FAU-14

Agro-Industry Profiles

COFFEE

PROFILES IN THIS SERIES:

ABSTRACT

The objective of this Profile is to provide a review of the coffee processing industry. It explores all aspects of the industry from cultivation practices to processing and marketing. It contains conversion coefficients, a glossary of key words, and a bibliography of useful references. It discusses primary processes such as wet processing, fermentation, washing, drying and hulling, and secondary processes such as grading, sorting, shipping, decaffeination, blending, roasting, grinding and the preparation of soluble coffee. Marketing aspects are also addressed, with an emphasis on quality considerations, price movements, international agreements and organizations, and packaging. Coffee storage and environmental concerns are also addressed. Annexes containing examples of investment and operating costs, and conversion tables (Metric/US) are included at the end of the Profile.

FOREWORD

The nature of project and sector work in the World Bank is such that staff are often called upon to work outside their major fields of specialization, if only to make an initial judgement on the utility of further, often costly, investigation. Under these circumstances, up-to-date and authoritative reference material is essential.

The profiles in this series are designed for use by operational staff with experience in the agricultural sector but who do not have a technical knowledge of the particular commodity under discussion. Their purpose is not to substitute for technical expertise but to provide a reliable inhouse reference which will help Bank staff to determine when and what expertise is needed in the detailed evaluation of investment proposals in agro-processing.

The conditions for any particular proposal are bound to be unique in a number of respects, and the use of norms and general data in project analyses could give rise to significant errors. On the other hand, by providing responsible staff with a guide to the issues on which appropriate expertise should be sought, these profiles can contribute to the overall quality of agro processing investment. Used with care, they should also facilitate broad pre-screening such as may occur during sector work and reconnaissance.

Questions, comments and further inquiries should be addressed to:

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Coffee

CONTENTS

Coffee

DATA SHEET

These figures are indicative; actual yields may vary. The differences between arabica and robusta should be particularly noted.

1 unit weight of C. arabica ripe cherry yields on average 16.5% of its weight as clean green coffee beans. (100 kg cherry = 16.5 kg clean beans).

1 unit weight of C. robusta ripe cherry yields on average 21% of its weight as clean green beans. (100 kg cherry = 21 kg clean beans).

1 unit weight of dry arabica cherry (dry processed 12% moisture content) yields on average 44% of its weight as clean green beans. (100 kg dry cherry = 44 kg clean beans).

1 unit weight of dry robusta cherry (dry processed 12% moisture content) yields on average 52% of its weight as clean green beans. (100 kg dry cherry = 52 kg clean green beans).

1 unit weight of arabica parchment (wet processed) yields on average 80% of its weight as clean green beans. (100 kg dry parchment = 80 kg clean beans).

1 unit weight of robusta parchment (wet processed) yields on average 84% of its weight as clean beans. (100 kg dry parchment = 84 kg clean beans).

1 unit weight of C. liberica ripe cherry yields on average 10% of its weight as clean green coffee. (100 kg ripe cherry = 10 kg clean beans).

The loss in weight in roasting coffee beans is on average 16%. (100 kg green beans = 84 kg roasted beans).

1 unit weight of green beans yields 38.5% of its weight as roasted soluble coffee. (100 kg clean green beans = 38.5 kg soluble coffee).

There is no weight or conversion loss related to decaffeination.

Green coffee is usually traded in 60 kg bags.

INTRODUCTION

Coffee is usually cultivated between latitudes 25°N and 25°S. Coffee arabica is normally grown at altitudes of 3,500 to 6,000 feet above sea level, while Coffee canephora (or robusta) is grown below 3,500 feet. Arabicas, largely from Latin America, are choice, mild in taste, and are preferred for coffees where taste outranks convenience. Robustas, hardier but a bit harsher in taste, come mainly from Africa and Asia and are processed primarily into soluble form. A third species, C. liberica, is grown in smaller quantities in similar conditions and altitudes to C. robusta but it is declining in use.

Coffee requires an average annual temperature range between 20° and 25°C. For short periods C.arabica can withstand minimum temperatures of just above freezing, but C.robusta is subject to damage at temperatures below 10°C.

Arabica is usually processed by the 'wet' method, while robusta is more commonly processed by the 'dry' method.

The grower harvests and will normally process the ripe cherry to the dry parchment stage in the case of arabica, or the dry cherry stage in the case of robusta. At this point the dry parchment or cherry is usually sold to a mill or hullery where it is processed to the clean green bean stage and bagged for dispatch to the country's Marketing Board for export.

Pre-processing on the farm is either by use of a 'wet' or a 'dry' process. Hulling, grading and cleaning are intermediate steps before storage and shipping and are usually beyond the resources of small growers. Roasting, grinding, decaffeination and soluble coffee production are final processes usually undertaken in consuming countries, although larger producers such as Brazil are now producing soluble coffee which in 1980 accounted for five percent of internationally-traded coffee products.

GLOSSARY

Blending	Mixing of green beans prior to roasting.
Cherry	Coffee fruit as harvested, red in color when ripe, dark brown or black when dry.

Decaffeination	Removal of caffeine from green coffee beans by solvent or water extraction.
'Dry' Process	Fresh cherries are dried and hulled to produce green beans.
Fermentation	Second stage of 'wet' process. Following pulping, the mucilage is digested and dispersed by enzyme action.
Green Coffee	Dry beans after hulling. Basis for most trade in coffee; raw material for roasting.
Grinding	Size reduction of roasted beans to accelerate or permit the transfer of flavor and aroma from the coffee to the hot water during brewing.
Hulling	One of the stages in processing the dry cherry to remove the hard dry outer husks (dry processing). Parchment coffee (wet processing) is peeled and polished to remove the thin parchment shell and some of the silverskin (a more gentle process than hulling).
Liquor	The product when boiling water is poured over roasted ground coffee under controlled conditions in order for the Liquorer (Taster) to classify a particular batch of coffee.
Mucilage	The pulpy substance between the outer skin of the cherry and the bean.
Parchment Coffee	Dried green bean with parchment and silverskin; product of 'wet' processing.
Pulping	First stage of 'wet' process. Removal of outer skin and pulp surrounding green bean.
Roasting	Development of flavor, aroma and body in green beans by rapid and uniform application of heat.
Silverskin	Thin layer or testa closest to the green bean.

