DESIGN OF A SMALL SCALE PLANT TO PRODUCE 1000 TONNES/ANNUM OF CARROT POWDER FROM CARROT

BY

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NOVEMBER, 2005

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A RESEARCH PROJECT SUBMITTED TO THE DEPARTMENT OF CHEMICAL ENGINEERING, SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE, NIGERIA

IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN CHEMICAL ENGINEERING

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DECLARATION

I, Garba Salisu (99/8177EH) hereby declare that this research project, "Design of a Small Scale Plant to Produce 1000 Tonnes/Annum of Carrot powder from Carrot", carried out under the supervision of Engr. Aishat B. Bwari. and presented in partial fulfilment of the requirement for the award of Bachelor of Engineering (B. Eng.) Degree in Chemical Engineering has not been presented for any degree elsewhere, to the best of my knowledge.

Garba Salisu

12-12-2005
Date

DEDICATION

This project work is dedicated to my lovely mother, Hajia Lantana Shehu Idris.

ACKNOWLEDGEMENT

My sincere thanks goes to Almighty Allah who despite all odds made life living.

Wish to express my profound gratitude to my supervisor Engr. Aishat B.Bwari for her numerous adviser and encouragement during the course of this research project. Also, in this respect my special thanks to the head of department Dr.F.A Aberugba, Engr.A kovo ,Engr Bashir Mohammed and the other staff of the chemical engineering department.

I acknowledgement with gratitude the help and support given to me by Mal Bello Suleiman and his family. Am also greatly indebtlyto the following personality for their support during the course of my studies. They are Abubakar S.dIris and his family and Aunty Hasia and her family.

My immerable gratitude goes to my fiancé Asmau Chiso Dattijo for all her support, love and courage during course of my studies.

My humble appreciation goes to all who help me in the course of this project both in the university and outside university. I cannot forget the effort of my family and friends Isah shehu, Rolex, Autress, Salim, Ummi, Hafsat, Jamila, Hadiza, Haj.Mari Shehu Idris, Malami. My friends are Baba Nura, Abu Aminu, Don Chi-Chi, Mohammed Bello, Hassan Albarna ,Musbahu Yuguda, Ziggi, Sadiq Mukhtar, Awwal Guru,Suleiman Manu,Uthman ,Alhakim Adamu, Hayatu bashir, Nasir Isah ,Karibu Hussaini, Yusuf Adamu ,Armiyau Bello, Salihu Maiwalima,a.k.a Roger, Aminu Abubakar, Sani Alhaji and other who has not mention.

Also include all my friend in and outside university.

Finally I wish to express my gratitude to my father Alh Garba Saidu and my mother Hajia Lantana Shehu Idris for moral and financial support all through to this part of my life.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 General Introduction

CARROT POWDER - proper name is Daucus carota. Queen Anne's Lace is the ancestor of the carrot you eat! If you pull up a young plant the tap root is worth steaming and eating. It will be whitish, though, and not orange. Other common names for this plant are: Queen-Anne's lace, Bees' Nest, Bird's Nest, Carot, Carotte, Carrot, Wild Carrot, Yarkuki, Zanahoria Wild Carrot, Birds Nest Weed, Devils Plague, Garden Carrot, Bee's nest plant, Bird's nest root. (www.herbal-connection.com/Carrot.html)

Carrot is a vegetable, rich in vitamins and minerals, including the recently celebrated carotene. Carrots are good for your eyes, and can help with night blindness, and weak vision. They may also help to lower cholesterol, and prevent some types of cancer. They are good for the digestive system, and may soothe diarrhea and indigestion. Ongoing studies are proving this to be a very valuable plant, useful in many areas of alternative medicine, a few are Alzheimer's, Crohn's disease, Parkinson's disease, Asthma-preventive, most types of cancer, Diabetes, Leukemia, HIV, Spina-bifida, Migraine headache, obesity, and much more, even the common cold. (www.herbal-connection.com/Carrot.html)

Carrot powder is a 100% natural product made from fresh specially grown carrots rich in carotene. (Natural Canine)

The cost of using carrot powder is equal to or less than the cost of using fresh carrots. With less waste and more convenience, you will never have to grind, clean up or refrigerate carrots again. Carrot powder takes all the hassle out of feeding carrots. (Natural Canine)

Carrot powder

- contains distilled oils to help fight worms and parasites.
- supports the immune system and improve health.
- builds resistance to infections.
- improves the skin and coat.
- acts as an antioxidant.
- is easy to store, needs no refrigeration, no spoilage.
- improve stool consistency.
- is convenient to carry on road trips. Dogs love the taste!
- contains iron and further the metabolism of the liver and thyroid.
- helps in the formation of blood cells.

1.2 Problem Statement

Design a plant to produce 1000 tons/annum of carrot powder from carrot.

1.3 Aim and Objectives

The aim of this research work is to design a plant to produce carrot powder from carrot. This aim will be achieved with the aid of the following objectives:

- Selection of a better process route for the production of carrot powder from carrot.
- Preparation of material balances
- Preparation of energy balances
- Equipment selection and costing

ABSTRACT

The design of a small scale plant to product 1000 tonnes/annum of carrot powder using carrot was carried out in this project. The operations involved in the production of carrot powder from carrot include washing of the carrot plant, drying, crushing, grinding and screening. The results of the project show that the purchased cost of equipments was calculated to be $39431.94. Based on further calculations, carried out using MathCAD Professional the project was found to have a fixed capital investment of $144261.74 and a working capital investment of $15868.79 while the total capital investment was $160130.53.

In conclusion, this plant has been found to be viable with a rate of return of 94.34% and a payback period of 1.06years.

1.4 *Scope of Work*

The scope of the work is limited to process design to prepare the material balances across the equipment, energy balances across the equipment, selection of equipment and economic analysis for the plant to produce carrot powder from carrot.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Carrot

Carrot is a hardy, cool-season biennial that is grown for the thickened root it produces in its first growing season. Although carrots can endure summer heat in many areas, they grow best when planted in early spring. Midsummer plantings, which mature quickly in cool fall weather, produce tender, sweet "baby" carrots that are much prized. Carrots are eaten both raw and cooked and they can be stored for winter use. They are rich in carotene (the source of vitamin A) and high in fiber and sugar content. (Wolford and Drusilla, 2005)

Botanical: Daucus carota

Family: N.O. Umbelliferae

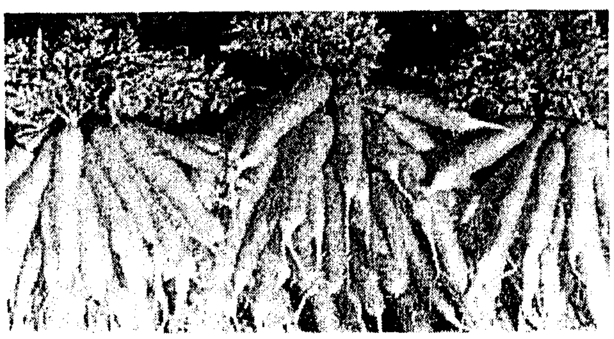


Fig. 2.1: Carrot

Source: (www.carrotmuseum.com)

2.1.1 History

The Carrot was well known to the ancients, and is mentioned by Greek and Latin writers under various names, being, however, not always distinguished from the Parsnip and Skirret, closely allied to it. The Greeks - Professor Henslow tells us - had three words: Sisaron, first occurring in the writings of Epicharmus, a comic poet

(500 B.C.); Staphylinos, used by Hippocrates (430 B.C.) and Elaphoboscum, used by Dioscorides (first century A.D.), whose description of the plant applies accurately to the modern Carrot. (www.botanical.com/botanical/mgmh/c/carrot24.html)

There is one kind of wild pastinaca which grows spontaneously; by the Greeks it is known as staphylinos. Another kind is grown either from the root transplanted or else from seed, the ground being dug to a very considerable depth for the purpose. It begins to be fit for eating at the end of the year, but it is still better at the end of two; even then, however, it preserves its strong pungent flavour, which it is found impossible to get rid of (Wolford, 2005).

In speaking of the medical virtue of the first species (which is evidently the Carrot, the second variety presumably the Parsnip), he adds, 'the cultivated has the same as the wild kind, though the latter is more powerful, especially when growing in stony places. (www.botanical.com/botanical/mgmh/c/carrot24.html)

The name Carota for the garden Carrot is found first in the writings of Athenaeus (A.D. 200), and in a book on cookery by Apicius Czelius (A.D. 230). It was Galen (second century A.D.) who added the name Daucus to distinguish the Carrot from the Parsnip, calling it D. pastinaca, and Daucus came to be the official name in the sixteenth century. and was adopted by Linnaeus in the eighteenth century.

From the time of Dioscorides and Pliny to the present day, the Carrot has been in constant use by all nations. It was long cultivated on the Continent before it became known in this country, where it was first generally cultivated in the reign of Queen Elizabeth, being introduced by the Flemings, who took refuge here from the persecutions of Philip II of Spain, and who, finding the soil about Sandwich peculiarly favourable for it, grew it there largely. As vegetables were at that time rather scarce in England, the Carrot was warmly welcomed and became a general favourite, its cultivation spreading over the country. It is mentioned appreciatively by Shakespeare in The Merry Wives of Windsor. In the reign of James I, it became the fashion for ladies to use its feathery leaves in their head-dresses. A very charming, fern-like decoration may be obtained if the thick end of a large carrot be cut off and placed in a saucer of water in a warm place, when the young and delicate leaves soon begin to sprout and form a pretty tuft of verdant green, well worth the slight trouble entailed.

Its root is small and spindle-shaped whitish, slender and hard, with a strong aromatic smell and an acrid, disagreeable taste, very different to the reddish, thick, fleshy, cultivated form, with its pleasant odour and peculiar, sweet, mucilaginous flavour. It penetrates some distance into the ground, having only a few lateral rootlets. (Seagate, 2001)

2.1.2 Description of carrot

The stems are erect and branched, generally about 2, feet high, tough and furrowed. Both stems and leaves are more or less clothed with stout, coarse hairs. The leaves are very finely divided, the lowest leaves considerably larger than the upper; their arrangement on the stem is alternate, and all the leaves embrace the stem with the sheathing base, which is so characteristic of this group of plants, the Umbelliferae, to which the Carrot belongs. The blossoms are densely clustered together in terminal umbels, or flattened heads, in which the flower-bearing stalks of the head all arise from one point in rays, like the ribs of an umbrella, each ray again dividing in the case of the Carrot, to form a secondary umbel, or umbellule of white flowers, the outer ones of which are irregular and larger than the others. The wild Carrot is in bloom from June to August, but often continues flowering much longer. The flowers themselves are very small, but from their whiteness and number, they form a conspicuous head, nearly flat while in bloom, or slightly convex, but as the seeds ripen, the umbels contract, the outer rays, which are to begin with 1 to 2 inches long, lengthening and curving inwards, so that the head forms a hollow cup hence one of the old popular names for the plant: Bird's Nest. The fruit is slightly flattened, with numerous bristles arranged in five rows. The ring of finely-divided and leaf-like bracts at the point where the umbel springs is a noticeable feature. (Wolford, 2005)

The Carrot is well distinguished from other plants of the same order by having the central flower of the umbel, or sometimes a tiny umbellule, of a bright red or deep purple colour, though there is a variety, D. maritimus, frequent on many parts of the sea coast in the south of England, which differs in having somewhat fleshy leaves and in being destitute of the central purple flower. In this case, all the flowers of the head have often a somewhat pinkish tinge. There was a curious superstition that this small purple flower of the Carrot was of benefit in epilepsy. (www.botanical.com/botanical/mgmh/c/carrot24.html)

2.1.3 *Cultivation of carrot*

The root of the Carrot consists of Bark and Wood: the bark of the Garden Carrot is the outer red layer, dark and pulpy and sweet to the taste; the wood forms the yellow core, gradually becoming hard, stringy and fibrous. The aim of cultivation, therefore, is to obtain a fleshy root, with the smallest part of wood. This depends on soil and the quality and kind of the seed. (Seagate, 2001)

For its successful cultivation, Carrot needs a light, warm soil, which has been well manured in the previous season. The most suitable soil is a light one inclining to sand, a somewhat sandy loam or dry, peaty land being the best, but even heavy ground, properly prepared, may be made to produce good Carrots. Formerly the cultivation of the Carrot was almost entirely confined to the light lands of Norfolk and Suffolk. (www.botanical.com/botanical/mgmh/c/carrot24.html)

The ground should be well prepared some months in advance; heavy ground should be lightened by the addition of wood ash, road scrapings, old potting soil and similar materials. It is essential that the soil be in such a state as to allow the roots to penetrate to their full length without interruption. Previous to sowing the seed, the soil should be lightly forked over, and, if possible, be given a dressing of leaf soil or well decayed vegetable matter, but no fresh manure must be dug into the top spit of ground intended for Carrots and Parsnips, as it may cause the roots to become forked. The crops will, however, benefit by about an ounce of superphosphate to the square yard, raked in before sowing, or by a light dressing of soot. (Wolford, 2005)

Sowing of the main crop should be done in calm weather about the middle of March or early in April. The seeds frequently adhere to one another by means of the forked hairs which surround them. These hairs can be removed by rubbing through the hands or a fine chaff sieve. The seeds should then be mixed with about twice the bulk of dry earth, sand or sifted ashes (about one bushel of seeds to 4 or 5 lb. of sand). When the ground is thoroughly prepared and has been firmly trodden, draw flat-bottomed drills from north to south, 1/2 inch deep and 3 inches wide. Distribute the seed along the row evenly and thinly and cover lightly. Carrots can hardly be covered too lightly, 1 inch of fine soil is quite enough, and for ordinary use they may be sown in drills one foot apart, but if extra large roots are desired, more room must be given between the rows. As soon as the young plants are large enough to handle they may be thinned to 6 inches or 8 inches apart. The thinning may be at first to a distance of 3 inches, and then a final thinning later, the second thinnings being used as young Carrots for culinary purposes. Frequent dustings of soot will greatly benefit the crop. Light hoeings between the rows to keep the crop free from weeds is all that is necessary during the period of growth. Partial shade from other crops is often found beneficial. (www.botanical.com/botanical/mgmh/c/carrot24.html)

Main-crop Carrots are generally taken up about the last week in October, or early in November, by three-pronged forks, and stored in sand in a dry place, where they can be kept till the following March or April Some of the roots dug in the autumn can be replanted in February, about 2 feet apart, with the crown or head a few inches below the surface. Leaves and flowers will spring from them, and the seeds produced will ripen in the autumn.

By making successional sowings, good crops of small roots will be always available. In gardens, Carrots are grown in succession of crops from the latter part of February to the beginning of August. For early Carrots sow on a warm border in February: such a sowing, if made as soon as the state of ground allows, will assure early Carrots just when fresh and quickly-grown vegetables are most highly prized. They will be off in time to leave the ground ready for other crops. (www.botanical.com/botanical/mgmh/c/carrot24.html)

After a good dressing of soot has been given, Carrots may be sown again, and even then it leaves the room vacant for winter greens or cabbage for use next spring. Sowing as late as July is generally successful in most districts. Main crops are often sown too early, especially on cold soils. Carrots are liable to attacks of grubs and insects, the upper part of the root being also attacked by the grub of a kind of fly, the best remedy being late sowing, to avoid the period at which these insects are evolved from the egg. Dusting with ashes and a little soot or lime wards off both birds and slugs from the young tender growths.

Carrots are a valuable product for the farmer in feeding his cattle, and for this purpose are raised in large quantities. The produce of an acre of Carrots in Suffolk is on an average 350 bushels per acre, but sometimes much more. In the Channel

Islands and Brittany, much larger crops of Carrots and Parsnips are obtained than are yielded in England, the soil being deeply trenched by a spade or specially-constructed plough. Far more Carrots are grown in France, Germany and Belgium for fodder than here. Horses are remarkably fond of Carrots, and when mixed with oats, Carrots form a very good food for them; with a small quantity of oats or other corn, a horse may be supported on from 20 to 30 lb. of Carrots daily. In Suffolk, Carrots were formerly given as a specific for preserving and restoring the wind of horses, but they are not considered good for cattle if fed too long on them. They may also with advantage be given both to pigs and poultry, and rabbits are especially fond of them. The kinds grown for farm purposes are generally larger than those in the kitchen garden and are known as Red Carrots, the more delicate Orange Carrot being the variety used in cooking. Some farmers sow the seeds on the top of the drills, which is said to be an improvement over the gardener, who makes his Carrot-bed on the flat in the ordinary way. This ridge system gives good results the Carrots being clean and well-shaped and free from grubs. The farmers reckon about 2 lb. of seed for an acre for drills, and 5 or 6 lb. if sown broadcast. For ordinary garden purposes, one ounce of seed is reckoned to be sufficient for about 600 feet sown in drills.

2.1.4 Chemical constituents of carrot

The juice of the Carrot when expressed contains crystallizable and uncrystallizable sugar, a little carrot, extractine gluten, albumen, volatile oil (on which the medicinal properties of the root depend and which is fragrant, aromatic and stimulating), vegetable jelly or pectin, saline matter, malic acid and a peculiar crystallizable, ruby-red neutral principle, without odour or taste, called Carotin.

