbabwe involves separating kernels to be wet processed into two grades. Kernels of different density are separated by floating in water to which salt has been added to alter its gravity. In Costa Rica a dry roasting technique is used. This is less sensitive to changes in oil content.

SUNFLOWER SEEDS (*HELIANTHUS ANNUUS*)

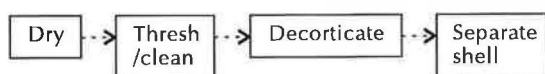
Sunflower seeds are grown primarily for oil extraction or for confectionery uses. Varieties that are grown for oil extraction have thinner shells and a higher oil content than those grown for confectionery, but are not necessarily required to shell easily. Efficient shelling is an important factor for confectionery nuts. This means that machinery used for shelling seeds for oil extraction is different from that used for shelling seeds for confectionery purposes.

Figure 22
Sunflower seed



The shell (1) of most confectionery grade sunflower seeds is brittle when dry and is readily broken free of the kernel (2).

Process flow



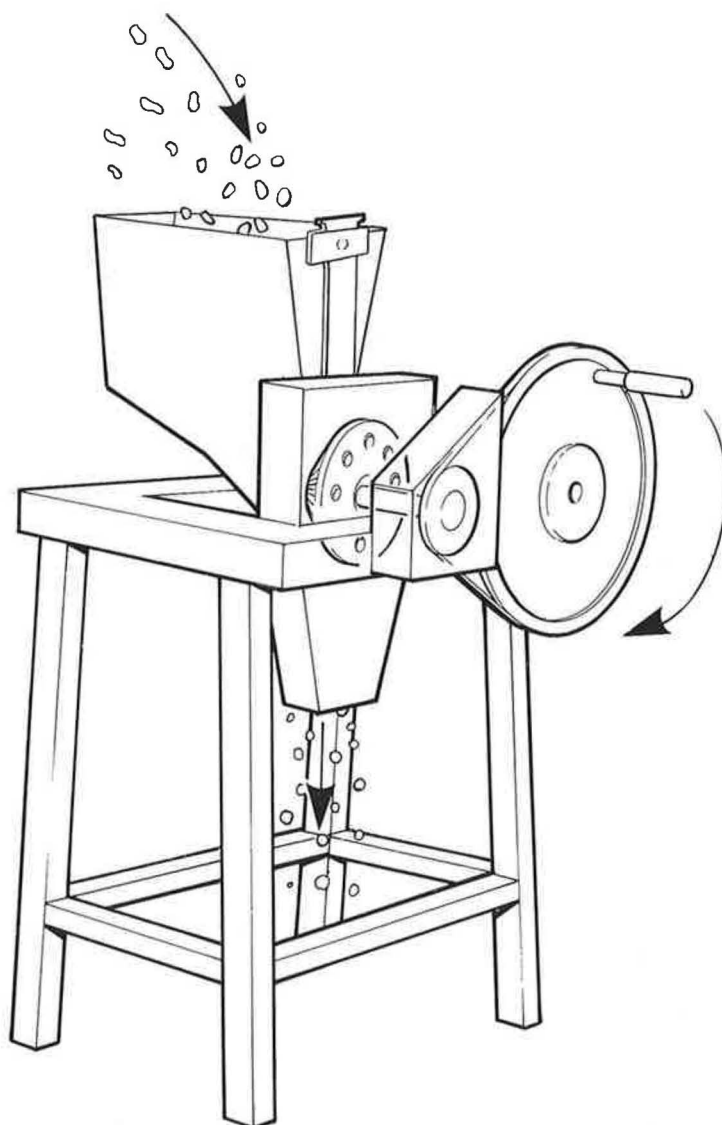
Decortication

It is difficult to shell large quantities of seeds by hand but a suitable machine will usually shell dried seeds without difficulty.