Soluble Coffee	Water-soluble solids and aromatic components of roasted coffee, extracted and dried.
Washed Coffee	Coffee processed by the 'wet' method.
Washing	Third stage of 'wet' process. Removal of digested mucilage after fermentation.
'Wet' Process	Ripe cherries are pulped, fermented and washed to produce parchment coffee.

RAW MATERIALS

Introduction

Coffee bushes normally take three to five years to develop from seedling to full-producing shrub. The shrub bears fruit for forty or more years, but productivity is greatest between five and fifteen years of age.

Mature fruits (cherries) are produced some six to nine months after flowering. Flowering may occur at one time, but there are often four or more successive flowerings triggered mainly by rainfall. The fruit on any one tree and in any one area does not necessarily ripen at the same time; the cherries stay in their prime for about a week.

Harvesting

The harvesting of coffee is normally by hand and therefore labor intensive. The type of picking practiced depends on local conditions and the type of processing to be used: either 'strip picking' used with dry processing or 'selective picking' with wet processing.

Strip picking involves removal of all the fruit from a tree after most of the fruit has matured. A large proportion of the harvested fruit may be over-ripe, immature, or even green. This results in an uneven end-product and reduced liquor quality. Such cherries of mixed maturity are dry-processed.

Wet processing requires soft fruit that is pulpable. This process must be accompanied by selective picking as only fruit

that is ripe or slightly under- or over-ripe can be used. Over-ripe cherries have started to dry and harden making pulping difficult. In some areas a combination of selective followed by strip picking is practiced so that larger proportions of ripe fruit suitable for wet processing are harvested.

Quality can be improved by attention to genetics, cultivation practices, and harvesting and processing techniques. High altitude varieties tend to have better quality than low-altitude coffees. Cultivation factors include shrub spacing, pruning, fertilizers, weeding, and pest and disease control. Quality control with strip picking is limited; selective picking however should reduce the number of contaminated, infected, moldy, or damaged berries that go for processing. Wet processing is normally associated with higher quality coffee than dry processing.

Climatic factors exert a strong influence on harvesting and processing methods. In parts of Brazil, long dry spells usually coincide with the harvest season. This causes a very rapid ripening and partial drying of the cherries making it virtually impossible to harvest higher quality ripe cherries for wet processing. The dryness facilitates natural drying and reduces the threat of re-wetting partially dry cherries. With proper screening, a good quality product can be realized under these conditions. In areas where rainfall coincides with the harvest season the period of ripeness tends to be longer. Partially dry cherries are more prone to damage from re-wetting however, and selective picking followed by wet processing may be appropriate. (Dry processing is common in Brazil and Ethiopia and for hard Arabicas as well as the majority of Robustas. Wet processing, developed in Jamaica, is used for mild Arabicas including Colombian, Kenyan, and Tanzanian varieties.)

Successive and fluctuating harvests create problems for labor scheduling and processing capacity. Selective picking involving multiple harvests has higher labor requirements than strip picking.

Seasonality

Given optimum weather and growing conditions the coffee bush tends to over-bear and suffer subsequent die-back. Annual yields tend to be cyclical with good years followed by bad. This cyclical trend can to some extent be mitigated by cultivation practices (pruning/shade/fertiliser).

Pests and diseases, as well as climatic hazards such as frost and drought, or rain in the flowering season, also cause cyclical yield patterns. Pests and diseases are partially controllable, but frost and drought periodically devastate whole regions, and cause severe crop losses which lead to high coffee prices on world markets.

PRIMARY PROCESSING

Introduction

Primary processing of coffee is conducted in the producing countries and the end-product is green coffee, most of which is exported. Dry cherry and parchment coffee are normally produced by the growers while hulling to produce green coffee is centralized near points of export.

Pulp, parchment and husk are by-products which can be used as mulch or as fuel for drying.