Carrots contain no less than 89 per cent of water; their most distinguishing dietical substance is sugar, of which they contain about 4.5 per cent. (www.botanical.com/botanical/mgmh/c/carrot24.html)

Owing to the large percentage of carbohydrate material contained by Carrots, rabbits fed for some days on Carrots alone, are found to have an increased amount of glycogen stored in the liver, carbohydrate being converted into glycogen in the body.

Sir Humphry Davy ascertained the nutritive matter of Carrots to amount to 98 parts in 1,000, of which 95 are sugar, and three are starch. Weight for weight, they stand third in nourishing value on the list of roots and tubers, potatoes and parsnips taking first and second places. Carrots containing less water and more nourlshing material than green vegetables have higher nutritive qualities than turnips, swedes, cabbage, sprouts, cauliflower, onions and leeks. Moreover, the fair proportion of sugar contained in their composition adds to their nourishing value. (Seagate, 2001)

In the interesting collection of the Food Collection at Bethnal Green Museum, prepared by Dr. Lankester, we learn that the maximum amount of work produceable by a pound of Carrots is that it will enable a man to raise 64 tons one foot high, so that it would appear to be a very efficient forceproducer. From 1 lb. of Carrots we can obtain 1 OZ. and 11 grains of sugar, while out of the 16 oz. fourteen are water. When we consider that in an average man of 11 stone or 154 lb. weight, about 111 of these are water, we see what a large supply is needful to repair waste and wear and tear.

2.1.5 Uses of carrot

The chief virtues of the carrot lie in the strong antiseptic qualities they possess, which prevent all putrescent changes within the body. (www.botanical.com/botanical/mgmh/c/carrot24.html)

Carrots were formerly of some medicinal repute as a laxative, vermifuge, poultice, etc., and the seeds have been employed as a substitute for caraways.

At Vichy, where derangements of the liver are specially treated, Carrots in one form or the other are served at every meal whether in soup or as vegetables and considerable efficacy of cure is attributed to them.

In country districts, raw Carrots are still sometimes given to children for expelling worms, and the boiled roots, mashed to a pulp, are sometimes used as a cataplasm for application to ulcers and cancerous sores.

Carrot sugar, got from the inspissated juice of the roots, may be used at table, and is good for the coughs of consumptive children.

A good British wine may be brewed from the root of the Carrot, and very tolerable bread prepared from the roots, dried and powdered. The pectic acid contained can be extracted from the root and solidifies into a wholesome, appetizing jelly.

In Germany, a substitute and adulteration for coffee has been made of Carrots chopped into small pieces, partially carbonized by roasting and then ground.

In France and Germany a spirit is distilled from the Carrot, which yields more spirit than the potato. The refuse after making the spirit is good for feeding pigs.

Attempts have also been made to extract sugar from Carrots, but the resulting thick syrup refuses to crystallize, and in competition with either cane sugar or that obtained from the beetroot, it has not proved commercially successful.

Carrots are also used in winter and spring in the dairy, to give colour and flavour to butter, and a dye similar to woad has been obtained from the leaves. (www.botanical.com/botanical/mgmh/c/carrot24.html)

2.1.6 *Medicinal action of carrot*

Diuretic, Stimulant, Deobstruent. An infusion of the whole herb is considered an active and valuable remedy in the treatment of dropsy, chronic kidney diseases and affections of the bladder. The infusion of tea, made from one ounce of the herb in a pint of boiling water, is taken in wineglassful doses. Carrot tea, taken night and morning, and brewed in this manner from the whole plant, is considered excellent for lithic acid or gouty disposition. A strong decoction is very useful in gravel and stone, and is good against flatulence. A fluid extract is also prepared, the dose being from 1/2 to 1 drachm. (www.botanical.com/botanical/mgmh/c/carrot24.html)

The seeds are carminative, stimulant and very useful in flatulence, windy colic, hiccough, dysentery, chronic coughs, etc. The dose of the seeds, bruised, is from one-third to one teaspoonful, repeated as necessary. They were at one time considered a valuable remedy for calculus complaints. They are excellent in obstructions of the viscera, in jaundice (for which they were formerly considered a specific), and in the beginnings of dropsies, and are also of service as an emmenagogue. They have a slight aromatic smell and a warm, pungent taste. They communicate an agreeable flavour to malt liquor, if infused in it while in the vat, and render it a useful drink in scorbutic disorders.

2.2 *Process route for the production of carrot powder*

The two main methods for the production of carrot powder are

(i) domestic method

(ii) industrial method

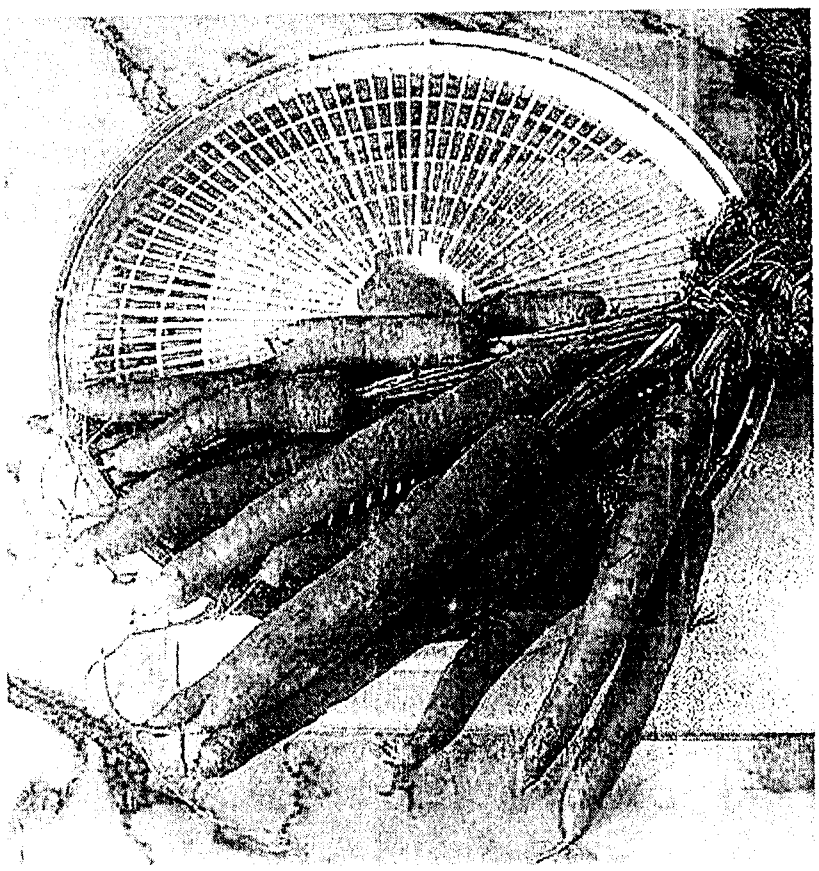
2.2.1 *Domestic method*

This is the method used for the production of carrot powder at home. Outlined below are the steps for the domestic production of carrot powder from carrot as designed by Klix (2005).

It should be noted that carrots contain a lot of water, so they will reduce in size quite considerably after production (Klix, 2005).

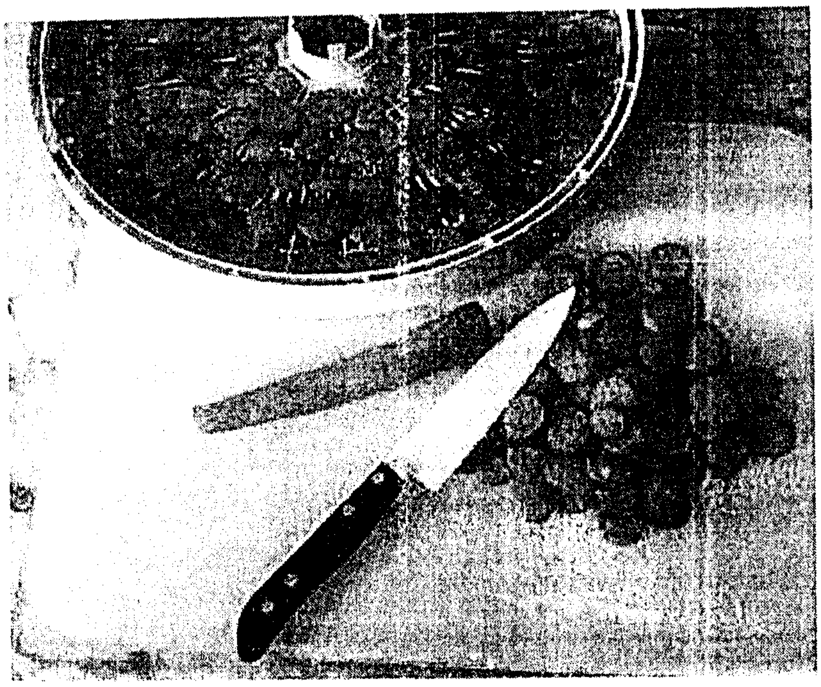
Figures 2.2a – 2.2e: Steps for the domestic production of carrot powder from carrot

(a)



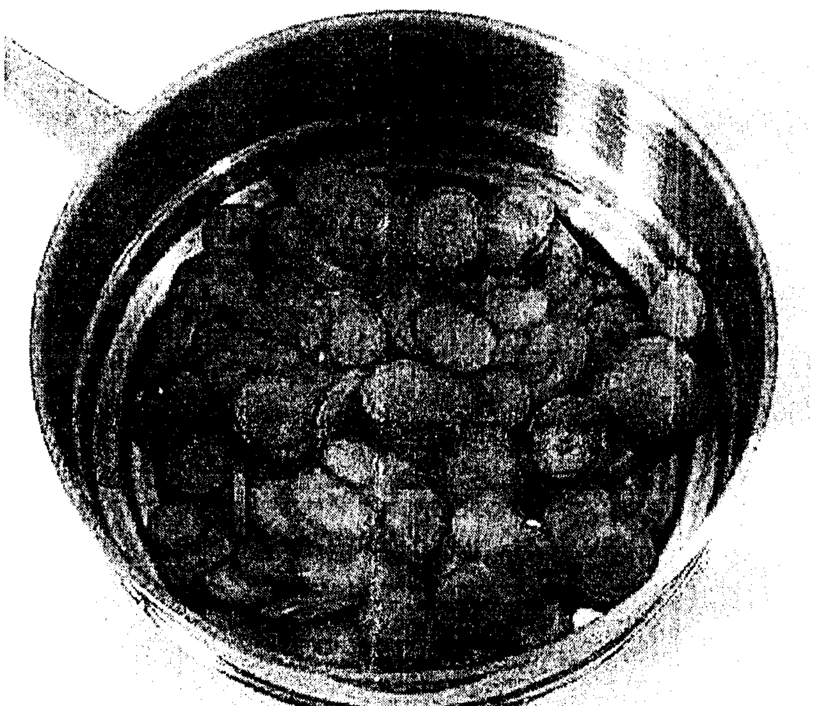
After topping and tailing the carrots, they were scrubbed in a bowl of water to remove any dirt.

(b)



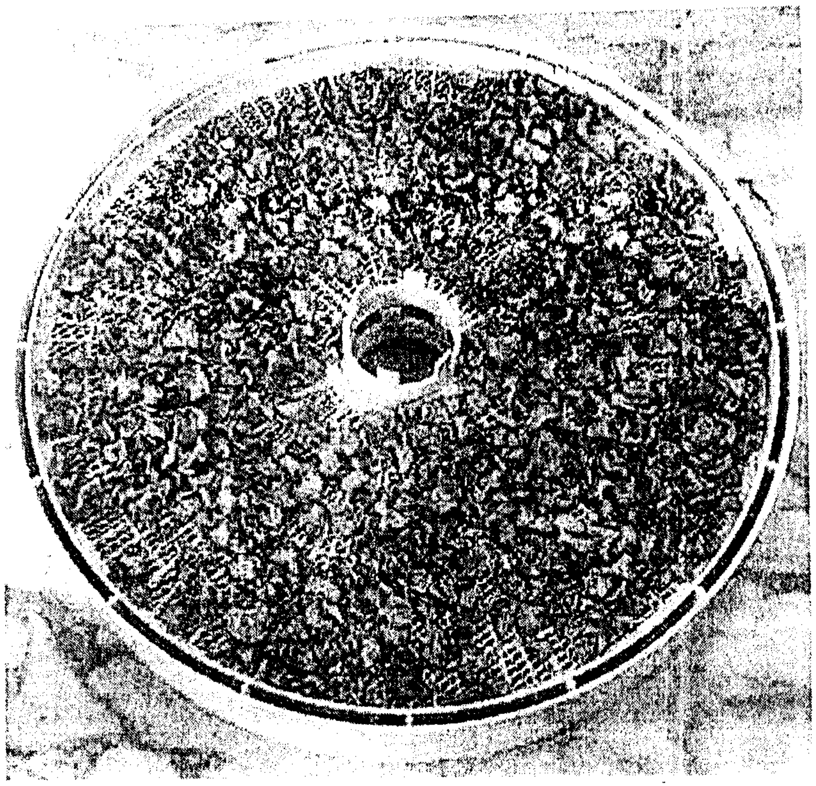
One may wish to peel the carrots if one has any worries about pesticides.

(c)



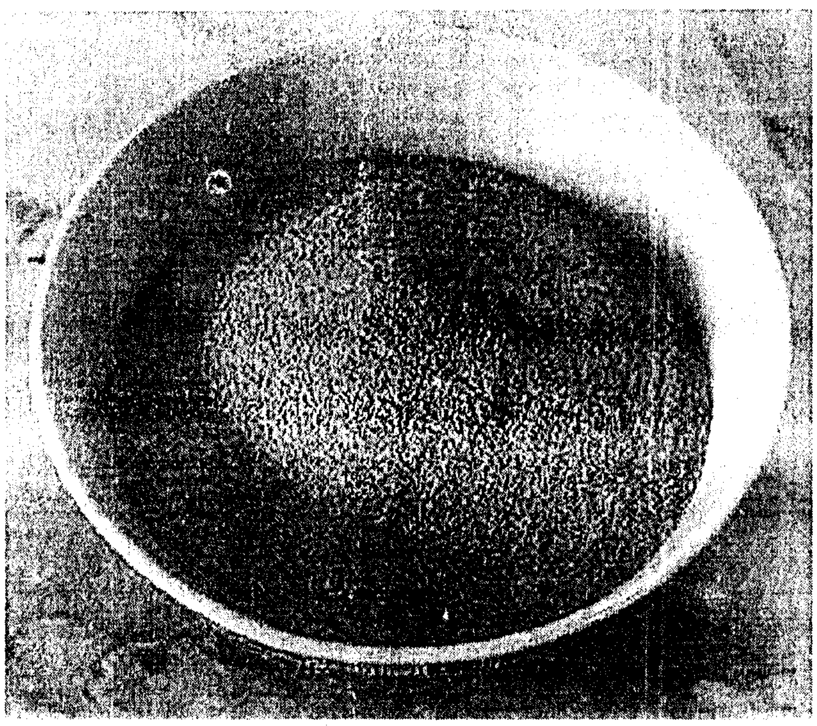
It is then chopped into 2-4mm slices and placed on the dryer trays.

(d)



After a few hours drying, the dry carrots were allowed to cool down.

(c)



The dry carrots is then ground to become powder

After about 10 hours, the carrots was crisped to the touch and packaged.

Dried carrots can be used directly in stews and casseroles (Klix, 2005).

2.2.2 *Industrial method*

The process flow sheet for the industrial production of carrot powder from carrot is as shown below.