Of the decortication methods described in Section 2, centrifugal, (see p.6), bar (see p.8) and parallel disc (see p.10) are likely to produce the best results. A centrifugal unit will be the most effective on relatively small quantities. Figure 3 in Section 2 (see p.7) indicates a typical impeller layout. Both the radial vanes and the target ring surrounding the impeller are subject to considerable erosion by the impacting seeds. On many units, particularly those derived from paddy husking machines, the target is made of a hard rubber which, as it wears, presents a changing and deteriorating surface profile to the approaching seeds. However, to obtain any results at all, the impeller must rotate at a speed greater than 2,000 r.p.m.: a speed which requires the use of either a motor, or for hand operation, an expensive speed-increasing transmission. The kernels and shells remain mixed together after impact in these units. Winnowing is required to separate the shell from the kernel and a hand-operated machine is described at the end of this section.

Rural Technology Guide No. 10 describes the construction of a hand-operated disc mill of a style described in Section 2 (p.10).

Figure 23
Hand-operated disc mill sunflower seed decorticator



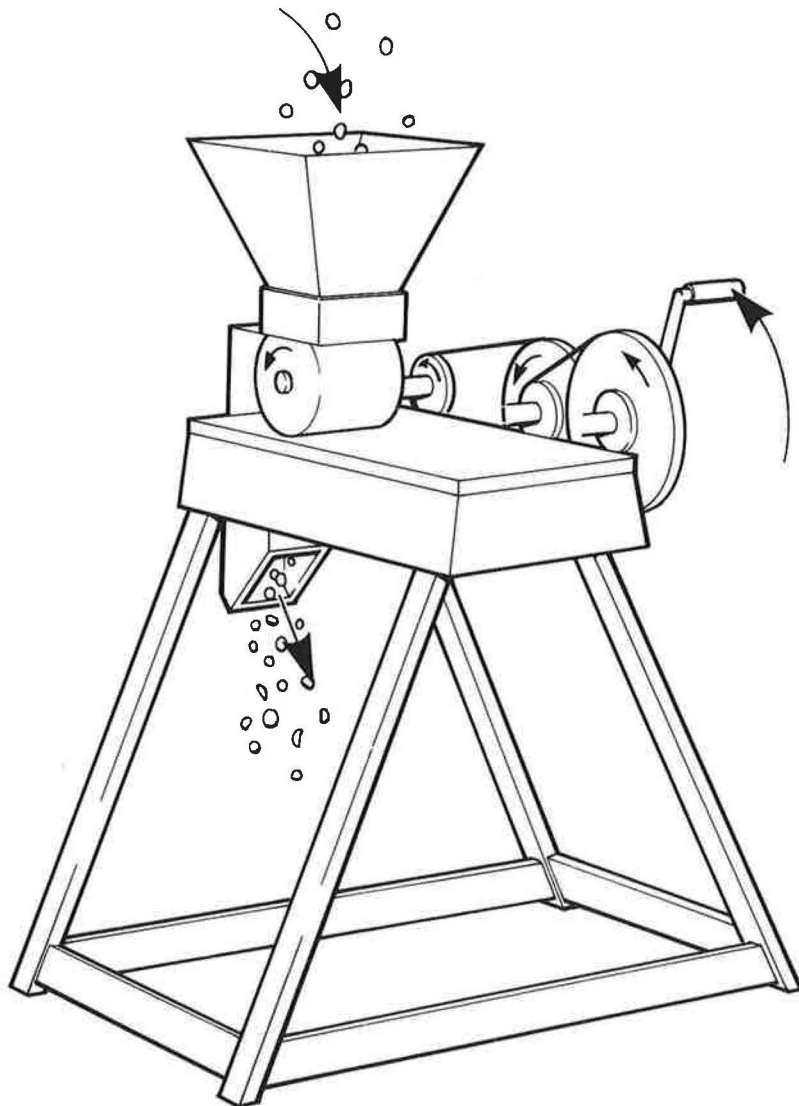
Although this mill will not have the performance of the centrifugal mill, it is more readily manufactured locally. Also the wear on the discs' working surfaces is reduced particularly if they are made from cast-iron (see Figure 23).

For high oil content varieties, bar mills as described in Section 2 (see p. 8) can be used. The smallest unit of this type is described in *Rural Technology Guide* No. 9. It is a hand cranked unit, designed for use only with oil-rich varieties (see Figure 24).