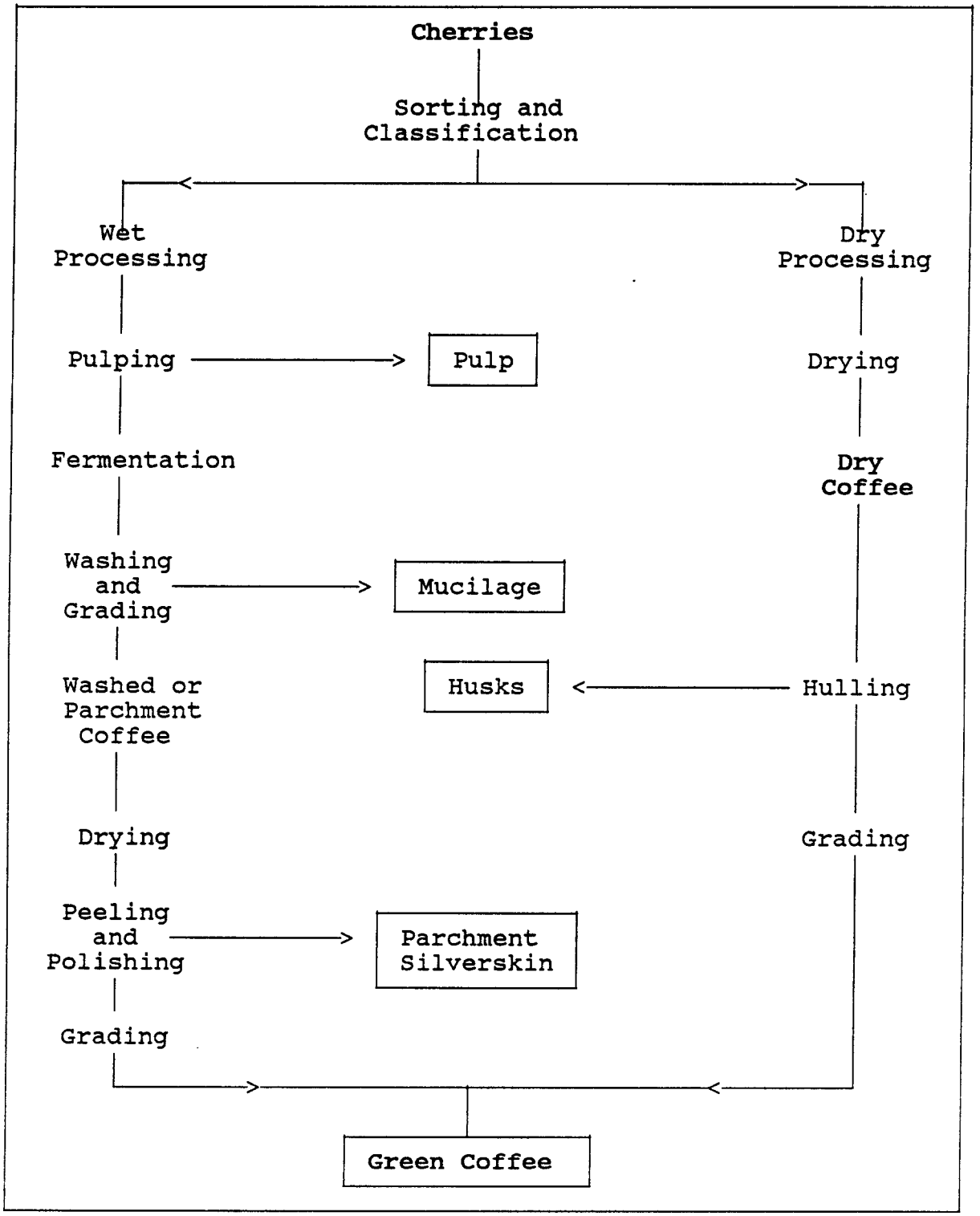
Process Overview

The object of primary processing is to separate the beans from the skin and pulp of the cherry. The basic operations of the 'dry' method are harvesting, drying and hulling, and of the 'wet' method are harvesting, pulping, fermentation and washing, drying, peeling and polishing.

The two systems differ principally in the bean separation stage. The dry process involves drying of the whole cherry until the green bean inside separates from the outer layers. The outer layers are then removed by hulling. Wet processing involves removal of the pulp and mucilage followed by drying. The parchment and silverskin are later removed by hulling. Flowchart 1 presents an overview of the primary processes.

The quality of coffee deteriorates as processing time increases. Unlike some commodities, in which quality is improved by processing, the aim of coffee processing is maintenance of the original bean quality. Only when dry is the bean relatively safe from quality deterioration. However, when the risk of showers or high humidity is small, slow drying results in better quality and sun drying enhances the color of the green bean.

Flowchart 1: Coffee - Primary Processing



Harvesting

Harvesting practices and their influence on processing are detailed in the section on raw materials. It is worth noting however that raw material requirements for wet and dry processing differ; the wet process requires ripe fruit which can be pulped, whereas the dry process is essentially a drying operation and partially dried, over-ripe fruits are acceptable.

Classification

Before further processing, the harvested cherries are separated by size and ripeness. Flotation in water and screen separation are two methods often used together.

Simple systems contain vibrating screens with small openings which remove impurities such as dirt and gravel, and screens with larger openings allow the cherries to fall through but not large stones, twigs or leaves. The cherries fall into a water tank where the heavier ripe fruit (sinkers) settle to the bottom and are taken for pulping. (Wet process.) The partially dry and over-ripe cherries (floaters) are processed separately.

Larger systems are more elaborate and may contain a series of float tanks to provide more complete separation.

Wet Processing

Three main operations are involved: pulping, fermentation and washing. The end product is wet parchment coffee.

Pulping

Pulping removes the skin and pulp from the bean. Disc or drum pulpers operate by squeezing and tearing the flesh away from the beans. It is important that the cherries be pulped as soon after picking as possible; delay allows uncontrolled fermentation and affects the final flavor. Classification by size before pulping and adjustment of the pulper to the cherry size minimizes damage to the beans. Water used in flushing must be free of external contaminants but it is recycled, and the gradual build-up of heat and enzymes accelerates the subsequent fermentation process.

Pulping machines are inexpensive, have large capacities and use little power. A medium sized machine can pulp about 3,000 lbs of cherries per hour (Sivetz & Desrosier, 1979).

Fermentation

After pulping, the beans remain coated with slippery mucilage which is insoluble in water. Fermentation breaks down the mucilage so that it can be readily separated from the parchment.

Natural fermentation takes from six to 72 hours depending on temperature, thickness of mucilage and concentration of enzymes present. Methods of accelerating the process include: addition of pectic enzymes, recirculation of washing water and addition of chemicals. Pectic enzymes reduce the fermentation time to between five and three hours; small doses of alkali further reduce it to less than an hour.

There is some contention that acceleration of fermentation reduces the quality of the green beans. However, little difference in quality has been observed between naturally fermented beans and those treated with accelerating agents (Sivetz & Desrosier, 1979). Material costs of rapid fermentation tend to be higher, but are balanced by lower capital cost for tanks.