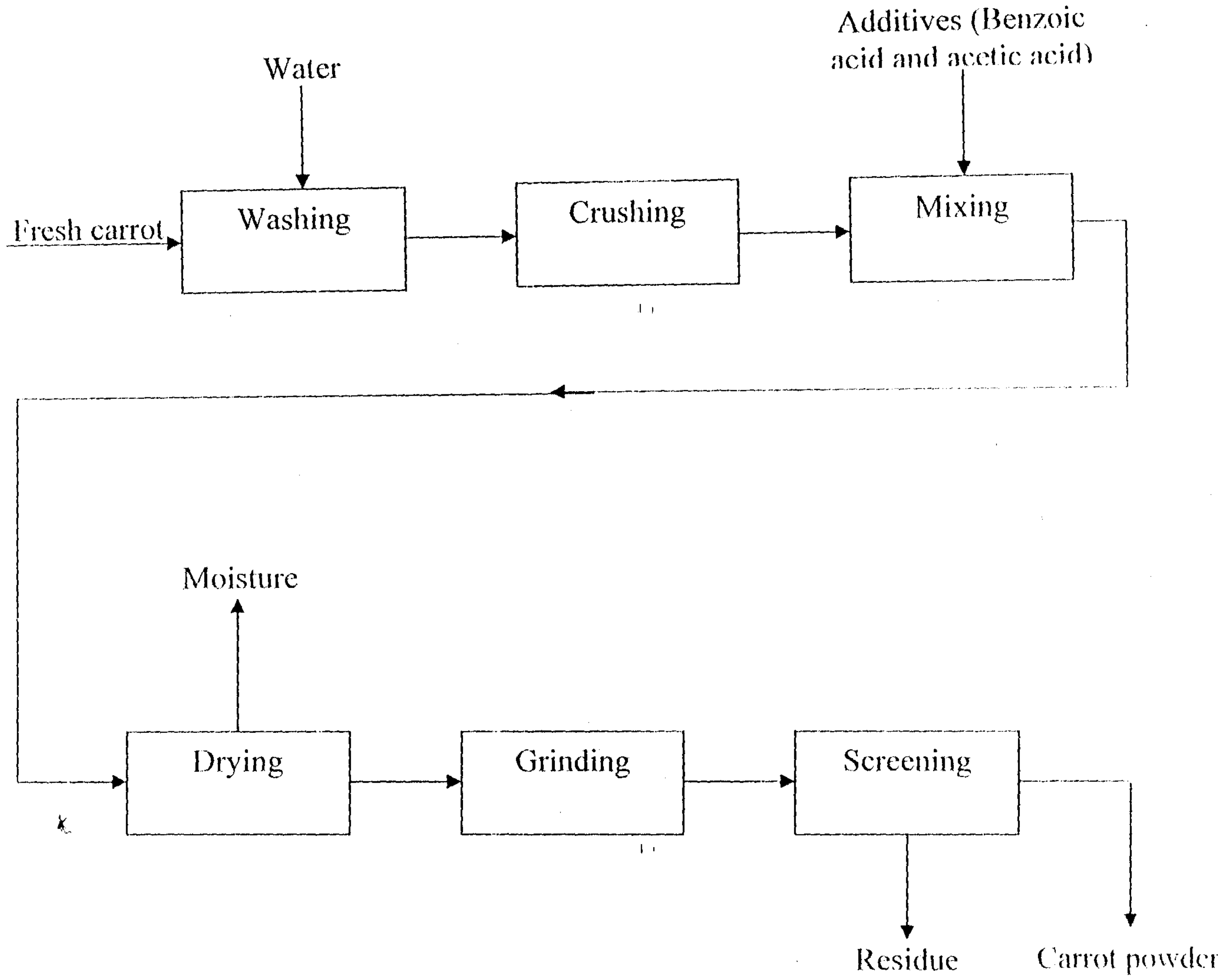


Fig. 2.3: Industrial production of carrot powder from carrot

2.3 *Description of the selected technology*

Based on the aim of this project to design a small-scale plant to produce carrot powder from carrot, the industrial method is chosen as the method of production. The description of the various operations involved in the technology of producing carrot powder from carrot on a small-scale industrial level are as outlined below.

2.3.1 Washing

This is the stage where the carrot plant is washed with water to remove the dirty particles that might have clung onto its body. All raw carrots carry foreign matter, consisting of sand, stones, etc. The presence of foreign matter in the crushing operation can be avoided by cleaning the carrot. The carrots can be passed into a mechanical washer which is known as vegetable and fruit washer.

2.3.2 Crushing

The washed carrot is crushed with crusher so that its size can be reduced. This can be carried out using a machine called Crusher A.

Crusher A rapidly reduces fruit to a consistency suitable for pressing. The hardwood frame fits over the cage of the 12 and 20 litre presses or over a bucket with the 9 litre press. There is a pair of contra-rotating shafts fitted with alternating serrated rollers and blades (made from acid-resistant alloy) driven by a cast iron hand wheel. Halved or quartered fruit is dropped into the stainless steel hopper, falls onto the blades, is cut and then crushed by the rollers. The only maintenance required is a hose-down with water after each use.

At this stage, the carrot is reduced to about 1cm in diameter.

2.3.3 Drying

The removal of free water from the crushed carrot obtained from the crusher or can be accomplished by evaporation, either in the open air (sun drying) or in ovens. In modern factories, oven drying is always combined with mechanical drying, the whole operation, as in all other phases of the process, being conducted so as to take the least possible time.

The simplest type of oven consists of a firing tunnel of brickwork covered with galvanized iron or copper plates on which the moist flour is spread in a thin layer. Firing should be moderate; so as to keep the temperature of the plates well below the gelatinization point of the starch, and the flour should be frequently raked up. The space above the oven should be vigorously ventilated. Enough wood is burned in the tunnel to heat the cement surface to the required temperature. The number of drying yards ranges from two to five, depending on the size of the factory and the kinds of products.

2.3.4 Grinding

The dried carrot is then ground into powdered form. It is always necessary to rupture the carrot plant in order to further reduce the size into powdery form. This can be done by mechanical action. The mechanical action is carried out by slicing passing the carrots into a grinding machine, which then grinds them into powder.

The size of the carrot (which is now in powdery form) is about 0.05mm.

2.3.5 Screening

The powdered form of the carrot obtained in the stage above contains some unwanted particles which need to be separated. The separation, in this case, is carried out with a screen. After the screening, the carrot powder is ready for packaging while the residue is also collected separately. A screen of appropriate mesh size which will prevent the loss of the carrot powder (the main product) is normally selected for this operation.

2.4 *Flow sheet*

The flow sheet for the production of carrot powder from carrot is the one shown in Fig. 2.4 below.

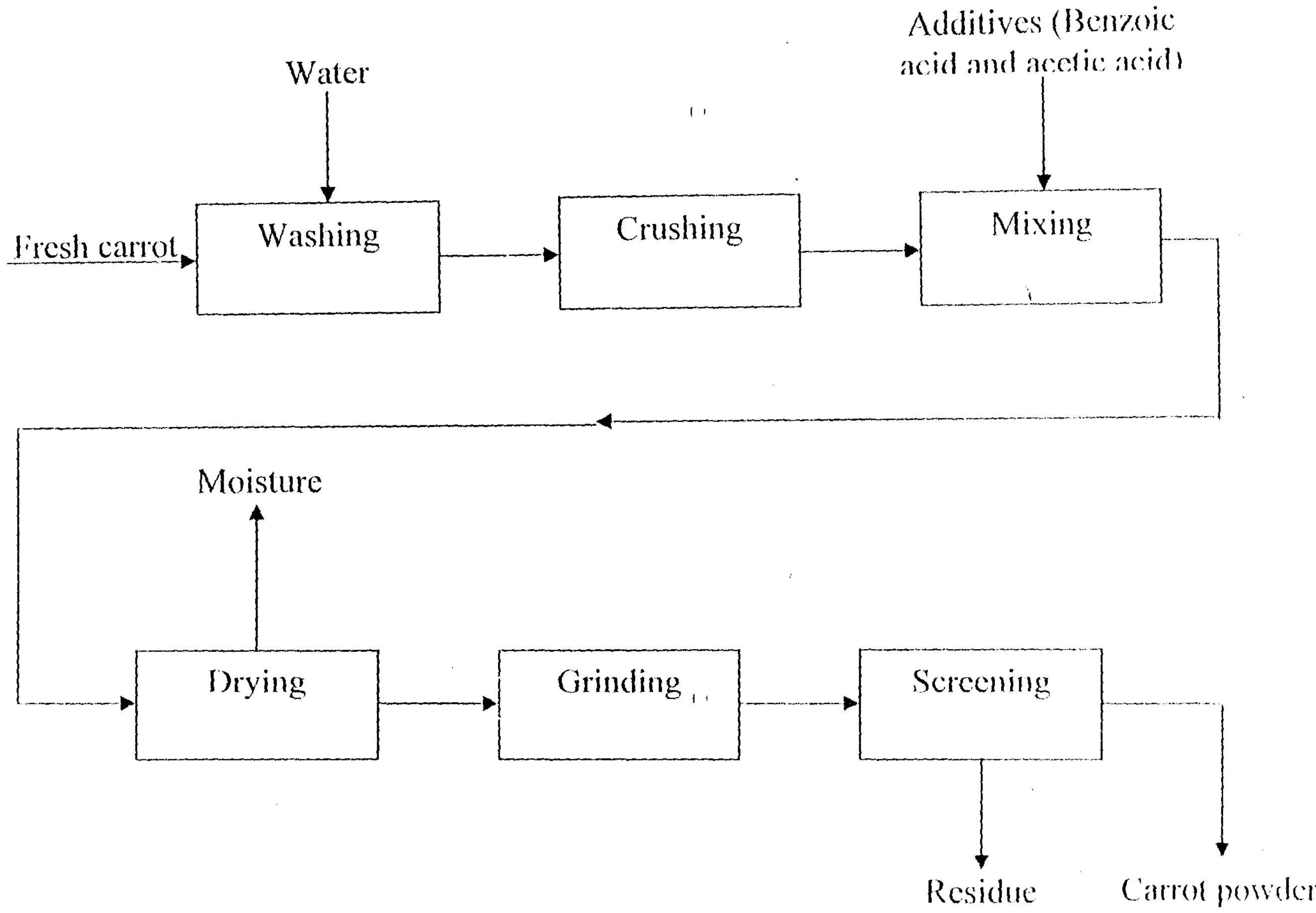


Fig. 2.4: Flow sheet for the production of carrot powder from carrot

2.5 *Justification of the selected technology*

The selection of the industrial method of production of carrot powder from carrot is the best option for the production process because high quality carrot powder is produced via this method. Apart from that, using this method, the entire process from seed selection, to growing, fertilizing and watering the crop can be properly controlled to ensure the highest quality, purity, taste and nutritional value of the carrot.

2.6 *Flowsheeting*

2.6.1 *Labelled Flow Sheet*

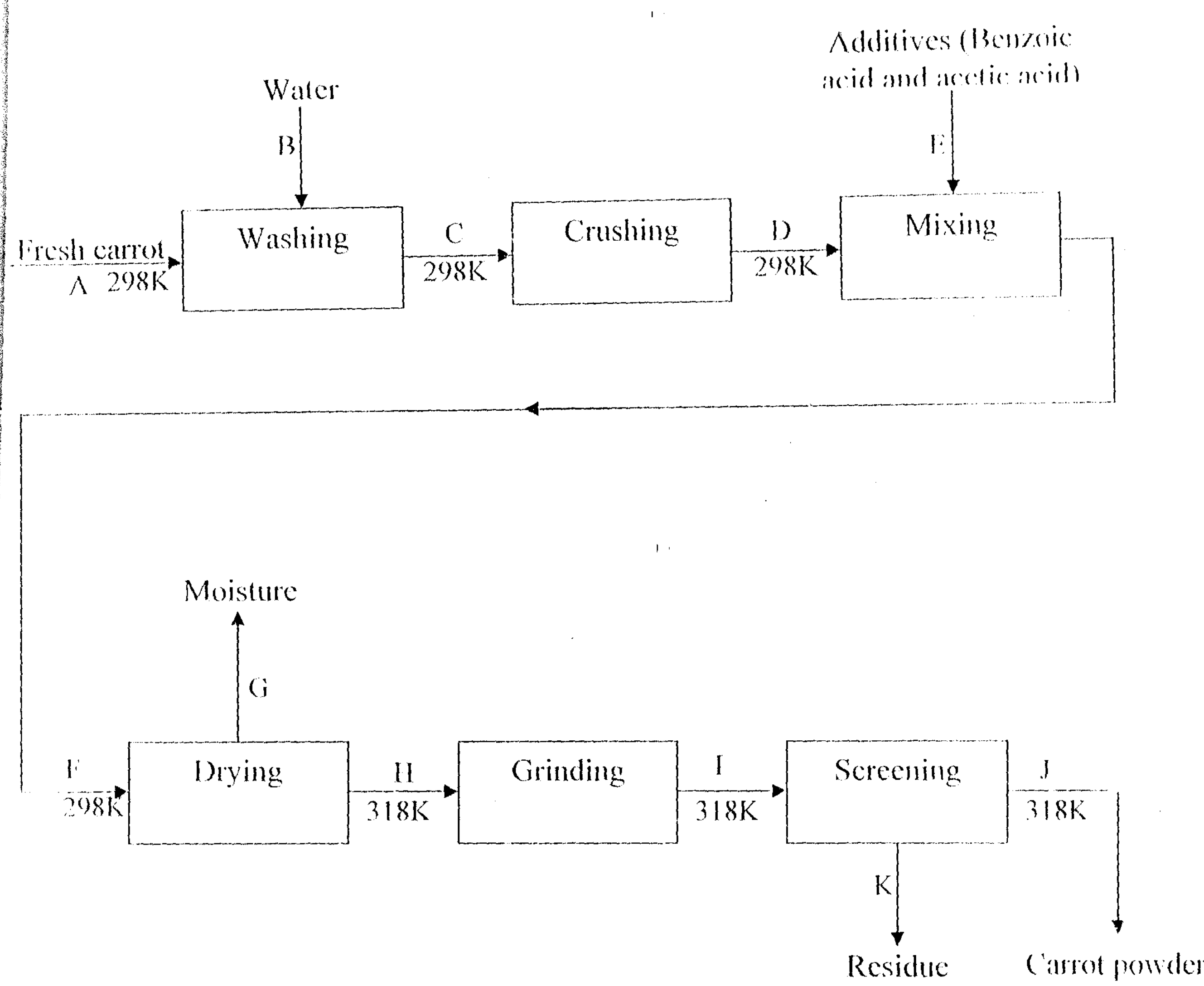


Fig. 2.5: Flow sheet for the production of carrot powder from carrot

26.2 *Flow sheeting table*

Stream	From	To	Phase	Temperature (K)	Component	Flowrates (kg/ann)
A	Input	Washer	Solid	298	Water	1437990.61
					Fats	3214.31
					Carbohydrates	171542.53
					Fiber	50752.23
					Potassium	5464.32

					Phosphor	744.37
					Sodium	592.11
					Calcium	456.77
					Magnesium	253.76
					Vitamin C	157.33
					Vitamin A	3400.40
					Vitamin B 6	2.37
					Niacin	15.56
					Folic acid	236.84
					Dirty particles	16917.41
					Additives	0.00
B	Input	Washer	Solid	298	Water	2537611.38
C	Washer	Crusher	Solid	298	Water	3975602.00
					Fats	3214.31
					Carbohydrates	171542.53
					Fiber	50752.23
					Potassium	5464.32
					Phosphor	744.37
					Sodium	592.11
					Calcium	456.77
					Magnesium	253.76
					Vitamin C	157.33
					Vitamin A	3400.40
					Vitamin B 6	2.37

					Niacin	15.56
					Folic acid	236.84
					Dirty particles	0.00
					Additives	0.00
D	Crusher	Mixer	Solid	298	Water	3975602.00
					Fats	3214.31
					Carbohydrates	171542.53
					Fiber	50752.23
					Potassium	5464.32
					Phosphor	744.37
					Sodium	592.11
					Calcium	456.77
					Magnesium	253.76
					Vitamin C	157.33
					Vitamin A	3400.40
					Vitamin B 6	2.37
					Niacin	15.56
					Folic acid	236.84
					Dirty particles	0.00
					Additives	0.00
E	Input	Mixer	Solid	298	Addt	54761.65
F	Mixer	Dryer	Solid	298	Water	3975602.00
					Fats	3214.31

					Carbohydrates	171542.53
					Fiber	50752.23
					Potassium	5464.32
					Phosphor	744.37
					Sodium	592.11
					Calcium	456.77
					Magnesium	253.76
					Vitamin C	157.33
					Vitamin A	3400.40
					Vitamin B 6	2.37
					Niacin	15.56
					Folic acid	236.84
					Dirty particles	0.00
					Additives	54761.65
G	Dryer	Grinder	Solid	318	Water	775204.58
					Fats	3214.31
					Carbohydrates	171542.53
					Fiber	50752.23
					Potassium	5464.32
					Phosphor	744.37
					Sodium	592.11
					Calcium	456.77
					Magnesium	253.76
					Vitamin C	157.33
					Vitamin A	3400.40

					Vitamin B 6	2.37
					Niacin	15.56
					Folic acid	236.84
					Dirty particles	0.00
					Additives	54761.65
11	Grinder	Sieve	Solid	318	Water	775204.58
					Fats	3214.31
					Carbohydrates	171542.53
					Fiber	50752.23
					Potassium	5464.32
					Phosphor	744.37
					Sodium	592.11
					Calcium	456.77
					Magnesium	253.76
					Vitamin C	157.33
					Vitamin A	3400.40
					Vitamin B 6	2.37
					Niacin	15.56
					Folic acid	236.84
					Dirty particles	0.00
					Additives	54761.65
1	Sieve	Storage	Solid	318	Water	775204.58
					Fats	3214.31
					Carbohydrates	171542.53

					Fiber	0.00
					Potassium	5464.32
					Phosphor	744.37
					Sodium	592.11
					Calcium	456.77
					Magnesium	253.76
					Vitamin C	157.33
					Vitamin A	3400.40
					Vitamin B 6	2.37
					Niacin	15.56
					Folic acid	236.84
					Dirty particles	0.00
					Additives	54761.65
J	Sieve	Bin	Solid	318	Fiber	50752.23

CHAPTER THREE

TERIAL BALANCES FOR THE PRODUCTION OF CARROT POWDER FROM CARROT

100 kg/day of carrot to be processed

position of carrot

ponents	wt percent
r	85.0006
	0.1900
ohydrates	10.1400
	3.0000
ssium	0.3230
phor	0.0440
um	0.0350
ium	0.0270
nesium	0.0150
min C	0.0093
min A	0.2010
min B 6	0.0001
in	0.0009
acid	0.0140
particles	1.0000
l	100.0000