The periphery of a solid wooden rotor is fitted with four hard steel bars set parallel to the shaft. The distance of the parallel stationary bar is adjusted to achieve efficient decortication of the specific size ranges of seeds. The action of passing a controlled flow of seeds through this gap provides a decortication effect which, although unimpressive, will be sufficient to disrupt the shell and to facilitate efficient extraction of oil in worm-screw types of oil extraction machinery. The resulting shells, kernels and seeds from this operation can be passed through a hand-operated winnower, as shown in Figure 25, to remove shell, and through simple hand sieves to recover minor quantities of kernel fragments.

The size of the rotor and the number of bars can be increased considerably once the unit is provided with a mechanical drive. As well as significantly improving the capacity, the same drive can be used to operate ancillary devices such as a system of reciprocating or rotating screens. These facilities will make continuous operation possible and, using selected sizes of screens, re-cycling and product grading become automatic. A simple extraction fan and cyclone collection system can be used to remove shell and dust at appropriate points in the machinery.

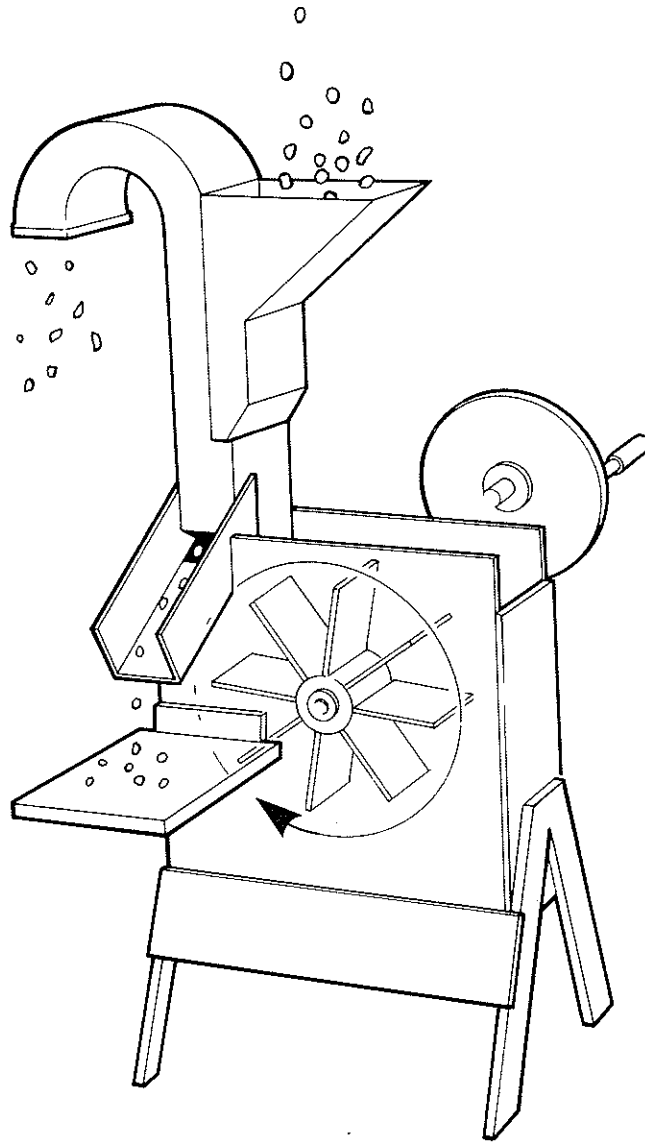
Figure 24
Hand-operated bar mill sunflower seed decorticator



Rural Technology Guide No. 11 describes the construction of a hand-operated winnowing machine which is specifically designed to separate shell and to clean production (see Figure 25).

The dust and shells are removed from the primary product in a contra-flow of air provided by the hand cranked fan. Undecorticated seeds are not separated from the final product by this unit and they must be removed by sieving before being re-cycled through the decorticators.

Figure 25
Hand-operated sunflower seed winnower



Concluding comments

This publication has described NRI's experience in the recovery of seven specific 'seed kernels' and features the range of experience that exists in decortication and related operations. Some areas of activity are being further investigated, particularly for cashew nut, coconut and balanites nut where prototype decortication equipment is being developed.

A complementary publication to *Decortication of tropical oilseeds and edible nuts* is intended. This follow-up will include further information on decortication and will review commercially available equipment.

The Institute welcomes comments on the content of this publication and will be pleased to answer enquiries:

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