Over-fermentation, especially during underwater fermentation, should be avoided as it results in quality deterioration.

Washing

After fermentation the coffee is repeatedly washed in clean water until the mucilage is removed. Washing soon after fermentation prevents micro organism damage to the bean itself. However, in places where water is scarce, fermented beans can be dried immediately without washing. This can create problems with initial handling of the sticky beans and lengthens the drying process by about one day.

Drying

Drying is critical to both wet and dry processing. Flavor, bean color and other quality factors are materially affected at this stage. Production of high quality beans requires the correct combination of temperatures, duration of heat, ventilation and light.

Parchment coffee has a fairly uniform initial moisture content, around 55-60%, whereas dry coffee cherries, because of strip harvesting, can vary in moisture content from 25 to 70%. Drying methods vary depending on the processing system.

Sun drying takes from five to ten days. It has high labor and space requirements, and a permanent drying terrace with protection from rain and insect attack is expensive to construct.

Drying directly on the ground results in contamination and the introduction of off-flavors in the liquor. Sun drying should take place on heavy duty polythene sheets spread on either slightly graded ground beds, cement floors, or drying tables.

Mechanical dryers reduce weather risks, take up less space, require less labor, and are faster than sun drying, thereby easing scheduling of the harvest. Sivetz & Desrosier (1979) provide details on different dryers and their capacities.

Pre-drying in the sun followed by machine drying is often practiced as a means of reducing capital and energy costs.

Over- or under-drying at incorrect temperatures or for inappropriate lengths of time adversely affect both bean quality and storing qualities. Moisture content should be reduced from to 10-15% as soon after washing as possible. Delayed drying can result in sourness and musty or onion flavors. Too much heat causes sourness to develop in the liquor; too rapid drying causes the parchment to crack.

Hulling

Parchment coffee (wet process) or dry coffee cherries (dry process) are transported to mills or hulleries for hulling. Correct moisture levels in the beans facilitate hulling, and some redrying or rewetting may be needed.

Removal of the dry outer layers is done by machine hullers.

Although different machines are required for parchment and natural coffee, the principles applied are the same. The hulling machine is a large, helically-pitched screw within a matching concave chamber. Hulling, or peeling, is achieved by creating friction among the beans lying along the screw. A subsequent polishing operation may be needed to remove the silverskin.

Assessment

The market for coffee is dictated by the quality of the final product. Attention to maintenance of quality during the primary processing operations is critical and the quality of the coffee bean is closely related to the processing technique employed.

The advantages claimed for dry processing are:

- simplicity;
- relatively low capital and recurrent costs per unit;
- unskilled labor.

The advantages claimed for wet processing are:

- shorter drying time;
- generally better quality, fewer defective beans, and better flavor;
- suitable for processing in inclement weather.

Although the choice of process is a cost-benefit issue the availability of water is an important factor. Wet processing requires substantial water resources for pulping and washing (estimated at 20,000 gallons per ton of clean coffee produced).

SECONDARY PROCESSING

Introduction

Most international coffee trade is in the form of graded, sorted, green beans. Further processing prior to consumption includes cleaning, blending, roasting, and grinding, and is normally performed in the consuming country. Decaffeination and soluble coffee production are optional stages depending on market demand. An overview of the secondary processes is presented in Flowchart 2 on the following page.

Grading and Sorting

Grading and sorting are primarily based on factors which influence the roasting qualities of the coffee. The object is to remove all defective, contaminated, broken, and unhulled beans as well as any foreign matter such as stones, dirt, and plant matter. The discarded material is known as 'triage'.

Grading is by shape, size, density, color, and maturity. Coffee graders are used to separate and grade the beans according to their width, thickness, and length. Reel graders separate the beans by size and airlifters separate them by density; grading by color and maturity is largely by hand although electronic eyes are increasingly being introduced.