All percentage addition of materials like the water and additivies are based on the weight of the carrot

nces across the units

t 1: Washer

eration: Washing of the carrot using water to remove the dirty particles

umption: 150% of water is added

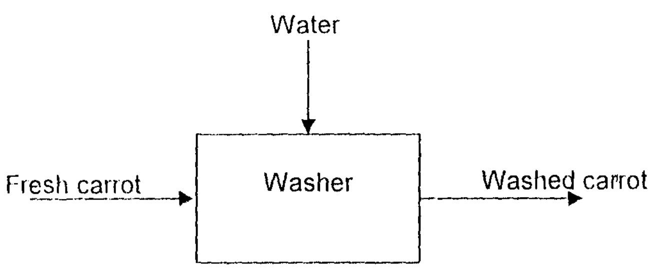


Fig. 3.1: Flows around the washer

	Input			Output		
mponents	kg/day	kg/annum	wt%	kg/day	kg/annum	wt%
ater	85.0006	1437990.6113	85.0006	235.0006	3975601.9950	94.3778
ts	0.1900	3214.3078	0.1900	0.1900	3214.3078	0.0763
arbohydrates	10.1400	171542.5295	10.1400	10.1400	171542.5295	4.0723
ber	3.0000	50752.2277	3.0000	3.0000	50752.2277	1.2048
otassium	0.3230	5464.3232	0.3230	0.3230	5464.3232	0.1297
hosphor	0.0440	744.3660	0.0440	0.0440	744.3660	0.0177
odium	0.0350	592.1093	0.0350	0.0350	592.1093	0.0141
alcium	0.0270	456.7700	0.0270	0.0270	456.7700	0.0108
agnesium	0.0150	253.7611	0.0150	0.0150	253.7611	0.0060
itamin C	0.0093	157 3319	0.0093	0.0093	157.3319	0.0037
itamin A	0.2010	3400.3993	0.2010	0.2010	3400.3993	0.0807
itamin B 6	0.0001	2.3684	0.0001	0.0001	2.3684	0.0001
iacin	0.0009	15.5640	0.0009	0.0009	15.5640	0.0004
olic acid	0.0140	236.8437	0.0140	0.0140	236.8437	0.0056
irty particles	1.0000	16917.4092	1.0000	0.0000	0.0000	0.0000
dditives	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
otal	100.0000	1691740.9225	100.0000	249.0000	4212434.8970	100.0000

Crusher

tion: Reduction of the size of the carrot

mption: No loss during the crushing operation

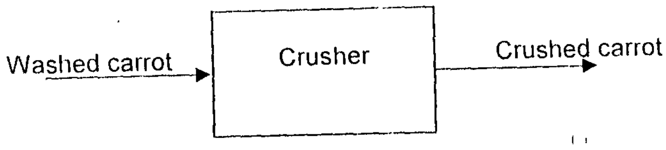


Fig. 3.2: Flows around the crusher

	Input			Output		
nponents	kg/day	kg/annum	wt%	kg/day	kg/annum	wt%
er	235.0006	3975601.9950	94.3778	235.0006	3975601.9950	94.3778
	0.1900	3214.3078	0.0763	0.1900	3214.3078	0.0763
bohydrates	10.1400	171542.5295	4.0723	10.1400	171542.5295	4.0723
er	3.0000	50752.2277	1.2048	3.0000	50752.2277	1.2048
assium	0.3230	5464.3232	0.1297	0.3230	5464.3232	0.1297
sphor	0.0440	744.3660	0.0177	0.0440	744.3660	0.0177
ium	0.0350	592.1093	0.0141	0.0350	592.1093	0.0141
cium	0.0270	456.7700	0.0108	0.0270	456.7700	0.0108
gnesium	0.0150	253.7611	0.0060	0.0150	253.7611	0.0060
min C	0.0093	157.3319	0.0037	0.0093	157.3319	0.0037
min A	0.2010	3400.3993	0.0807	0.2010	3400.3993	0.0807
min B 6	0.0001	2.3684	0.0001	0.0001	2.3684	0.0001
cin	0.0009	15.5640	0.0004	0.0009	15.5640	0.0004
c acid	0.0140	236.8437	0.0056	0.0140	236.8437	0.0056
y particles	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
litives	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
al	249.0000	4212434.8970	100.0000	249.0000	4212434.8970	100.0000

t 3: Mixer

eration: Addition of benzoic acid and acetic acid as preservatives

sumption: 1.3% additives are added to the carrot

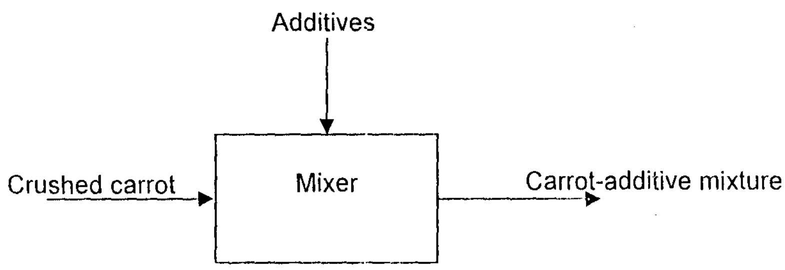


Fig. 3.3: Flows around the mixer

	Input			Output		
mponents	kg/day	kg/annum	wt%	kg/day	kg/annum	wt%
ater	235.0006	3975601.9950	94.3778	235.0006	3975601.9950	93.1666
s	0.1900	3214.3078	0.0763	0.1900	3214.3078	0.0753
rbohydrates	10.1400	171542.5295	4.0723	10.1400	171542.5295	4.0200
er	3.0000	50752.2277	1.2048	3.0000	50752.2277	1.1894
tassium	0.3230	5464.3232	0.1297	0.3230	5464.3232	0.1281
osphor	0.0440	744.3660	0.0177	0.0440	744.3660	0.0174
dium	0.0350	592.1093	0.0141	0.0350	592.1093	0.0139
lcium	0.0270	456.7700	0.0108	0.0270	456.7700	0.0107
gnesium	0.0150	253.7611	0.0060	0.0150	253.7611	0.0059
amin C	0.0093	157.3319	0.0037	0.0093	157.3319	0.0037
amin A	0.2010	3400.3993	0.0807	0.2010	3400.3993	0.0797
amin B 6	0.0001	2.3684	0.0001	0.0001	2.3684	0.0001
acin	0.0009	15.5640	0.0004	0.0009	15.5640	0.0004
lic acid	0.0140	236.8437	0.0056	0.0140	236.8437	0.0056
ty particles	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
dditives	0.0000	0.0000	0.0000	3.2370	54761.6537	1.2833
tal	249.0000	4212434.8970	100.0000	252.2370	4267196.5507	100.0000

yer
n: Removal of moisture from the carrot
ption: 75% loss of water

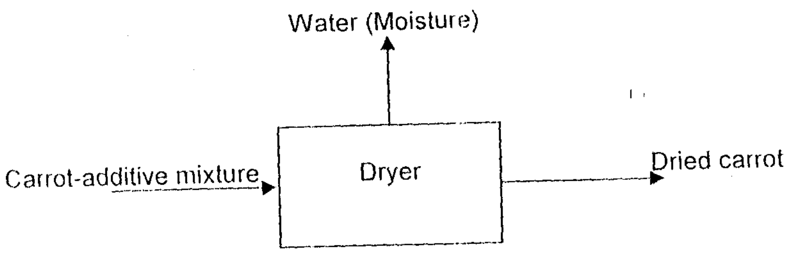


Fig. 3.4: Flows around the dryer

	Input			Output		
ponents	kg/day	kg/annum	wt%	kg/day	kg/annum	wt%
er	235.0006	3975601.9950	93.1666	45.8229	775204.5820	72.6664
	0.1900	3214.3078	0.0753	0.1900	3214.3078	0.3013
ohydrates	10.1400	171542.5295	4.0200	10.1400	171542.5295	16.0801
r	3.0000	50752.2277	1.1894	3.0000	50752.2277	4.7574
ssium	0.3230	5464.3232	0.1281	0.3230	5464.3232	0.5122
sphor	0.0440	744.3660	0.0174	0.0440	744.3660	0.0698
ium	0.0350	592.1093	0.0139	0.0350	592.1093	0.0555
cium	0.0270	456.7700	0.0107	0.0270	456.7700	0.0428
gnesium	0.0150	253.7611	0.0059	0.0150	253.7611	0.0238
min C	0.0093	157.3319	0.0037	0.0093	157.3319	0.0147
min A	0.2010	3400.3993	0.0797	0.2010	3400.3993	0.3187
min B 6	0.0001	2.3684	0.0001	0.0001	2.3684	0.0002
cin	0.0009	15.5640	0.0004	0.0009	15.5640	0.0015
c acid	0.0140	236.8437	0.0056	0.0140	236.8437	0.0222
y particles	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
litives	3.2370	54761.6537	1.2833	3.2370	54761.6537	5.1333
al	252.2370	4267196.5507	100.0000	63.0593	1066799.1377	100.0000

it 5: Grinder
eration: Grinding of carrot into powder
sumption: No loss of material

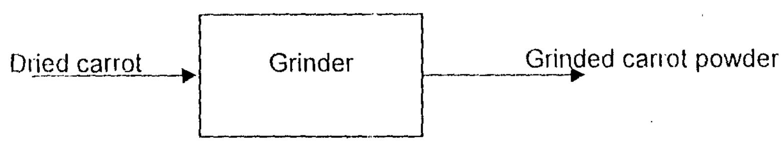


Fig. 3.5: Flows around the grinder

	Input			Output		
omponents	kg/day	kg/annum	wt%	kg/day	kg/annum	wt%
ater	45.8229	775204.5820	72.6664	45.8229	775204.5820	72.6664
ats	0.1900	3214.3078	0.3013	0.1900	3214.3078	0.3013
arbohydrates	10.1400	171542.5295	16.0801	10.1400	171542.5295	16.0801
iber	3.0000	50752.2277	4.7574	3.0000	50752.2277	4.7574
otassium	0.3230	5464.3232	0.5122	0.3230	5464.3232	0.5122
hosphor	0.0440	744.3660	0.0698	0.0440	744.3660	0.0698
odium	0.0350	592.1093	0.0555	0.0350	592.1093	0.0555
alcium	0.0270	456.7700	0.0428	0.0270	456.7700	0.0428
agnesium	0.0150	253.7611	0.0238	0.0150	253.7611	0.0238
itamin C	0.0093	157.3319	0.0147	0.0093	157.3319	0.0147
itamin A	0.2010	3400.3993	0.3187	0.2010	3400.3993	0.3187
itamin B 6	0.0001	2.3684	0.0002	0.0001	2.3684	0.0002
iacin	0.0009	15.5640	0.0015	0.0009	15.5640	0.0015
olic acid	0.0140	236.8437	0.0222	0.0140	236.8437	0.0222
irty particles	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
dditives	3.2370	54761.6537	5.1333	3.2370	54761.6537	5.1333
otal	63.0593	1066799.1377	100.0000	63.0593	1066799.1377	100.0000

Sieve

tion: Separation of the residue (especially the fiber) from the carrot powder

nption: Total removal of the fiber

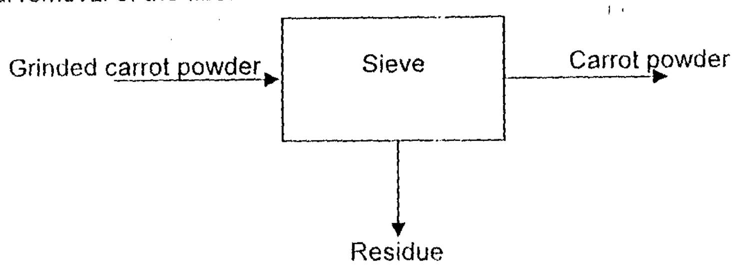


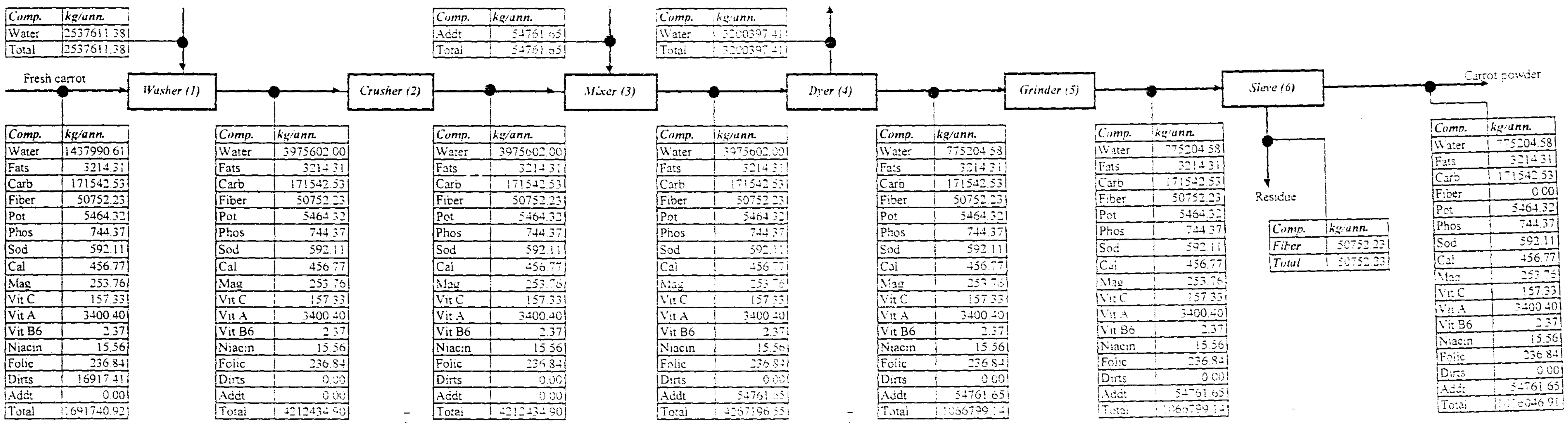
Fig. 3.6: Flows around the sieve

	Input			Output		
ponents	kg/day	kg/annum	wt%	kg/day	kg/annum	wt%
er	45.8229	775204.5820	72.6664	45.8229	775204.5820	76.2961
	0.1900	3214.3078	0.3013	0.1900	3214.3078	0.3164
bohydrates	10.1400	171542.5295	16.0801	10.1400	171542.5295	16.8833
er	3.0000	50752.2277	4.7574	0.0000	0.0000	0.0000
assium	0.3230	5464.3232	0.5122	0.3230	5464.3232	0.5378
sphor	0.0440	744.3660	0.0698	0.0440	744.3660	0.0733
lium	0.0350	592.1093	0.0555	0.0350	592.1093	0.0583
cium	0.0270	456.7700	0.0428	0.0270	456.7700	0.0450
gnesium	0.0150	253.7611	0.0238	0.0150	253.7611	0.0250
amin C	0.0093	157.3319	0.0147	0.0093	157.3319	0.0155
amin A	0.2010	3400.3993	0.3187	0.2010	3400.3993	0.3347
amin B 6	0.0001	2.3684	0.0002	0.0001	2.3684	0.0002
cin	0.0009	15.5640	0.0015	0.0009	15.5640	0.0015
ic acid	0.0140	236.8437	0.0222	0.0140	236.8437	0.0233
ty particles	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
ditives	3.2370	54761.6537	5.1333	3.2370	54761.6537	5.3897
tal	63.0593	1066799.1377	100.0000	60.0593	1016046.9100	100.0000

alcualation of scale up factor

onversion	1 ton =	1016.0469
	annum	335.0000
arrot powder production rate =		1000.0000
hich is the equal to		1016046.9100
nd also the same as		3032.9759
arrot powder obtained from the basis =		60.0593
cale up factor =		50.4997

FLOWSHEET FOR THE PRODUCTION OF CARROT POWDER FROM CARROT



Comp.	kg/ann.
Water	2537611.38
Total	2537611.38

Comp.	kg/ann.
Water	1437990.61
Fats	3214.31
Carb	171542.53
Fiber	50752.23
Pot	5464.32
Phos	744.37
Sod	592.11
Cal	456.77
Mag	253.76
Vit C	157.33
Vit A	3400.40
Vit B6	2.37
Niacin	15.56
Folic	236.84
Dirts	16917.41
Addt	0.00
Total	1691740.92

Comp.	kg/ann.
Water	3975602.00
Fats	3214.31
Carb	171542.53
Fiber	50752.23
Pot	5464.32
Phos	744.37
Sod	592.11
Cal	456.77
Mag	253.76
Vit C	157.33
Vit A	3400.40
Vit B6	2.37
Niacin	15.56
Folic	236.84
Dirts	0.00
Addt	0.00
Total	4212434.90

Comp.	kg/ann.
Addt	54761.65
Total	54761.65

Comp.	kg/ann.
Water	3975602.00
Fats	3214.31
Carb	171542.53
Fiber	50752.23
Pot	5464.32
Phos	744.37
Sod	592.11
Cal	456.77
Mag	253.76
Vit C	157.33
Vit A	3400.40
Vit B6	2.37
Niacin	15.56
Folic	236.84
Dirts	0.00
Addt	0.00
Total	4212434.90

Comp.	kg/ann.
Water	3200397.41
Total	3200397.41

Comp.	kg/ann.
Water	3975602.00
Fats	3214.31
Carb	171542.53
Fiber	50752.23
Pot	5464.32
Phos	744.37
Sod	592.11
Cal	456.77
Mag	253.76
Vit C	157.33
Vit A	3400.40
Vit B6	2.37
Niacin	15.56
Folic	236.84
Dirts	0.00
Addt	54761.65
Total	4267196.55

Comp.	kg/ann.
Water	775204.58
Fats	3214.31
Carb	171542.53
Fiber	50752.23
Pot	5464.32
Phos	744.37
Sod	592.11
Cal	456.77
Mag	253.76
Vit C	157.33
Vit A	3400.40
Vit B6	2.37
Niacin	15.56
Folic	236.84
Dirts	0.00
Addt	54761.65
Total	1066799.14

Comp.	kg/ann.
Water	775204.58
Fats	3214.31
Carb	171542.53
Fiber	50752.23
Pot	5464.32
Phos	744.37
Sod	592.11
Cal	456.77
Mag	253.76
Vit C	157.33
Vit A	3400.40
Vit B6	2.37
Niacin	15.56
Folic	236.84
Dirts	0.00
Addt	54761.65
Total	1066799.14

Comp.	*kg/ann.*
Fiber	50752.23
Total	50752.23

Comp.	kg/ann.
Water	775204.58
Fats	3214.31
Carb	171542.53
Fiber	0.00
Pot	5464.32
Phos	744.37
Sod	592.11
Cal	456.77
Mag	253.76
Vit C	157.33
Vit A	3400.40
Vit B6	2.37
Niacin	15.56
Folic	236.84
Dirts	0.00
Addt	54761.65
Total	1016046.91

Fig. 2. Flow sheet for the production of carrot powder from carrot

CHAPTER THREE

3.2 Energy balances

Assumptions:

In carrying out the energy balances, the following assumptions are made:

- The dryer is the only unit that has energy changes, so it is the only unit around which the energy balances will be carried out.
- The datum temperature is 298K.
- The drier is 99% efficient.

3.2.1 Energy balances around the dryer

Given that,

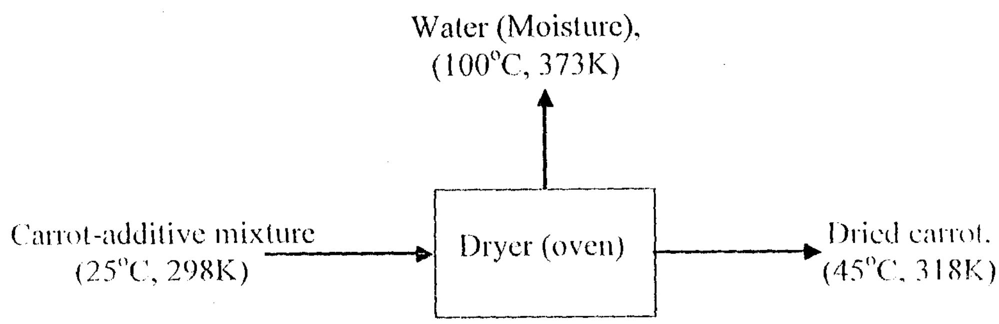


Fig. 3.7: Energy flows around the dryer

The mass of materials around the dryer is given as

$$M_i := \begin{pmatrix} 3975601.9950 \\ 3214.3078 \\ 171542.5295 \\ 50752.2277 \\ 5464.3232 \\ 744.3660 \\ 592.1093 \\ 456.7700 \\ 253.7611 \\ 157.3319 \\ 3400.3993 \\ 2.3684 \\ 15.5640 \\ 236.8437 \\ 0.0000 \\ 54761.6537 \end{pmatrix} \cdot \frac{kg}{annum} \qquad \begin{pmatrix} \text{Water} \\ \text{Fats} \\ \text{Carbohydrates} \\ \text{Fiber} \\ \text{Potassium} \\ \text{Phosphor} \\ \text{Sodium} \\ \text{Calcium} \\ \text{Magnesium} \\ \text{"Vitamin C"} \\ \text{"Vitamin A "} \\ \text{"Vitamin B 6 "} \\ \text{Niacin} \\ \text{"Folic acid "} \\ \text{"Dirty particles"} \\ \text{Additives} \end{pmatrix} \qquad M_o := \begin{pmatrix} 775204.5820 \\ 3214.3078 \\ 171542.5295 \\ 50752.2277 \\ 5464.3232 \\ 744.3660 \\ 592.1093 \\ 456.7700 \\ 253.7611 \\ 157.3319 \\ 3400.3993 \\ 2.3684 \\ 15.5640 \\ 236.8437 \\ 0.0000 \\ 54761.6537 \end{pmatrix} \cdot \frac{kg}{annum}$$

The mass of carrot in the dryer is $\sum M_i = 4.267 \times 10^6 \frac{kg}{annum}$

That is, $carrot_{in} := \sum M_i$

Mass of water in the carrot entering the dryer is $water_{in\_carrot} := M_{i_1}$

$$water_{in\_carrot} = 3.976 \times 10^6 \frac{kg}{annum}$$

Mass of water in the carrot leaving the dryer is $water_{out\_carrot} := M_{o_1}$

$$water_{out\_carrot} = 7.752 \times 10^5 \frac{kg}{annum}$$

Hence, water removed by the dryer is calculated as

$$water\_removed := water_{in\_carrot} - water_{out\_carrot}$$

$$water\_removed = 3.2 \times 10^6 \frac{kg}{annum}$$

Oven temperature, $T_{oven} := 318 \cdot K$

Inlet temperature of carrot $T_{carrot\_in} := 298 \cdot K$

Outlet temperature of carrot, $T_{feed\_out} := 318 \cdot K$

The heat capacity of carrot is calculated using the heat capacities of water and carbohydrates

because they are the main constituents of carrot.

For water,

$$C_{pw} = \left[\frac{19.2964}{18} + \frac{47.212 \cdot 10^{-2}}{18} \cdot \left(\frac{T}{K}\right) - \frac{133.88 \cdot 10^{-5}}{18} \cdot \left(\frac{T}{K}\right)^2 + \frac{1314.2 \cdot 10^{-9}}{18} \cdot \left(\frac{T}{K}\right)^3\right] \cdot \frac{kJ}{kg \cdot K}$$

Considering the fraction of water in the carrot, which is 0.85 (85%)

$$C_{pw} = \left[\frac{19.2964}{18} + \frac{47.212 \cdot 10^{-2}}{18} \cdot \left(\frac{T}{K}\right) - \frac{133.88 \cdot 10^{-5}}{18} \cdot \left(\frac{T}{K}\right)^2 + \frac{1314.2 \cdot 10^{-9}}{18} \cdot \left(\frac{T}{K}\right)^3\right] \cdot 0.85 \cdot \frac{kJ}{kg \cdot K}$$

$$C_{pw} = \left[0.911 + 0.022 \cdot \left(\frac{T}{K}\right) - 6.322 \cdot 10^{-5} \cdot \left(\frac{T}{K}\right)^2 + 6.206 \cdot 10^{-8} \cdot \left(\frac{T}{K}\right)^3\right] \cdot \frac{kJ}{kg \cdot K}$$

For carbohydrates,

$$C_{pcarb} = 0.301 \cdot \left(\frac{T}{K}\right) \cdot \frac{kJ}{kg \cdot K}$$

Considering the fraction of water in the carrot, which is 0.1014 (10.14%)

$$C_{pcarb} = 0.301 \cdot \left(\frac{T}{K}\right) \cdot 0.1014 \cdot \frac{kJ}{kg \cdot K}$$

$$C_{pcarb} = 0.031 \cdot \left(\frac{T}{K}\right) \cdot \frac{kJ}{kg \cdot K}$$

So, the heat capacity of carrot is then given as

$$C_{pc} = \left[0.911 + 0.053 \cdot \left(\frac{T}{K}\right) - 6.322 \cdot 10^{-5} \cdot \left(\frac{T}{K}\right)^2 + 6.206 \cdot 10^{-8} \cdot \left(\frac{T}{K}\right)^3\right] \cdot \frac{kJ}{kg \cdot K}$$

With the oven temperature of

$$T_{oven} = 318\,K \qquad T := T_{oven}$$

$$C_{pcarrot} := \left[0.911 + 0.053 \cdot \left(\frac{T}{K}\right) - 6.322 \cdot 10^{-5} \cdot \left(\frac{T}{K}\right)^2 + 6.206 \cdot 10^{-8} \cdot \left(\frac{T}{K}\right)^3\right] \cdot \frac{kJ}{kg \cdot K}$$

$$C_{pcarrot} = 13.368 \frac{kJ}{kg \cdot K}$$

According to assumption No. 2, the reference temperature, $T_{ref} := 298K$

The heat required to raise the temperature of carrot from 298K to 318K is calculated thus;

$$carrot_{in} = 4.267 \times 10^6 \frac{kg}{annum} \qquad T_{ref} = 298\,K \qquad T_o := 318 \cdot K$$

$$C_{pcarrot} = 13.368 \frac{kJ}{kg \cdot K}$$

$$H_{carrot} := carrot_{in} \cdot C_{pcarrot} \cdot (T_o - T_{ref}) \qquad H_{carrot} = 1.141 \times 10^9 \frac{kJ}{annum}$$

From Basic Principles and Calculations in Chemical Engineering, Table C.1, page

646, the latent heat of water at (100°C, 212 °F)was found to be

$$\lambda_{water} := 970.3 \cdot \frac{BTU}{lb}$$

which is equal to

$$\lambda_{water} = 2.257 \times 10^{3} \frac{kJ}{kg}$$

$$H_{water} := water\_removed \cdot \lambda_{water}$$

$$H_{water} = 7.223 \times 10^{9} \frac{kJ}{annum}$$

The total heat of the dryer is then given as

$$H_{dryer} := H_{carrot} + H_{water}$$

$$H_{dryer} = 8.364 \times 10^{9} \frac{kJ}{annum}$$

3.3 *Specification of equipments*

3.3.1 *Specification of washer*

The washer vessel is to be designed as a cylindrical vessel to contain the carrot to be washed

in order to remove the dirty particles in the carrot. As such, it is desired to determine the volume

of the washer to accommodate the carrot.
The amount and densities of the materials in the washer as

	Mass in kg	Density in kg/m³
Water	85.0006	1000
Fats	0.1900	970
Carbohydrates	10.1400	680
Fiber	3.0000	1130
Potassium	0.3230	860
Phosphor	0.0440	1820
Sodium	0.0350	970
Calcium	0.0270	1550
Magnesium	0.0150	1740
"Vitamin C"	0.0093	1207
"Vitamin A "	0.2010	1059
"Vitamin B 6 "	0.0001	1045
Niacin	0.0009	1290
"Folic acid "	0.0140	1429
"Dirty particles"	1.0000	1300
Additives	0.0000	1266

$M :=$ (mass vector) $\cdot kg$ $\qquad \rho :=$ (density vector) $\cdot \frac{kg}{m^3}$

Calculating, the average density of the mixture is

$$\rho_{av} := \frac{\left(M_1 \cdot \rho_1 + M_2 \cdot \rho_2 + M_3 \cdot \rho_3 + M_4 \cdot \rho_4 + M_5 \cdot \rho_5 + M_6 \cdot \rho_6 + M_7 \cdot \rho_7 + M_8 \cdot \rho_8 + M_9 \cdot \rho_9 \ldots + M_{10} \cdot \rho_{10} + M_{11} \cdot \rho_{11} + M_{12} \cdot \rho_{12} + M_{13} \cdot \rho_{13} + M_{14} \cdot \rho_{14} + M_{15} \cdot \rho_{15} + M_{16} \cdot \rho_{16}\right)}{\left(\sum M\right)}$$

$$\rho_{av} = 974.753 \frac{kg}{m^3}$$

So, the volume of washer is

$$V_{washer} := \frac{\sum M}{\rho_{av}} \qquad V_{washer} = 4.931\, m^3$$

Taking the washer to be cylindrical, this means that, from the formula of a cylinder,

$V = \pi \cdot r^2 \cdot h$ (Mathematical Four Figure Tables) and, since

$$r = \frac{d}{2}$$

$$V = \pi \cdot \left(\frac{d}{2}\right)^2 \cdot h$$

$$V = \pi \cdot \frac{d^2}{4} \cdot h$$

Let h = pd, where p is a constant

Therefore,

$$V = \pi \cdot \frac{d^2}{4} \cdot (p \cdot d)$$

$$4 \cdot V = p \cdot \pi \cdot d^3$$

Making d the subject of the formular

$$d = \left(\frac{4 \cdot V}{p \cdot \pi}\right)^{\frac{1}{3}}$$

assuming that $p := 1.55$

$$d_{washer} := \left(\frac{4 \cdot V_{washer}}{p \cdot \pi}\right)^{\frac{1}{3}} \qquad d_{washer} = 1.594\,m$$

From

$$h_{washer} := p \cdot d_{washer} \qquad h_{washer} = 2.471\,m$$

The area of the dilution tank is therefore,

$$A_{washer} := 2\pi \cdot \frac{d_{washer}}{2} \cdot h_{washer} + 2\pi \cdot \left(\frac{d_{washer}}{2}\right)^2 \qquad A_{washer} = 16.364\,m^2$$

It should be noted the washer will have something like an agitator inside which will ensure proper

mixing of the carrot and the water for good washing operation. The design of the agitator is as

outlined thus;
The power of washer is given as

$$P = \frac{K_2}{g_c} \cdot \mu \cdot (N)^2 \cdot (D)^3 \qquad \text{(Applied Process Design)}$$

where K_2 is a consant

N is the speed of the agitator

D is the diameter of the agitator

m is the viscosity of the liquid

Knowing that

$$g_c := \frac{1kg \cdot m}{newton \cdot s^2}$$

$$K_2 := 215.00$$

$$\mu := 1 \cdot 10^{-2} \cdot \frac{kg}{m \cdot s}$$

$$D := 0.50 \cdot m$$

$$N := 90 \cdot \frac{rad}{s}$$

$$P_{washer} := \frac{K_2}{g_c} \cdot \mu \cdot (N)^2 \cdot (D)^3$$ (Applied Process Design)

$$P_{washer} = 2.177 kW$$

For the voltage of 150V, the amount of current required is

$$Vol_{washer} := 210 \cdot volt$$

$$P_{washer} = I_{washer} \cdot Vol_{washer}$$

$$I_{washer} := \frac{P_{washer}}{Vol_{washer}}$$

$$I_{washer} = 10.366 A$$

3.3.2 *Specification of crusher*

Given the amount of materials in the crusher:

$$
\begin{pmatrix} \text{Water} \\ \text{Fats} \\ \text{Carbohydrates} \\ \text{Fiber} \\ \text{Potassium} \\ \text{Phosphor} \\ \text{Sodium} \\ \text{Calcium} \\ \text{Magnesium} \\ \text{"Vitamin C"} \\ \text{"Vitamin A "} \\ \text{"Vitamin B 6 "} \\ \text{Niacin} \\ \text{"Folic acid "} \\ \text{"Dirty particles"} \\ \text{Additives} \end{pmatrix}
\qquad
\text{Mass in kg} \quad M := \begin{pmatrix} 235.0006 \\ 0.1900 \\ 10.1400 \\ 3.0000 \\ 0.3230 \\ 0.0440 \\ 0.0350 \\ 0.0270 \\ 0.0150 \\ 0.0093 \\ 0.2010 \\ 0.0001 \\ 0.0009 \\ 0.0140 \\ 0.0000 \\ 0.0000 \end{pmatrix} \cdot kg
\qquad
\text{Density in kg/m}^3 \quad \rho := \begin{pmatrix} 1000 \\ 970 \\ 680 \\ 1130 \\ 860 \\ 1820 \\ 970 \\ 1550 \\ 1740 \\ 1207 \\ 1059 \\ 1045 \\ 1290 \\ 1429 \\ 1300 \\ 1266 \end{pmatrix} \cdot \frac{kg}{m^3}
$$