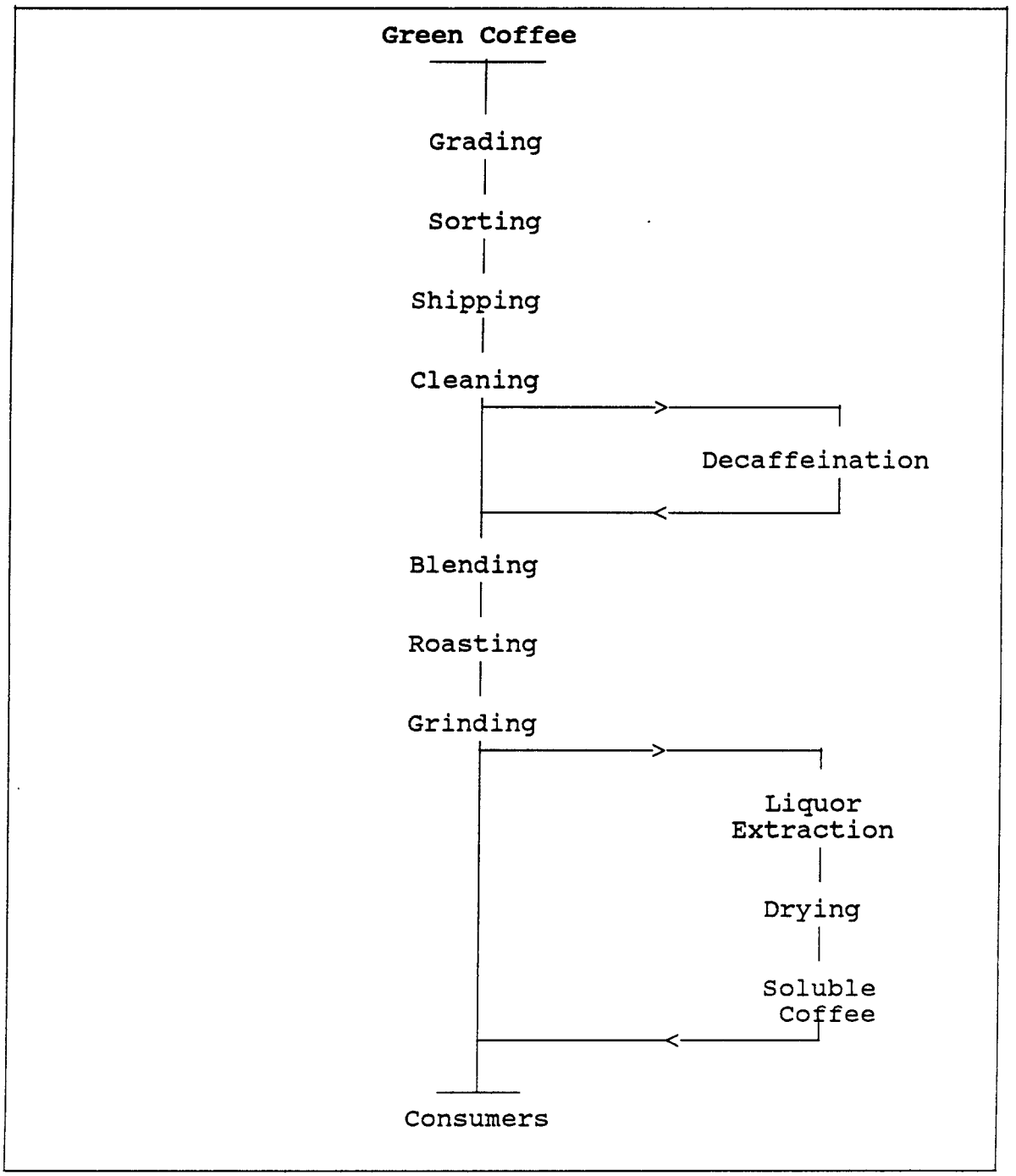
Shipping

Parchment and unwashed dry cherry coffees from the growers are collected at central mills or factories for hulling, grading, sorting, and shipping. Green beans are normally stored in the producer countries pending sale to processors in consuming countries. Coffee storage is discussed later in this profile. Coffee is shipped in bags on pallets or in containers.

Cleaning

Despite the sorting and grading operations in the producing area, coffee on arrival at the roasting plant often needs further cleaning.

Flowchart 2: Coffee - Secondary Processing



Decaffeination

The amount of caffeine present in green coffee varies between 0.8% and 1.5% in arabica and 1.6% to 2.5% in robusta coffees. Recent health concerns related to caffeine consumption have created a growing demand for decaffeinated coffee.

The major technique for decaffeination is solvent extraction. There are five steps in solvent extraction: 1) steaming green coffee beans for several hours; 2) caffeine extraction by treatment with an organic solvent - methylene chloride - for 12 to 18 hours; 3) solvent recovery by steaming; 4) vacuum or air drying; and 5) roasting. Certain solvents used in the past (chloroform, trichlorethylene) have been found to contribute to cancer in rats and mice and are now rarely used. Thorough extraction of the solvent from the coffee is critical. Solvent, steam, and water requirements in this process are substantial.

Water extraction was developed as an alternative to the use of chemical solvents and their residue problems but it is not widely practiced.

Caffeine extracted from both methods is condensed and purified for use in the pharmaceutical industry.

Blending

Coffee beans are mixed or blended to create certain flavor, aroma, and other qualitative characteristics. The main objective in blending is the production of uniform coffee on a regular basis, at least cost and utilizing available raw materials.

Small scale blending can be done in the roaster; large scale operations usually blend the beans before roasting. Beans for blending are weighed, combined and roasted together. Large continuous operations automatically blend according to pre-determined 'recipes'.

In situations where the combination of different green beans roasted together would produce poor overall flavor development, blending can be performed after each batch of beans has been roasted separately.

Roasting

Aromatic and taste qualities of coffee are developed during roasting. Traditional roasting is a batch process but increasingly the trend is towards large-scale continuous operations.

Coffee roasters operate by the passage of hot air through a tumbling bed of green beans in a rotary drum. The whole operation takes between five and twenty minutes depending on the degree of roast required, type of bean and moisture content. After roasting the beans are cooled usually with a heat transfer system using water.

A major objective in roasting is the achievement of uniformity. This is obtained by constant movement of the beans in the roaster and by good grading and sorting beforehand.

Grinding

Coffee grinding technology has evolved from pulverization of beans between pestle and stone to gradual reduction through a series of corrugated roller mills. The object is to efficiently and economically produce a wide range of standardized grinds which conform to predetermined size and density specifications. Fineness of the grind determines the speed at which water, filtering through the coffee, absorbs aroma and flavor.

Soluble Coffee

Instant coffee is manufactured by extraction and drying of the soluble solids and aromatic compounds in roasted coffee. In this sophisticated and capital-intensive process, roasted and ground coffee is percolated through a battery of columns; the concentrated extract is then filtered and either spray- or freeze- dried. Reconstituted coffee is formed by the addition of hot water.

Coffee flavor is altered during percolation and drying. Blends selected for soluble coffee tend to be of lower quality than those sold for "regular" consumption, but they are chosen on the basis of their ability to withstand percolation and drying with the minimum of flavor deterioration. The insoluble spent grounds are dried and utilized as fuel.

MARKETING ASPECTS

Quality Considerations

The most important market factor to be considered is the quality of the beans, which is based on factors influencing the flavor of the liquor brewed from them. Tasting is more of an art than a science and coffee is judged on several factors including acidity and sourness, bitterness, and body. Many adjectives are used to describe the taste and aroma sensations, including: acidy, acrid, bitter, bland, green, sweet, balanced, sour, stale, mushy, bricky and woody. Reliability and consistency of supply in relation to these factors is also critical.