The average density of the mixture in the crusher is calculated thus:

$$\rho_{av} := \frac{\begin{pmatrix} M_1 \cdot \rho_1 + M_2 \cdot \rho_2 + M_3 \cdot \rho_3 + M_4 \cdot \rho_4 + M_5 \cdot \rho_5 + M_6 \cdot \rho_6 + M_7 \cdot \rho_7 + M_8 \cdot \rho_8 + M_9 \cdot \rho_9 \ldots \\ + M_{10} \cdot \rho_{10} + M_{11} \cdot \rho_{11} + M_{12} \cdot \rho_{12} + M_{13} \cdot \rho_{13} + M_{14} \cdot \rho_{14} + M_{15} \cdot \rho_{15} + M_{16} \cdot \rho_{16} \end{pmatrix}}{\left(\sum M\right)}$$

$$\rho_{av} = 988.656 \frac{kg}{m^3}$$

So, the volume is

$$V_{crusher} := \frac{\sum M}{\rho_{av}} \qquad V_{crusher} = 3.613\, m^3$$

The volume given is the volume of the crusher without considering the volume that will be

occupied by the rolls. Considering the rolls, the volume of the crusher occupied by the rolls

can be given as

$$Q = \frac{(d \cdot L \cdot S)}{2.96 \cdot s^{-1}} \qquad \text{(Perry, 1998)}$$

where

Q is the capacity of the crusher rolls in cm^3/min

d is the distance between the rolls, cm

L is the length of rolls, cm

s is the peripheral speed, cm/min

Now, if

$d := 5 \cdot cm$

$L' := 6.1 \cdot cm$

$S := 29500 \cdot \frac{cm}{min}$

$Q_{crusher} := \frac{(d \cdot L' \cdot S)}{2.96 \cdot s^{-1}}$ $\qquad Q_{crusher} = 5.066 \times 10^{-3} m^3$

The total volume of the crusher is thus

$V_{Tcrusher} := V_{crusher} + Q_{crusher}$ $\qquad V_{Tcrusher} = 3.618 m^3$

Assuming that the crusher is cylindrical, this implies that

$V = \pi \cdot r^2 \cdot h$ (Mathematical Four Figure Tables)

and, since

$r = \frac{d}{2}$

$V = \pi \cdot \left(\frac{d}{2}\right)^2 \cdot h$

$V = \pi \cdot \frac{d^2}{4} \cdot h$

Let h = pd, where p is a constant

substituting for h,

$V = \pi \cdot \frac{d^2}{4} \cdot (p \cdot d)$

$4 \cdot V = p \cdot \pi \cdot d^3$

Making d the subject of the formular

$$d = \left(\frac{4 \cdot V}{p \cdot \pi}\right)^{\frac{1}{3}}$$

assuming that $p := 1.23$ and knowing that $V_{Tcrusher} := V_{Tcrusher}$

$$d_{crusher} := \left(\frac{4 \cdot V_{Tcrusher}}{p \cdot \pi}\right)^{\frac{1}{3}} \qquad d_{crusher} = 1.553\,m$$

From

$$h_{crusher} := p \cdot d_{crusher} \qquad h_{crusher} = 1.91\,m$$

The area of the crusher is therefore,

$$A_{crusher} := 2\pi \cdot \frac{d_{crusher}}{2} \cdot h_{crusher} + 2\pi \cdot \left(\frac{d_{crusher}}{2}\right)^2 \qquad A_{crusher} = 13.108\,m^2$$

The net power to drive a roll ball was found to be

$$E = [(1.64 \cdot L - 1) \cdot K + 1] \cdot (1.64 \cdot D)^{2.5} \cdot E_2$$

(Perry, 1998)

where

E is the net power to drive a roll

L is the inside length of the crusher, m

D is the mean inside diameter of the crusher, m

E_2 is the net power used by a 0.6-m laboratory roll under similar operating conditions

K is a constant which is 0.9 for rolls less than 1.5m long and 0.85 for mills over 1.5m long

Choosing

$$L = 1 \times 10^{-3}\,m^3$$

$$K := 0.93$$

$$D := d_{crusher}$$

$$E_2 := 11.5 \cdot W$$

So,

$$E = [(1.64 \cdot L - 1) \cdot K + 1] \cdot (1.64 \cdot D)^{2.5} \cdot E_2 \qquad E_{roll} = 19.41\,W$$

3.3.3 *Specification of mixer*

Given that the amount of materials in the mixer is

	Mass in kg	Density in kg/m³
Water	235.0006	1000
Fats	0.1900	970
Carbohydrates	10.1400	680
Fiber	3.0000	1130
Potassium	0.3230	860
Phosphor	0.0440	1820
Sodium	0.0350	970
Calcium	0.0270	1550
Magnesium	0.0150	1740
"Vitamin C"	0.0093	1207
"Vitamin A "	0.2010	1059
"Vitamin B 6 "	0.0001	1045
Niacin	0.0009	1290
"Folic acid "	0.0140	1429
"Dirty particles"	0.0000	1300
Additives	0.0000	1266

$M :=$ (mass column) $\cdot kg$ $\qquad \rho :=$ (density column) $\cdot \frac{kg}{m^3}$

The average density of the mixture in the crusher is calculated thus;

$$\rho_{av} := \frac{\left(\begin{array}{l} M_1 \cdot \rho_1 + M_2 \cdot \rho_2 + M_3 \cdot \rho_3 + M_4 \cdot \rho_4 + M_5 \cdot \rho_5 + M_6 \cdot \rho_6 + M_7 \cdot \rho_7 + M_8 \cdot \rho_8 + M_9 \cdot \rho_9 \ldots \\ + M_{10} \cdot \rho_{10} + M_{11} \cdot \rho_{11} + M_{12} \cdot \rho_{12} + M_{13} \cdot \rho_{13} + M_{14} \cdot \rho_{14} + M_{15} \cdot \rho_{15} + M_{16} \cdot \rho_{16} \end{array}\right)}{\left(\sum M\right)}$$

$$\rho_{av} = 988.656 \frac{kg}{m^3}$$

The volume is

$$V_{mixer} := \frac{\sum M}{\rho_{av}} \qquad V_{mixer} = 3.613\,m^3$$

Assuming that the mixing tank is cylindrical, this implies that

$$V = \pi \cdot r^2 \cdot h$$ (Mathematical Four Figure Tables)

and, since

$$r = \frac{d}{2}$$

$$V = \pi \cdot \left(\frac{d}{2}\right)^2 \cdot h$$

$$V = \pi \cdot \frac{d^2}{4} \cdot h$$

Let h = pd, where k is a constant

substituting for h,

$$V = \pi \cdot \frac{d^2}{4} \cdot (p \cdot d)$$

$$4 \cdot V = p \cdot \pi \cdot d^3$$

Making d the subject of the formular

$$d = \left(\frac{4 \cdot V}{k \cdot \pi}\right)^{\frac{1}{3}}$$

assuming that $p := 1.05$

$$V_{mixer} := V_{mixer}$$

$$d_{mixer} := \left(\frac{4 \cdot V_{mixer}}{p \cdot \pi}\right)^{\frac{1}{3}} \qquad d_{mixer} = 1.636\,m$$

From

$$h_{mixer} := p \cdot d_{mixer} \qquad h_{mixer} = 1.718\,m$$

The area of the dilution tank is therefore,

$$A_{mixer} := 2\pi \cdot \frac{d_{mixer}}{2} \cdot h_{mixer} + 2\pi \cdot \left(\frac{d_{mixer}}{2}\right)^2 \qquad A_{mixer} = 13.039\,m^2$$

3.3.4 *Specification of dryer*

	Mass in kg	Mass out in kg
Water	235.0006	45.8229
Fats	0.1900	0.1900
Carbohydrates	10.1400	10.1400
Fiber	3.0000	3.0000
Potassium	0.3230	0.3230
Phosphor	0.0440	0.0440
Sodium	0.0350	0.0350
Calcium	0.0270	0.0270
Magnesium	0.0150	0.0150
"Vitamin C"	0.0093	0.0093
"Vitamin A "	0.2010	0.2010
"Vitamin B 6 "	0.0001	0.0001
Niacin	0.0009	0.0009
"Folic acid "	0.0140	0.0140
"Dirty particles"	0.0000	0.0000
Additives	0.0000	3.2370

$M_i :=$ (Mass in column) $\cdot kg$ $\qquad M_o :=$ (Mass out column) $\cdot kg$

Amount of water in feed, $water\_in := M_{i_1}$ $\qquad water\_in = 235.001\ kg$

Dry solid in feed, $solid := \sum M - M_{i_1}$ $\qquad solid = 3.337 \times 10^{1}\ kg$

Water content in product, $water\_out := M_{o_1}$ $\qquad water\_out = 45.823\ kg$

Hence, water removed in the dryer is

$water\_removed := water\_in - water\_out$ $\qquad water\_removed = 189.178\ kg$

Inlet air temperature, $T_{iair} := (100 + 273) \cdot K$

Outlet air temperature, $T_{oair} := (29 + 273) \cdot K$

Inlet temperature of feed, $T_{ifeed} := (31 + 273) \cdot K$

Discharge temperature, $T_d := (63 + 273) \cdot K$

Asssuming that the Number of Transfer Units (NTU) is

$NTU := 1.5$

Using the relationship of the NTU which is,

$$NTU = \ln\left[\frac{(t_{g1} - t_w)}{t_{g2} - t_w}\right] \qquad \text{(Joshi, 2002)}$$

$t_{g1} := T_{iair}$

$t_w := T_d$

$$t_{g2} := \frac{\left(\exp(NTU) \cdot t_w + t_{g1} - t_w\right)}{\exp(NTU)} \qquad t_{g2} = 320.158$$

The energy balance has shown that the total energy required to raise the product to the discharge temperature is

$$Q_t := 2.193 \times 10^6 \cdot \frac{kJ}{day}$$

The Log Mean Temperature Difference (LMTD) across the dryer, ΔT_m, is

$$\Delta T_m := \frac{\left[\left(T_{iair} - T_{ifeed}\right) - \left(T_d - T_{oair}\right)\right]}{\ln\left[\frac{\left(T_{iair} - T_{ifeed}\right)}{\left(T_d - T_{oair}\right)}\right]} \qquad \Delta T_m = 45.991$$

Amount of air required is calculated using the relatioship

$$Q_t = M \cdot C_p \cdot \Delta T$$

$$M = \frac{Q_t}{\left(C_p \cdot \Delta T\right)}$$

Given that

$$Q_t = 2.193 \times 10^6 \frac{kJ}{day}$$

$$C_p := 4.187 \cdot \frac{kJ}{kg \cdot K}$$

$$\Delta T := T_{iair} - T_{oair}$$

So,

$$M_{air} := \frac{Q_t}{\left(C_p \cdot \Delta T\right)} \qquad M_{air} = 7.377 \times 10^3 \frac{kg}{day}$$

If the velocity of air is taken to be

$$v_{air} := 2.9 \cdot 10^2 \cdot \frac{kg}{day \cdot m^2}$$

Area of dryer is thus calculated to be

$$A_{dryer} := \frac{M_{air}}{v_{air}} \qquad A_{dryer} = 25.438\ m^2$$

Using the formula for the area of dryer which is

$$A_{dryer} = \pi \cdot r_{dryer}^2$$

where A_{dryer} is the area of dryer

r_{dryer} is the radius of dryer

If d_{dryer} is used to denote the diameter of dryer,

$$A_{dryer} = \pi \cdot \left(\frac{d_{dryer}}{2}\right)^2$$

$$A_{dryer} = \pi \cdot \frac{d_{dryer}^2}{4}$$

$$4 \cdot A_{dryer} = \pi \cdot d_{dryer}^2$$

$$d_{dryer}^2 = \frac{4 \cdot A_{dryer}}{\pi}$$

The diameter of dryer is thus equal to

$$d_{dryer} := \sqrt{\frac{4 \cdot A_{dryer}}{\pi}} \qquad d_{dryer} = 5.691\,m$$

Length of transfer unit has been related to mass velocity and diameter by the following relation,

$$LTU = 0.00064 \cdot C_p \cdot (G)^{0.84} \cdot d_{dryer} \qquad \text{(Joshi, 2002)}$$

where G is the mass velocity which is equal to $G := v_{air}$, that is,

$$G = 290 \frac{kg}{day \cdot m^2}$$

So,

$$LTU := 0.00064 \cdot \frac{C_p}{\frac{kJ}{kg\,K}} \cdot \left(\frac{G}{\frac{kg}{day \cdot m^2}}\right)^{0.84} \cdot d_{dryer} \qquad LTU = 1.785\,m$$

Length of the dryer calculated from the formula which is given as

$$L_{dryer} := LTU \cdot NTU \qquad L_{dryer} = 2.678\,m$$

3.3.5 *Specification of grinder*

Given the amount of materials in the grinder to be

	Mass in kg	Density in kg/m³
Water	45.8229	1000
Fats	0.1900	970
Carbohydrates	10.1400	680
Fiber	3.0000	1130
Potassium	0.3230	860
Phosphor	0.0440	1820
Sodium	0.0350	970
Calcium	0.0270	1550
Magnesium	0.0150	1740
"Vitamin C"	0.0093	1207
"Vitamin A "	0.2010	1059
"Vitamin B 6 "	0.0001	1045
Niacin	0.0009	1290
"Folic acid "	0.0140	1429
"Dirty particles"	0.0000	1300
Additives	3.2370	1266

$M := (\ldots) \cdot kg \qquad \rho := (\ldots) \cdot \frac{kg}{m^3}$

The average density of the materials in the grinder is calculated as

$$\rho_{av} := \frac{\begin{pmatrix} M_1 \cdot \rho_1 + M_2 \cdot \rho_2 + M_3 \cdot \rho_3 + M_4 \cdot \rho_4 + M_5 \cdot \rho_5 + M_6 \cdot \rho_6 + M_7 \cdot \rho_7 + M_8 \cdot \rho_8 \ldots \\ + M_9 \cdot \rho_9 + M_{10} \cdot \rho_{10} + M_{11} \cdot \rho_{11} + M_{12} \cdot \rho_{12} + M_{13} \cdot \rho_{13} + M_{14} \cdot \rho_{14} + M_{15} \cdot \rho_{15} + M_{16} \cdot \rho_{16} \end{pmatrix}}{\left(\sum M\right)}$$

$$\rho_{av} = 968.86 \frac{kg}{m^3}$$

So, the volume is

$$V_{grinder} := \frac{\sum M}{\rho_{av}} \qquad V_{grinder} = 0.934\, m^3$$

The volume given is the volume of the grinder without considering the volume that will be

occupied by the rolls. Considering the rolls, the volume of the grinder occupied by the rolls can

be given as

$$Q = \frac{(d \cdot L' \cdot S)}{2.96 \cdot s^{-1}} \qquad \text{(Perry, 1998)}$$

where

Q is the apparentcapacity of the grinder in cm^3/min

d is the distance between the rolls, cm

L is the length of rolls, cm

s is the peripheral speed, cm/min

Now, if

$d := 5.5 \cdot cm$

$L' := 6.5 \cdot cm$

$S := 27500 \cdot \frac{cm}{min}$

$Q_{grinder} := \frac{(d \cdot L' \cdot S)}{2.96 \cdot s^{-1}}$

$Q_{grinder} = 5.536 \times 10^{-3} m^3$

The total volume of the grinder is thus

$V_{Tgrinder} := V_{grinder} + Q_{grinder}$

$V_{Tgrinder} = 0.939 m^3$

Assuming that the grinder is cylindrical, this implies that

$V = \pi \cdot r^2 \cdot h$ (Mathematical Four Figure Tables)

and, since

$r = \frac{d}{2}$

$V = \pi \cdot \left(\frac{d}{2}\right)^2 \cdot h$

$V = \pi \cdot \frac{d^2}{4} \cdot h$

Let h = pd, where p is a constant

substituting for h,

$V = \pi \cdot \frac{d^2}{4} \cdot (p \cdot d)$

$4 \cdot V = p \cdot \pi \cdot d^3$

Making d the subject of the formular

$$d = \left(\frac{4 \cdot V}{p \cdot \pi}\right)^{\frac{1}{3}}$$

assuming that $p := 1.83$ and knowing that $V_{Tgrinder} := V_{Tgrinder}$

$$d_{grinder} := \left(\frac{4 \cdot V_{Tgrinder}}{p \cdot \pi}\right)^{\frac{1}{3}} \qquad d_{grinder} = 0.868\,m$$

From

$$h_{grinder} := p \cdot d_{grinder} \qquad h_{grinder} = 1.588\,m$$

The area of the grinder is therefore,

$$A_{grinder} := 2\pi \cdot \frac{d_{grinder}}{2} \cdot h_{grinder} + 2\pi \cdot \left(\frac{d_{grinder}}{2}\right)^2 \qquad A_{grinder} = 5.513\,m^2$$

The power reqired by the grinder is given as

$$E = [(1.64 \cdot L - 1) \cdot K + 1] \cdot (1.64 \cdot D)^{2.5} \cdot E_2 \qquad \text{(Perry, 1998)}$$

where

E is the net power to drive the grinder shaft

L is the inside length of the grinder, m

D is the mean inside diameter of the grinder, m

E_2 is the net power used by a laboratory grinder shaft under similar operating conditions

K is a constant which has value 0.9 for grinder shaft

Taking

$L = 1 \times 10^{-3}\,m^3$

$K := 0.9$

$D := d_{grinder}$

$E_2 := 9.5 \cdot W$

As such,

$$E = [(1.64 \cdot L - 1) \cdot K + 1] \cdot (1.64 \cdot D)^{2.5} \cdot E_2 \qquad E_{shaft} = 4.498\,W$$

3.3.6 *Specification of sieve*

Given that the amount of materials in the sieve is

	Mass in kg	Density in kg/m³
Water	45.8229	1000
Fats	0.1900	970
Carbohydrates	10.1400	680
Fiber	3.0000	1130
Potassium	0.3230	860
Phosphor	0.0440	1820
Sodium	0.0350	970
Calcium	0.0270	1550
Magnesium	0.0150	1740
"Vitamin C"	0.0093	1207
"Vitamin A "	0.2010	1059
"Vitamin B 6 "	0.0001	1045
Niacin	0.0009	1290
"Folic acid "	0.0140	1429
"Dirty particles"	0.0000	1300
Additives	3.2370	1266

$$M := \begin{pmatrix} 45.8229 \\ 0.1900 \\ 10.1400 \\ 3.0000 \\ 0.3230 \\ 0.0440 \\ 0.0350 \\ 0.0270 \\ 0.0150 \\ 0.0093 \\ 0.2010 \\ 0.0001 \\ 0.0009 \\ 0.0140 \\ 0.0000 \\ 3.2370 \end{pmatrix} \cdot kg \qquad \rho := \begin{pmatrix} 1000 \\ 970 \\ 680 \\ 1130 \\ 860 \\ 1820 \\ 970 \\ 1550 \\ 1740 \\ 1207 \\ 1059 \\ 1045 \\ 1290 \\ 1429 \\ 1300 \\ 1266 \end{pmatrix} \cdot \frac{kg}{m^3}$$

The average density of the mixture in the crusher is calculated thus;

$$\rho_{av} := \frac{\begin{pmatrix} M_1 \cdot \rho_1 + M_2 \cdot \rho_2 + M_3 \cdot \rho_3 + M_4 \cdot \rho_4 + M_5 \cdot \rho_5 + M_6 \cdot \rho_6 + M_7 \cdot \rho_7 + M_8 \cdot \rho_8 + M_9 \cdot \rho_9 \ldots \\ + M_{10} \cdot \rho_{10} + M_{11} \cdot \rho_{11} + M_{12} \cdot \rho_{12} + M_{13} \cdot \rho_{13} + M_{14} \cdot \rho_{14} + M_{15} \cdot \rho_{15} + M_{16} \cdot \rho_{16} \end{pmatrix}}{\left(\sum M\right)}$$

$$\rho_{av} = 968.86 \frac{kg}{m^3}$$

The volume is

$$V_{sieve} := \frac{\sum M}{\rho_{av}} \qquad V_{sieve} = 0.934\, m^3$$

Assuming that the mixing tank is cylindrical, this implies that

$$V = \pi \cdot r^2 \cdot h$$

and, since

$$r = \frac{d}{2}$$

$$V = \pi \cdot \left(\frac{d}{2}\right)^2 \cdot h$$

$$V := \pi \cdot \frac{d^2}{4} \cdot h$$

Let h = pd, where k is a constant

substituting for h,

$$V = \pi \cdot \frac{d^2}{4} \cdot (p \cdot d)$$

$$4 \cdot V = p \cdot \pi \cdot d^3$$

Making d the subject of the formular

$$d = \left(\frac{4 \cdot V}{k \cdot \pi}\right)^{\frac{1}{3}}$$

assuming that $p := 1.05$

$$V_{sieve} := V_{sieve}$$

$$d_{sieve} := \left(\frac{4 \cdot V_{sieve}}{p \cdot \pi}\right)^{\frac{1}{3}} \qquad d_{sieve} = 1.042\,m$$

From

$$h_{sieve} := p \cdot d_{sieve} \qquad h_{sieve} = 1.094\,m$$

The area of the dilution tank is therefore,

$$A_{sieve} := 2\pi \cdot \frac{d_{sieve}}{2} \cdot h_{sieve} + 2\pi \cdot \left(\frac{d_{sieve}}{2}\right)^2 \qquad A_{sieve} = 5.29\,m^2$$

3.3.7 *Detail Design of Dryer*

3.3.7.1 *Chemical Engineering Design of Dryer*

Component	Mass in kg (M_i)	Mass out in kg (M_o)	Density in kg/m³ (ρ)
Water	235.0006	45.8229	1000
Fats	0.1900	0.1900	970
Carbohydrates	10.1400	10.1400	680
Fiber	3.0000	3.0000	1130
Potassium	0.3230	0.3230	860
Phosphor	0.0440	0.0440	1820
Sodium	0.0350	0.0350	970
Calcium	0.0270	0.0270	1550
Magnesium	0.0150	0.0150	1740
"Vitamin C"	0.0093	0.0093	1207
"Vitamin A "	0.2010	0.2010	1059
"Vitamin B 6 "	0.0001	0.0001	1045
Niacin	0.0009	0.0009	1290
"Folic acid "	0.0140	0.0140	1429
"Dirty particles"	0.0000	0.0000	1300
Additives	0.0000	3.2370	1266

$M_i := (\ldots) \cdot kg \qquad M_o := (\ldots) \cdot kg \qquad \rho := (\ldots) \cdot \frac{kg}{m^3}$

$$\rho_{av} := \frac{\left(M_{i_1}\cdot\rho_1 + M_{i_2}\cdot\rho_2 + M_{i_3}\cdot\rho_3 + M_{i_4}\cdot\rho_4 + M_{i_5}\cdot\rho_5 + M_{i_6}\cdot\rho_6 + M_{i_7}\cdot\rho_7 + M_{i_8}\cdot\rho_8 + M_{i_9}\cdot\rho_9 \ldots + M_{i_{10}}\cdot\rho_{10} + M_{i_{11}}\cdot\rho_{11} + M_{i_{12}}\cdot\rho_{12} + M_{i_{13}}\cdot\rho_{13} + M_{i_{14}}\cdot\rho_{14} + M_{i_{15}}\cdot\rho_{15} + M_{i_{16}}\cdot\rho_{16}\right)}{\left(\sum M_i\right)}$$

$$\rho_{av} = 988.656\ \frac{kg}{m^3}$$

Amount of water in feed, $water\_in := M_{i_1}$ $\qquad water\_in = 235.001\ kg$

Dry solid in feed, $solid := \sum M - M_{i_1}$ $\qquad solid = 669.71\ kg$

Water content in product, $water\_out := M_{o_1}$ $\qquad water\_out = 45.823\ kg$

Hence, water removed in the dryer is

$water\_removed := water\_in - water\_out$ $\qquad water\_removed = 189.178\ kg$

Inlet air temperature, $T_{iair} := (100 + 273)\cdot K$

Outlet air temperature, $T_{oair} := (29 + 273)\cdot K$

Inlet temperature of feed, $T_{ifeed} := (31 + 273) \cdot K$

Discharge temperature, $T_d := (63 + 273) \cdot K$

Asssuming that the Number of Transfer Units (NTU) is

$NTU := 1.5$

Using the relationship of the NTU which is,

$$NTU = \ln\left[\frac{(t_{g1} - t_w)}{t_{g2} - t_w}\right]$$ (Joshi, 2002)

$t_{g1} := T_{iair}$

$t_w := T_d$

$$t_{g2} := \frac{(\exp(NTU) \cdot t_w + t_{g1} - t_w)}{\exp(NTU)} \qquad t_{g2} = 309.83$$

The energy balance has shown that the total energy required to raise the product to the discharge temperature is

$$Q_t := 2.193 \times 10^6 \cdot \frac{kJ}{day}$$

The Log Mean Temperature Difference (LMTD) across the dryer, ΔT_m, is

$$\Delta T_m := \frac{[(T_{iair} - T_{ifeed}) - (T_d - T_{oair})]}{\ln\left[\frac{(T_{iair} - T_{ifeed})}{(T_d - T_{oair})}\right]} \qquad \Delta T_m = 44.507$$

Amount of air required is calculated using the relatioship

$Q_t = M \cdot C_p \cdot \Delta T$

$$M := \frac{Q_t}{(C_p \cdot \Delta T)}$$

Given that

$$Q_t = 2.193 \times 10^6 \frac{kJ}{day}$$

$$C_p := 4.187 \cdot \frac{kJ}{kg \cdot K}$$

$\Delta T := T_{iair} - T_{oair}$

So,

$$M_{air} := \frac{Q_t}{(C_p \cdot \Delta T)}$$ $$M_{air} = 7.377 \times 10^3 \frac{kg}{day}$$

If the velocity of air is taken to be

$$v_{air} := 2.9 \cdot 10^2 \cdot \frac{kg}{day \cdot m^2}$$

Area of dryer is thus calculated to be

$$A_{dryer} := \frac{M_{air}}{v_{air}}$$ $$A_{dryer} = 25.438\, m^2$$

Using the formula for the area of dryer which is

$$A_{dryer} = \pi \cdot r_{dryer}^2$$

where A_{dryer} is the area of dryer

r_{dryer} is the radius of dryer

If d_{dryer} is used to denote the diameter of dryer,

$$A_{dryer} = \pi \cdot \left(\frac{d_{dryer}}{2}\right)^2$$

$$A_{dryer} = \pi \cdot \frac{d_{dryer}^2}{4}$$

$$4 \cdot A_{dryer} = \pi \cdot d_{dryer}^2$$

$$d_{dryer}^2 = \frac{4 \cdot A_{dryer}}{\pi}$$

The diameter of dryer is thus equal to

$$d_{dryer} := \sqrt{\frac{4 \cdot A_{dryer}}{\pi}}$$ $$d_{dryer} = 5.691\, m$$

Length of transfer unit has been related to mass velocity and diameter by the following relation,

$$LTU = 0.00064 \cdot C_p \cdot (G)^{0.84} \cdot d_{dryer}$$ (Joshi, 2002)

where G is the mass velocity which is equal to $G := v_{air}$, that is,

$$G = 290\,\frac{kg}{day \cdot m^2}$$

So,

$$LTU := 0.00064 \cdot \frac{C_p}{\frac{kJ}{kg \cdot K}} \cdot \left(\frac{G}{\frac{kg}{day \cdot m^2}}\right)^{0.84} \cdot d_{dryer}$$

$LTU = 1.785\,m$

Length of the dryer calculated from the formula which is given as

$$L_{dryer} := LTU \cdot NTU$$

$L_{dryer} = 2.678\,m$

3.3.7.2 *Mechanical Engineering Design of Dryer*

1. *Flight design:*

(Brownell and Young, 2003)

$$Number\_of\_flights := 3 \cdot d_{dryer}$$

$Number\_of\_flights = 17.073\,m$

Radial height is taken as 1/8 of diameter,

That is,

$$Radial\_height := \frac{d_{dryer}}{8}$$

(Brownell and Young, 2003)

$Radial\_height = 0.711\,m$

2. *Thickness of dryer:*

Let x be the thickness of dryer.

Mild steel can be used since it can withstand temperature up to 200°C.

$$Density\_of\_steel := 7688.86 \cdot \frac{kg}{m^3}$$

$$D_2 - D_1 = 2 \cdot x$$

$$Volume\_of\_mild\_steel = \left(\pi \cdot \frac{D_2^{\,2}}{4} - \pi \cdot \frac{D_1^{\,2}}{4}\right) \cdot L$$

(Brownell and Young, 2003)

Since $D_2 = D_1 + 2 \cdot x$

$$Volume\_of\_mild\_steel = \left[\pi \cdot \frac{(D_1 + 2 \cdot x)^2}{4} - \pi \cdot \frac{D_1^{\,2}}{4}\right] \cdot L$$

$$Volume\_of\_mild\_steel = \pi \cdot D \cdot L \cdot x$$

Assume $x := 15 \cdot mm$

$$W_{dryer} := \pi \cdot d_{dryer} \cdot L_{dryer} \cdot x \cdot Density\_of\_steel$$

$$W_{dryer} = 5.522 \times 10^{3} kg$$

Assume hold up of 0.2, that is, $hold\_up := 0.2$

Volume of dryer filled with material is given as

$$V_f := \pi \cdot d_{dryer}^{2} \cdot L_{dryer} \cdot hold\_up \qquad V_f = 54.494 m^{3}$$

Weight of material at any time, $W_{at} := V_f \cdot \rho_{av}$

$$W_{at} = 5.388 \times 10^{4} kg$$

The dryer is supported over two-tension roll assemblies, 20ft apart. It is uniformly distributed load.

$$M_{bm} := \frac{W_{dryer} \cdot L_{dryer}}{8} \qquad \text{(Brownell and Young, 2003)} \qquad M_{bm} = 1.818 \times 10^{3} kg\,m$$

3. ***Diameter of the feed pipe:***

Feed rate, $F_r := \frac{\sum M_i}{day}$ $\qquad F_r = 10.375 \frac{kg}{hr}$

Density of feed, $\rho_{av} = 988.656 \, kg\, m^{-3}$

Hence, volumetric feed rate, $v_{dryer} := \frac{F_r}{\rho_{av}}$ (Brownell and Young, 2003)

$$v_{dryer} = 0.252 \frac{m^{3}}{day}$$

Assuming the velocity of air, $vel_{air} := 150 \cdot \frac{m}{hr}$

Cross section of feed chute, $A_{chute} := \frac{v_{dryer}}{vel_{air}}$

$$A_{chute} = 6.996 \times 10^{-5} m^{2}$$

Diameter of feed chute, $d_{chute} := \sqrt{\frac{A_{chute} \cdot 4}{\pi}}$ (Brownell and Young, 2003)

$$d_{chute} = 9.438 \times 10^{-3} m$$

3.4 ECONOMIC ANALYSIS

Calculation of Equipment Costs

Generally, the equation for the purchased cost of equipment is given as

$$Ce = C \cdot S^n$$

where Ce = purchased equipment cost

S = characteristic size parameter

C = cost constant

n = index for that type of equipment

Purchased Cost of Washer

The cost of carrot washer is given as

$$Ce = C \cdot S^n$$

From the selection of the equipment, the volume of the washer was calculated to be

$$V_{washer} := 4.93 \cdot m^3$$

So,

$$C := 2400$$

$$S := \frac{V_{washer}}{m^3} \qquad S = 4.93$$

From Richardson and Coulson's Chemical Engineering, page 258,

$$n := 0.60$$

So, from the expression,

$$Ce_{washer} := C \cdot S^n$$

The cost of the washer is, therefore, $Ce_{washer} = 9.376 \times 10^5$ naira

Cost of crusher

The cost of carrot crusher is given as

$$Ce = C \cdot S^n$$

From the selection of the equipment, the volume of the crusher was calculated to be

$$V_{crusher} := 3.61 \cdot m^3$$

So,

$$C := 2400$$

$$S := \frac{V_{crusher}}{m^3} \qquad S = 3.61$$

From Richardson and Coulson's Chemical Engineering, page 258,

$n := 0.60$

So, from the expression,

$$Ce_{crusher} := C \cdot S^n$$

The cost of the crusher is, therefore, $Ce_{crusher} = 7.777 \times 10^5$ naira

Cost of mixer

The cost of mixer is given as

$$Ce = C \cdot S^n$$

From the selection of the equipment, the volume of the mixer was calculated to be

$$V_{mixer} := 3.61 \cdot m^3$$

So,

$C := 2400$

$$S := \frac{V_{mixer}}{m^3} \qquad S = 3.61$$

From Richardson and Coulson's Chemical Engineering, page 258,

$n := 0.60$

So, from the expression,

$$Ce_{mixer} := C \cdot S^n$$

The cost of the mixer is, therefore, $Ce_{mixer} = 7.777 \times 10^5$ naira

Cost of dryer

The cost of dryer is given as

$$Ce = C \cdot S^n$$

From the selection of the equipment, the heat transfer area of the dryer was calculated to be

$$A_{dryer} := 25.44 \cdot m^2$$

So,

$C := 2400$

$S := \frac{A_{dryer}}{m^2}$ $S = 25.44$

From Richardson and Coulson's Chemical Engineering, page 258,

$n := 0.53$

So, from the expression,

$Ce_{dryer} := C \cdot S^n$

The cost of the dryer is, therefore, $Ce_{dryer} = 2.001 \times 10^6$ naira

Cost of grinder

The cost of grinder is given as

$Ce = C \cdot S^n$

From the selection of the equipment, the volume of the grinder was calculated to be

$V_{grinder} := 3.11 \cdot m^3$

So,

$C := 2400$

$S := \frac{V_{grinder}}{m^3}$ $S = 3.11$

From Richardson and Coulson's Chemical Engineering, page 258,

$n := 0.60$

So, from the expression,

$Ce_{grinder} := C \cdot S^n$

The cost of the grinder is, therefore, $Ce_{grinder} = 7.111 \times 10^5$ naira

Cost of sieve

The cost of sieve is given as

$Ce = C \cdot S^n$

From the selection of the equipment, the volume of the sieve was calculated to be

$V_{sieve} := 3.10 \cdot m^3$

So,

$C := 2400$

$S := \frac{V_{sieve}}{m^3}$ $\qquad S = 3.10$

From Richardson and Coulson's Chemical Engineering, page 258,

$n := 0.60$

So, from the expression,

$Ce_{sieve} := C \cdot S^n$

The cost of the sieve is, therefore, $\qquad Ce_{sieve} = 7.098 \times 10^3$ naira

The total cost of equipment is, therefore, given as

$C_{eT} := Ce_{washer} + Ce_{crusher} + Ce_{mixer} + Ce_{dryer} + Ce_{grinder} + Ce_{sieve}$