Quality control at every stage of production and processing is critical to final quality. Beans that are off-color, diseased, defective, or old will be rejected by the buyers. Poor harvesting, handling, pulping, fermentation, drying, storage, or shipping result in beans with poor 'liquoring' qualities. Inadequate classification, grading, sorting, or cleaning will increase the proportion of defective beans and reduce their acceptability and price.

In addition to inadequate processing control, the choice of process and variety is significant. Generally the wet process produces higher quality than the dry process. Robusta coffee has a higher caffeine content than arabica and is better able to withstand percolation and dehydration in the manufacture of soluble coffee. However, the flavor of robusta is not normally considered as 'desirable', so that most soluble coffees are a blend of the two types of coffees.

Pricing

Movements of world coffee prices have historically been inversely related to world stocks. In the pre-WWII international coffee market a strong price support policy by Brazil and in later years the International Coffee Organization's (ICO) use of export quotas and trigger prices have worked to sustain a relatively stable price environment. The high levels of stocks and low real prices characteristic of the 1960s and early 1970s were reversed, however, by a severe frost which damaged the Brazilian crop in 1975. Likewise, Brazil's recovery in later years has led to a build-up of coffee stocks and a subsequent decline in price.

Once again, however, damage to the Brazilian crop in 1985 has led to a surge in prices and a decision to the ICO to suspend export quotas.

A decline in coffee prices in the mid-1950s resulted in the 1962 International Coffee Agreement (ICA 1962) which led to the establishment of the International Coffee Organiztion (ICO). The ICO's objectives were to balance the supply and demand for coffee while catering to both producers and consumers needs. Under the auspices of the ICO, the International Coffee Council (ICC), consisting of all member countries, was established as the highest authority; it works to set quotas, determine regulatory instruments and monitor the international coffee market.

By the 1976 ICA, buffer stocks were the main market regulatory instruments, used in conjunction with export quotas and trigger prices to regulate prices. The tools of ICA 1983 are the same as those of ICA 1976, though there are changes in how quotas are determined. ICA 1983 will be in force until 1989, at which time a succeeding agreement will probably come into effect.

The ICO and ICAs are important factors in the world coffee market, and it is important to distinguish between ICA member countries and non-member countries, especially in the export markets. Prices and export levels differ substantially in these two markets, and thus contribute to the growth of dissension among ICO member exporting countries in need of foreign exchange. In 1983/84, world coffee exports were 66.8 million bags. ICO members were expected to export between 56.0 to 57.5 million bags (83.8% to 86% of world exports) to member importing countries, while at the same time, exporting between 8.7 to 10.2 million bags (13% to 15.3%) to non-ICO member countries. Non-member countries are reported to pay up to 50% less for coffee than members whose prices are influenced by the $1.20 - $1.40 per/lb. ICO price range.

The development of this two-tier market of importing countries with large price discounts being given to importing non-ICO members has contributed to both the dissatisfaction of importing ICO members and the growing dissension among ICO member exporting countries. These latter countries need foreign exchange and are burdened with large carry-over stocks. They are hoping to push even more high quality coffee onto non-member ICO markets. (Coffee & Cocoa International, vol.12, no.1, 1985). From October 1984 to March 1985 4.5 million bags of coffee went to non-members, while members tolerated a 2.7 million bag under-

shipment. This is in violation of Article Two of the ICA; nevertheless, the trend is continued into 1985.

The ICO has countered with a resolution setting strict guidelines and penalties governing export levels and prices, but it remains to be seen whether its effect will be significant.

Packaging

To maintain quality and meet different consumer requirements, roast coffee is packaged in bags, jars, pouches, and tins. Improperly packaged coffee has a very short shelf life and 'ages' within a few weeks, primarily as a result of exposure to oxygen or moisture. Selection of packaging materials and techniques is a critical factor in the reduction of 'staling', rancidity, off-flavors, and aroma loss.

OTHER FACTORS

Coffee Storage

Storage capacity is needed to cope with seasonal harvest peaks and market-imposed restrictions on shipment. Coffee is stored in parchment form by wet processors and dry cherry coffee is stored by producers and traders where dry processing is used. Without correct procedures dry coffee will deteriorate during storage because of the rapidity with which it absorbs moisture. Good initial storage will reduce deterioration in subsequent poor conditions, such as in shipping.

Cherries. Ripe cherries for pulping should not be stored more than a few hours or fermentation will begin. If the cherries do need to be stored for a short time before processing, storage under water minimizes fermentation.

Parchment coffee. In tropical countries, coffee tends to store better in its parchment or unhulled state than when hulled or polished as green coffee. In good storage conditions parchment coffee will retain its quality for at least 12 months.

Green coffee. Under ideal conditions (well-ventilated warehouses in temperate climates) green coffee can be stored for up to three years. In tropical areas, however, storage time is considerably

reduced: Robusta coffee remains commercially viable for up to two years but arabica coffee begins to deteriorate after only six months.

Generally, green coffee is bagged and stored with 10% to 11% moisture content. (12% maximum.) Attention to the following storage factors will ensure high quality coffee:

- good sorting and drying before storage.
- maintenance of cool conditions, controlled ventilation, and relatively constant temperature during storage.
- maintenance of the correct moisture content in the beans.

Environmental Aspects

There are two main sources of pollution during primary processing; water used for fermentation and skins, hulls and water from pulping and hulling. In both cases these by-products can be reclaimed for use in fertilizers, irrigation, animal feed or as mulch.

Smoke from the coffee roaster may be controlled by thermal recovery, afterburners or wet scrubbing but in some cases the cost of these measures is prohibitive.

Dust is the major problem associated with grinding. It can be controlled by the installation of cyclones or dust filter bags. During grinding, workers also need protection from hazardous buildup of carbon dioxide and other volatile ingredients of coffee which are released. Approximately 250 liters of gas are released from 100 kg of ground coffee.

Water pollution from soluble coffee manufacture arises from washing spray driers, tanks, pipelines, floors, etc.

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ANNEX I:

EXAMPLES OF INVESTMENT AND OPERATING COSTS

Representative Investment and Operating Costs

COFFEE WASHING FACILITY

Construction of a three disc coffee washing facility.

COUNTRY: Kenya

NOTE: These data are representative only and are unique to the time, country, and circumstance of the identified investment. Their applicability to other situations may vary considerably.

ANNUAL PRODUCTION AT FULL DEVELOPMENT:

120 tons clean coffee
144 tons parchment coffee

Per Cent of Full Capacity Utilization: 80.00%

	US$ '000		
	Local	Foreign	Total
	Jan, 1980 Prices		
I. Investment Costs			
Buildings and Civil Works			
water tank	1.29	0.86	2.16
sorting shed	1.78	1.18	2.96
cherry hopper	2.28	1.52	3.79
pulper house	1.49	0.99	2.48
fermentation tanks	2.96	1.98	4.94
soak tanks	1.98	1.32	3.30
tank shade	1.58	1.05	2.63
coffee bag store	4.73	3.15	7.89
chemical bag store	1.58	1.05	2.63

(Continued on Page 2)

Representative Investment and Operating Costs

NOTE: These data are representative only and are unique to the time, country, and circumstance of the identified investment. Their applicability to other situations may vary considerably.

	US$ '000		
	Local Jan,	Foreign 1980 Prices	Total
Buildings & C.W. (cont'd)			
pump houses	1.08	0.72	1.80
washing channel	0.47	0.32	0.79
skin tower	0.30	0.20	0.50
other	2.13	1.42	3.55
Sub-Total Buildings and C.W.	23.65	15.77	39.43
Machinery & Equipment			
skin drying tables	0.94	0.40	1.34
retention tank	0.70	0.46	1.16
pulper house machinery	10.88	3.63	14.50
recirculation pumps	8.53	2.84	11.38
main water pumps	3.70	1.23	4.94
drying tables	29.34	12.57	41.91
Sub-Total Machinery and Equipment	54.08	21.14	75.23
Total Investment Costs	77.73	36.91	114.65

Representative Investment and Operating Costs

NOTE: These data are representative only and are unique to the time, country, and circumstance of the identified investment. Their applicability to other situations may vary considerably.

	US$ '000 Total Jan, 1980 Prices
II. Annual Full Development Operating Costs	
Fixed Costs	
repairs & maintenance	11.60
management staff	10.48
Sub-Total Fixed Costs	22.08
Variable Costs	
labor	3.93
processing materials	1.84
utilities & power	0.82
Sub-Total Variable Costs	6.59
Total Operating Costs	28.66

DATA SOURCE: Adapted from Kenya Smallholder Coffee Improvement Project, Staff Appraisal Report No. 2253-KE, Volume II, Annex 3, January, 1979.

NOTES:
1. Exchange rate - Kenya Shillings 7.33 = US $ 1.00.
2. Data are net of contingencies.
3. Foreign/local operating cost breakdown is not available.
4. Depreciation expenses not shown in operating cost estimates.

Representative Investment and Operating Costs

COFFEE WASHING STATION

Construction of a coffee washing station.

COUNTRY: Ethiopia

NOTE: These data are intended as representative only and are unique to the time, country, and circumstance of the identified investment. Their applicability to other situations may vary considerably.

ANNUAL FULL DEVELOPMENT PRODUCTION:

150 tons of clean coffee

Per Cent of Full Capacity Utilization: 100.00%

	US$ '000		
	Local	Foreign	Total
	1979 prices		
I. Investment Costs			
Civil Works			
reception area	0.92	0.31	1.23
cherry hopper	0.94	0.24	1.18
pulping house	0.61	0.20	0.82
fermentation tanks	5.10	1.70	6.80
channels/skin drying tables	1.43	0.36	1.79
skin/coffee pits	0.34	0.08	0.42
pump house	0.31	0.10	0.41
header tank	0.43	0.14	0.57
external piping	0.42	3.76	4.18
drying tables	18.32	6.11	24.43
fence	1.46	0.49	1.94
bag/chemical store	1.47	0.49	1.96
parchment coffee store	3.42	1.14	4.56
Sub-Total Civil Works	35.16	15.12	50.28

Representative Investment and Operating Costs

NOTE: These data are intended as representative only and are unique to the time, country, and circumstance of the identified investment. Their applicability to other situations may vary considerably.

	US$ '000		
	Local	Foreign	Total
	1979 prices		
Equipment & Machinery			
rotary feeder 3 disc	0.04	0.40	0.44
3 disc pulper	0.36	3.20	3.56
pre-grader	0.23	2.03	2.25
disc repasser	0.14	1.27	1.42
diesel generator set	0.49	4.37	4.86
diesel pump	0.42	3.82	4.24
moisture meter/sample huller	0.09	0.81	0.90
spring balance 100 kg	0.03	0.23	0.26
light duty platform scale	0.05	0.47	0.52
Sub-Total Equipment and machinery	1.84	16.60	18.45
Total Investment Costs	37.00	31.73	68.73

Representative Investment and Operating Costs

NOTE: These data are intended as representative only and are unique to the time, country, and circumstance of the identified investment. Their applicability to other situations may vary considerably.