$C_{eT} = 5.915 \times 10^6$ naira

The purchased equipment cost is the total cost of equipment and is defined as thus:

$PEC := C_{eT}$

$PEC = 5.915 \times 10^6$ naira

Estimation of Capital Investment Cost

I. Direct Costs

A. Equipment + installation + instrumentation + piping + electrical + insulation + painting

1. ***Purchased equipment cost (PEC):***

The purchased equipment cost (PEC) = total cost of equipment,

i.e., $\qquad PEC := C_{eT}$ $\qquad PEC = 5.915 \times 10^6$ naira

2. ***Installation, including insulation and painting:*** (25-55% of purchased equipment cost)

Considering the installation cost to be 40% of purchased equipment cost

i.e., $\qquad Insta := 40\% \cdot PEC$

$Insta = 2.366 \times 10^6$ naira

3. ***Instrumentation and controls, installed:*** (6-30% of purchased equipment cost)

Considering the instrumentation cost to be 11% of purchased equipment cost

i.e., $Instr := 11\% \cdot PEC$ $\quad Instr = 6.506 \times 10^5$ naira

4. ***Piping installed:*** (10-80% of purchased equipment cost)

Considering the piping cost to be 30% of purchased equipment cost

i.e., $Pip := 30\% \cdot PEC$ $\quad Pip = 1.774 \times 10^6$ naira

5. ***Electrical, installed:*** (10-40% of purchased equipment cost)

Considering the electrical cost to be 15% of purchased equipment cost

i.e., $Elect := 15\% \cdot PEC$ $\quad Elect = 8.872 \times 10^5$ naira

So, the cost of equipment, installation, instrumentation, piping, electrical, insulation and

painting is given as

$CA := PEC + Insta + Instr + Pip + Elect$ $\quad CA = 1.159 \times 10^7$ naira

B. Buildings, process and auxiliary: (10-70% of purchased equipment cost)

Considering the buildings, process and auxiliary cost to be 20% of purchased equipment cost

i.e., $Build := 20\% \cdot PEC$ $\quad Build = 1.183 \times 10^6$ naira

C. Service facilities and yard improvements: (40-100% of purchased equipment cost)

Considering the cost of service facilities and yard improvement to be 50% of PEC

i.e., $Servi := 50\% \cdot PEC$ $\quad Servi = 2.957 \times 10^6$ naira

D. Land: (1-2% of fixed capital investment or 4-8% of purchased equipment cost)

Considering the cost of land to be 5% of PEC

i.e., $Lan := 5\% \cdot PEC$ $\quad Lan = 2.957 \times 10^5$ naira

Thus, the direct cost is equal to

$Direct\_Cost := CA + Build + Servi + Lan$ $\quad Direct\_Cost = 1.603 \times 10^7$ naira

II. Indirect costs: expenses which are not directly involved with material and labour of

actual installation of complete facility (15-30% of fixed capital investment)

A. Engineering and supervision: (5-30% of direct cost)

Considering the cost of engineering and supervision to be 13% of direct cost

i.e., $\text{Engin} := 13\% \cdot \text{Direct\_Cost}$ $\qquad$ $\text{Engin} = 2.084 \times 10^{6}$ naira

B. Construction expense and contractor's fee: (6-30% of direct cost)

Considering the construction expense and contractor's fee to be 15% of direct cost

i.e., $\text{Const} := 15\% \cdot \text{Direct\_Cost}$ $\qquad$ $\text{Const} = 2.404 \times 10^{6}$ naira

C. Contingency: (5-15% of direct cost)

Considering the contingency cost to be 7% of fixed capital investment

i.e., $\text{Conti} := 7\% \cdot \text{Direct\_Cost}$ $\qquad$ $\text{Conti} = 1.122 \times 10^{6}$ naira

Thus, indirect cost is equal to

$\text{Indirect\_Cost} := \text{Engin} + \text{Const} + \text{Conti}$ $\qquad$ $\text{Indirect\_Cost} = 5.61 \times 10^{6}$ naira

III. Fixed Capital Investment:

Fixed capital investment to be Direct cost + Indirect cost

i.e., $\text{Fixed\_CI} := \text{Direct\_Cost} + \text{Indirect\_Cost}$ $\qquad$ $\text{Fixed\_CI} = 2.161 \times 10^{7}$ naira

IV. Working Capital: (11-20% of fixed capital investment)

i.e., $\text{Working\_C} := 11\% \cdot \text{Fixed\_CI}$ $\qquad$ $\text{Working\_C} = 2.38 \times 10^{6}$ naira

V. Total Capital Investment (TCI):

Total capital investment to be Fixed capital investment + Working capital

i.e., $\text{Total\_CI} := \text{Fixed\_CI} + \text{Working\_C}$ $\qquad$ $\text{Total\_CI} = 2.402 \times 10^{7}$ naira

Estimation of Total Production Cost:

I. ***Manufacturing Cost*** to be Direct production + Fixed charges + Plant overhead cost

A. ***Fixed Charges:*** (10-20% of total product cost)

i. ***Depreciation:*** (This depends on life period, salvage value and method of calculation

- about 13% of FCI for machinery and equipment and 2-3% of building value for

buildings
Considering depreciation to be 10% of FCI for machinery and equipment and 3% of

building value for buildings)

i.e., $Depre := 10\% \cdot Fixed\_CI + 3\% \cdot Build$ $Depre = 2.199 \times 10^{6}$ naira

ii. ***Local Taxes:*** (1-4% of fixed capital investment)

Considering the local taxes to be 3.5% of fixed capital investment

i.e., $Tax := 3.5\% \cdot Fixed\_CI$ $Tax = 7.574 \times 10^{5}$ naira

iii. ***Insurance:*** (0.4-1% of fixed capital investment)

Considering the insurance to be 0.6% of fixed capital investment

i.e., $Insur := 0.6\% \cdot Fixed\_CI$ $Insur = 1.298 \times 10^{5}$ naira

iv. ***Rent:*** (8-12% of value of fixed capital investment)

Considering rent to be 10% of value of fixed capital investment

i.e., $Ren := 10\% \cdot Fixed\_CI$ $Ren = 2.164 \times 10^{6}$ naira

Thus, fixed charges is given as

$Fixed := Depre + Tax + Insur + Ren$ $Fixed = 5.251 \times 10^{6}$ naira

Considering the fixed charges to be 15% of total product cost

that is,

$$Fixed\_C = 15\% \cdot TPC$$

making total product cost, TPC, the subject of the formula,

$$TPC = \frac{FC}{15\%}$$

$$TPC := \frac{Fixed}{15\%} \qquad TPC = 3.5 \times 10^7 \text{ naira}$$

B. *Direct Production Cost:*

i. *Raw materials:* (10-50% of total product cost)

Considering the cost of raw materials to be 15% of total product cost

$$Raw\_mat := 15\% \cdot TPC \qquad Raw\_mat = 5.251 \times 10^6 \text{ naira}$$

ii. *Operating Labour (OL):* (10-20% of total product cost)

Considering the cost of operating labour to be 10% of total product cost

$$OperL := 10\% \cdot TPC \qquad OperL = 3.5 \times 10^6 \text{ naira}$$

iii. *Direct Supervisory and Clerical Labour (DS & CL):* (10-25% of OL)

Considering the cost for direct supervisory and clerical labour to be 15% of OL

$$DireS := 15\% \cdot OperL \qquad DireS = 5.251 \times 10^5 \text{ naira}$$

iv. *Utilities:* (10-20% of total product cost)

Considering the cost of utilities to be 12.5% of total product cost

$$Util := 12.5\% \cdot TPC \qquad Util = 4.375 \times 10^6 \text{ naira}$$

v. *Maintenance and repairs (M & R):* (2-10% of fixed capital investment)

Considering the maintenance and repair cost to be 3.7% of fixed capital investment

$$Maint := 3.7\% \cdot Fixed\_CI \qquad Maint = 8.007 \times 10^5 \text{ naira}$$

vi. *Operating Supplies:* (10-20% of M & R or 0.5-1% of FCI)

Considering the cost of operating supplies to be 17% of M & R

$$OperS := 17\% \cdot Maint \qquad OperS = 1.361 \times 10^5 \text{ naira}$$

vii. *Laboratory Charges:* (10-20% of OL)

Considering the laboratory charges to be 15% of OL

$$Lab := 15\% \cdot OperS \qquad Lab = 2.042 \times 10^4 \text{ naira}$$

*viii. **Patent and Royalties:*** (0-6% of total product cost)

Considering the cost of patent and royalties to be 4.5% of total product cost

$Paten := 4.5\% \cdot TPC$ $\qquad$ $Paten = 1.575 \times 10^{6}$ naira

Thus, direct production cost is

$DPC := Raw\_mat + OperL + DireS + Util + Maint + OperS + Lab + Paten$

$DPC = 1.618 \times 10^{7}$ naira

C. Plant Overhead Costs: (50-70% of operating labour, supervision, and maintenance or

5-15% of total product cost); includes for the following: general plant upkeep and overhead,

payroll overhead, packaging, medical services, safety and protection, restaurants, salvage,

laboratories, and storage facilities.

Considering the plant overhead cost to be 55% of OL, DS & CL and M & R

Therefore,

$Plant := 55\% \cdot (OperL + DireS + Maint)$ $\qquad$ $Plant = 2.654 \times 10^{6}$ naira

Manufacture cost = Direct production cost + Fixed charges + Plant overhead cost

$Manuf := DPC + Fixed + Plant$ $\qquad$ $Manuf = 2.409 \times 10^{7}$ naira

II. General Expenses = Administrative costs + distribution and selling costs + research

and development costs

A. Administrative costs: (2-6% of total product cost)

Considering the administrative to be 3% of total product cost

$Admin := 3\% \cdot TPC$ $\qquad$ $Admin = 1.05 \times 10^{6}$ naira

B. Distribution and Selling Costs: (2-20% of total product cost); includes costs for

sales offices, salesmen, shipping, and advertising.

Considering the distribution and selling costs to be 11% of total product cost

$Distr := 11\% \cdot TPC$ $\qquad$ $Distr = 3.85 \times 10^{6}$ naira

C. Research and Development Costs: (about 3% of total product cost)

Considering the research and development costs to be 3% of total product cost

Resesa := 3% · TPC Resea = 1.05×10^{6} naira

Thus, general expenses,

Gener := Admin + Distr + Resea Gener = 5.951×10^{6} naira

IV. Total Product Cost = Manufacture Cost + General Expenses

Total_prod_cost := Manuf + Gener Total_prod_cost = 3.004×10^{7} naira

V. Gross Earnings/Income:

The selling price of carrot powder is equal to N75 per kg

$$Selling\_price := 75 \cdot \frac{naira}{kg}$$

Quantity_produced := 1016046.91 · kg

Total income = Selling price x quantity of product manufactured

i.e., Total_income := Selling_price · Quantity_produced Total_income = 7.62×10^{7} naira

Gross income = Total income - Total Product Cost

i.e., Gross_income := Total_income − TPC Gross_income = 4.12×10^{7} naira

Assuming the tax rate to be 45% (common), Tax_rate := 45%

Net profit = Gross income - Taxes

Taxes := 45% · Gross_income Taxes = 1.854×10^{7} naira

Net_profit := Gross_income − Taxes Net_profit = 2.266×10^{7} naira

Calculation of Rate of Return:

$$Rate\_of\_return = \frac{Net\_profit}{Total\_CI} \cdot 100\%$$

Therefore,

$$Rate\_of\_return := \frac{Net\_profit}{Total\_CI} \cdot 100\%$$

Rate_of_return = 94.339 %

Calculation of Pay-Back Period

The pay-back period is calculated as the reciprocal of the rate of return.

Therefore,

$$Pay\_back\_period := \frac{1}{Rate\_of\_return} \cdot yr \qquad Pay\_back\_period = 1.06\,yr$$

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

The summary of the results obtained from this project are as summarized in the tables below.

4.1.1 Material balances' results

Table 4.1: Results of the material and energy balances

	Input (kg)	Output (kg)
Washer	4229352.31	4212434.90
Crusher	4212434.90	4212434.90
Mixer	4267196.55	4267196.55
Dryer	4267196.55	4267196.55
Grinder	1066799.14	1066799.14
Screener	1066799.14	1066799.14

4.1.2 Equipments specification' results

Table 4.2: Results of equipments' specification

Equipments	Volume (m^3)	Area (m^2)	Diameter (m)	Height (m)
Washer	4.93	16.36	2.47	1.59
Crusher	3.61	13.11	1.91	1.55
Mixer	3.61	13.04	1.72	1.64
Dryer		25.44	2.68	5.69
Grinder	0.93	5.51	1.59	0.87
Screener	0.93	5.29	1.09	1.04

4.1.3 *Economic analysis' results*

Table 4.3: Results of the economic analysis

Equipments	Cost (₦)
Washer	937600
Crusher	777700
Mixer	777700
Dryer	2000100
Grinder	711100
Screener	5915000

4.2 *Discussion of Results*

The results of this project are as shown in Tables 4.1, 4.2 and 4.3. As can be observed from the results, Table 4.1 shows the results material balances and Table 4.2 shows the results of equipment specification while Table 4.3 shows the results of the economic analysis of the production of carrot powder from carrot.

Table 4.1, which shows the results of material balances, reveals that material entering the washer was 4229352.31kg while the mass of the material leaving the was calculated to be 4212434.90kg. Similarly, the mass of material entering the crusher was calculated to be 4212434.90kg while the one coming out of the crusher was 4212434.90kg. All the mass in and mass out of each equipment are presented in Table 4.1. Observing the results very well, it will be discovered that, in some equipments, mass in is not equal to mass out, even though it is a unit operation. The reason for this being the loss encountered in the equipment.

Table 4.2 that which shows the results of equipments' specification shows that the volume of the washer for the carrot is 4.93m^3 while its diameter 2.47m and the height was calculated to be 1.59m which finally gave the total surface area of the washer to be 16.36m^2 for the small scale production of carrot powder from carrot. The dimensions of all other equipments are shown thus in the table (Table 4.2).

Based on the sizes of the equipments, the costs were calculated and tabulated in Table 4.3. According to the results, the cost of carrot washer was found to be 937600 while that of crusher was found to be ₦777700. As shown in the same table (Table 4.3), the cost of mixer, dryer, grinder and screener were found to be ₦777700, ₦2000100, ₦711100 and ₦5915000 respectively.

The purchased equipment cost was calculated as the sum of the costs of all the equipment to be ₦5915000. This, after applying the standard method of costing as shown in the calculations of the economic analysis, the plant was found to have the fixed capital investment of ₦21640000 and working capital of ₦2380000. Thus, the total capital investment was calculated to be ₦24020000.

In conclusion, this plant has been found to be viable with the rate of return of 94.34% and payback period of at most 1.06years.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The results of the project show that the purchased cost of equipments was calculated to be ₦5915000. Based on the further calculations, the project was found to have fixed capital investment of ₦21640000 and working capital investment of ₦2380000 while the total capital investment was ₦24020000.

In conclusion, this plant has been found to be viable with the rate of return of 94.34% and payback period of at most 1.06years.

5.2 Recommendation

In this project, the design of a plant for the production of carrot powder using carrot was carried out for a small scale plant; it is, therefore, recommended that a large scale plant should also be designed for the production of the same product (carrot powder) using carrot.

REFERENCES

1) Himmelblau, D. M. (1996), "Basic Principles and Calculations in Chemical Engineering", Prentice-Hall of India Private Limited, New Jersey, U.S.A, 6th Edition.

2) Klix M (2005); Newsflash on Carrot, eFoundry, Yeovil, Somerset. (www.ezidri.co.uk/index.php?option=com_content&task=view&id=34&Itemid=45?xml version="1.0" encoding="iso-8859-1"?><HTML)

3) Natural Canine, 100% Certified Organic Carrots for Canines, Vermout. (www.naturalcanine.com/html/carrot_powder.html)

4) Ron Wolford and Drusilla Banks (2005); Carrot, University of Illinois Extension. (www.urbanext.uiuc.edu/veggies/carrot1.html)

5) Sinnot, R. K. (1999), "Coulson and Richardson's Chemical Engineering", Vol. 6, 3rd Edition, Butterworth, Heinemann, Oxford, UK.

6) www.botanical.com/botanical/mgmh/c/carrot24.html

7) www.urbanext.uiuc.edu/veggies/carrot1.html

8) http://website.lineone.net/~stolarczyk/maroon.html

9) http://www.seagateproducts.com/carrot-powder-information.html

10) www.botanicalonline.com

11) www.carrotmuseum.com

12) www.seagateproducts.com/carrot-garlic.html

APPENDIX

A: CALCULATION OF FLOW OF MATERIALS

The flow of materials were calculated using the principle of law of conservation of mass which states that

Input + Generation = Output + Loss

For instance, the weight leaving one unit to another unit will be calculated as

Output = Input - Loss

Based on this principle, all the flow of materials was calculated using spreadsheet.

B: CALCULATION OF WEIGHT PERCENTAGES

The weight percentages were calculated using the formula given as

$$wt\% = \frac{wt}{Total\_wt} \cdot 100$$

where

wt is the weight of individual component

Total_wt is the total weight of all the components