II. Annual Full Development Operating Costs (excluding raw material costs)	US$ '000 Total 1979 prices
Fixed costs	
administrative staff	4.95
repair & maintenance	1.45
administrative overheads	0.88
depreciation	8.12
Sub-Total Fixed Costs	15.39
Variable Costs	
seasonal labor	6.26
fuel & lubricants	0.46
bag purchase	0.82
miscellaneous	0.69
Sub-Total Variable Costs	8.23
Total Operating Costs	23.62

DATA SOURCE: Adapted from Preparation Report for the Second Coffee Processing Project, Ethiopia, April, 1979. Prepared by the Coffee and Tea Development and Marketing Authority.

NOTES:
1. Exchange rate Ethiopian Birr 2.07 = US $ 1.00. IMF's International Financial Statistics, May, 1985.
2. Data are net of contingencies.
3. Full development is year 4 after project start-up.
4. Foreign/local operating cost breakdown is not available.

Representative Investment and Operating Costs

COFFEE ROASTING, GRINDING, AND PACKING

Completion of a facility for coffee roasting, grinding, and packing. Initial purchase of machinery and equipment provided capacity for processing up to 1,120 bags of coffee. This was upgraded to 6,000 bags following second purchase of machinery and equipment.

COUNTRY: Kenya

NOTE: These data are representative only and are unique to the time, country, and circumstance of the identified investment. Their applicability to other situations may vary considerably.

ANNUAL FULL DEVELOPMENT PRODUCTION:

6,000 50 kg bags of roasted, ground coffee

Per Cent of Full Capacity Utilization: 100.00%

	US$ '000 Total 1979 prices
I. Investment Costs	
Machinery & Equipment	
- initial purchase	
coffee roaster	3.55
cooler	1.91
grinder	2.05
weighing scale	0.41
gas cylinders	0.38
scales	0.56
miscellaneous	0.29
installation charges	5.02
Sub-Total First Purchase	14.16

Representative Investment and Operating Costs

NOTE: These data are representative only and are unique to the time, country, and circumstance of the identified investment. Their applicability to other situations may vary considerably.

	US$ '000 Total 1979 prices
Machinery & Equipment	
- second purchase	
coffee roaster	7.78
cooler	2.46
automatic packer	32.74
grinder	1.49
dust collector	2.73
gas tank installation	1.09
miscellaneous	0.55
Sub-Total Second Purchse	48.83
Pre-Operating Expenses	2.05
Total Investment Costs	65.03

Representative Investment and Operating Costs

NOTE: These data are representative only and are unique to the time, country, and circumstance of the identified investment. Their applicability to other situations may vary considerably.

II. Annual Full Development Operating Costs (excluding raw material costs)	US$ '000 Total 1979 prices
Fixed Costs	
administrative staff	28.31
administrative expenses	4.23
depreciation	17.46
maintenance and repair	14.19
insurance	2.32
Sub-Total Fixed Costs	66.50
Variable Costs	
labor	22.83
packing materials	143.11
water & electricity	17.74
fuel and oil	17.46
miscellaneous	2.05
Sub-Total Variable Costs	203.20
Total Operating Costs	269.70

DATA SOURCE: Adapted from Sub-Project File for the M/S Matara Trading Company Limited, Kenya Industrial Estates, Ltd. appraisal report, November, 1979, financed under IDA Credit 750-KE.

NOTES:
1. Exchange rate Kenya Shillings 7.33 = US $ 1.00.
2. Land and buildings for the above facility are rented, and are included under fixed costs (administrative expenses).
3. Data are net of contingencies.
4. Foreign/local cost breakdown is not available.
5. Full development is year 4 after project start-up.

ANNEX II:

CONVERSION TABLES

WEIGHTS AND MEASURES

avoirdupois

Ton: short ton	20 short hundredweight, 2000 pounds; 0.907 metric tons;
long ton	20 long hundredweight, 2240 pounds; 1.016 metric tons.
Hundredweight	cwt;
short hundredweight	100 pounds, 0.05 short tons; 45.359 kilograms;
long hundred weight	112 pounds, 0.05 long tons; 50.802 kilograms.
Pound	lb or lb av; also #; 16 ounces, 7000 grains; 0.453 kilograms.
Ounce	oz or oz av; 16 drams, 437.5 grains; 28.349 grams.
Dram	dr or dr av; 27.343 grains, 0.0625 ounces; 1.771 grams.
Grain	gr; 0.036 drams, 0.002285 ounces; 0.0648 grams.

Troy

Pound	lb t; 12 ounces, 240 pennyweight, 5760 grains; 0.373 kilograms.
Ounce	oz t; 20 pennyweight, 480 grains; 31.103 grams.
Pennyweight	dwt also pwt; 24 grains, 0.05 ounces; 1.555 grams.
Grain	gr; 0.042 pennyweight, 0.002083 ounces; 0.0648 grams.

METRIC SYSTEM

Square kilometer	sq km or km^2; 1,000,000 square meters; 0.3861 square mile.
Hectare	ha; 10,000 square meters; 2.47 acres.
Hectoliter	hl; 100 liters; 3.53 cubic feet; 2.84 bushels;
Liter	l; 1 liter; 61.02 cubic inches; 0.908 quart (dry); 1.057 quarts (liquid).
Deciliter	dl; 0.10 liters; 6.1 cubic inchs; 0.18 pint (dry); 0.21 pint (liquid).
Centiliter	cl; 0.01 liters; 0.6 cubic inch; 0.338 fluidounce.
Metric ton	MT or t; 1,000,000 grams; 1.1 US tons.
Quintal	q; 100,000 grams; 220.46 US pounds.
Kilogram	kg; 1,000 grams; 2.2046 US pounds.
Gram	g or gm; 1 gram; 0.035 ounce.