VANILLA

Post-harvest Operations

INPhO - Post-harvest Compendium

Food and Agriculture Organization
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Vanilla: Post-harvest Operations

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1. Introduction

Vanilla (*Vanilla planifolia A.*) is a major natural flavor widely used in many industries as food, beverages, sodas, pharmaceutics, cosmetics tobacco and traditional crafts. Vanilla beans originated in Mexico, and in some Central American countries as Costa Rica and Honduras. However, today vanilla beans are cultivated in many areas of the world and the main producing countries are (Fig. 1) Madagascar, Indonesia, China, Comores and in a lesser extent Tonga, Reunion, Turkey and Guadeloupe. In México, the main producing area is located in the Totonacapan, located in the northern part of the state of Veracruz. In recent years the Mexican states of Oaxaca and Puebla have joined Veracruz for production and processing of vanilla beans (Musalem, 2002).

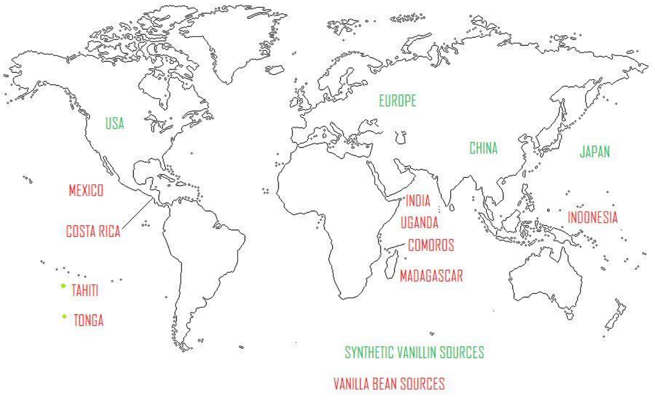

Fig.1 Vanilla beans producing areas

Chemical composition of processed vanilla

Composition of processed vanilla beans is fairly variable and complex due to a number of variables such as species, growth conditions, soil composition, fruit maturity and mainly, the type of processing. All these variables define the relative content of the chemical constituents in the processed beans, which makes it difficult to define their typical composition. Ranadive (1994) reported a composition based on literature reports. In a general manner, processed beans contain vanillin, vanillic acid, p-hydroxybenzoic acid, p-hydroxybenzaldehyde, proteins, sugars, fiber as hemicellulose and cellulose, waxes, resins, pigments, tannins, minerals and essential oils. Most of these components have been reported by Rao & Ravishankar (2000) and are shown on Table 1.

Table 1 Chemical composition of processed vanilla beans

COMPONENT	g/kg bean	(d.m.)
Vanillin	20	
vanillic acid	1	
p-hydroxybenzaldehyde	2	
p-hydroxybenzoic acid	0.2	
Sugars	250	
Lipids	150	
Cellulose	150-300	
Minerals	60	
Water	350	

(Rao & Ravishankar, 2000).

a) Origin

From historic archives, the first data on vanilla dates back to 1427-1440 AD, which is period when the Aztecs conquered the Totonacan empire, which offered vanilla to the conquerors as a duty. Vanilla was named “tlil-xochitl” in Nahuatl, which means “black flower”. The Aztecs used vanilla as flavor and aroma ingredient for chocolate, a drink destined only for Aztec noble families. Spaniards took vanilla to Europe in 1519, when Hernán Cortés sent Francisco

Montejo y Portocarrero to Spain as bearer of the profits from the expedition, together with a number of novel products, including vanilla.

In 1793 vanilla was taken to Paris' botanical gardens, and then to England. In 1822 vanilla plants from France were sent to Reunion island from where this orchid was propagated through the Indic ocean countries.

By 1850, more plants were taken from Reunion and Paris to Madagascar, where the crop became an important source of income such that Madagascar is now the largest producer of vanilla in the world (Rao and Ravishankar, 2000).

b) Taxonomy

Vanilla planifolia (also known as Vanilla fragrans Salisb. Ames) is the most important and most studied variety. Purseglove et al. (1981) described nearly 110 vanilla species distributed in tropical regions of the world. Vanilla planifolia belongs to the orchids family, la large family that comprises ca. 700 genera and over 20 000 species. However, vanilla is the only edible fruit that contains relevant flavor and aroma compounds (Ranadive, 1994; Rain, 1996). Taxonomy of vanilla was described by Mabberley et al. (1997) and depicted in Table 2

Table 2 Taxonomical classification of vanilla

Kingdom	Vegetal
Type	Fanerogamae
Class	Monocotyledonae
Order	Microspermae
Family	Orchidaceae
Tribe	Vanilleae Blume
Genre	Vanilla Swartz
Species	Vanilla planifolia Andrews Vanilla pompona Schiede Vanilla tahitense J.W Moore

(Mabberley et al., 1997)

c) Botanical description

There are three main systems for intensive cultivation of vanilla, which are dependent on the type of soil. Two systems use native trees as 'Acahuales' or native forest trees; while the third system is used for areas without trees. In each system, the goal is to attain 2 Tonnes of green vanilla beans per hectare, propagation material (cutting) totally productive and extend the productive life of the vanilla orchard to five years of full production.

d) Cultivars

Characteristics of the main vainilla varieties of the world

Species Vainilla fragans
Cultivation areas Bourbon islands, Indonesia, México and Tonga.
Flavor profiles Typical with soft creamy end notes, full aftertaste to dry fruits that reminds to cinnamon extract.
Aroma is round and equilibrated, and represents the most complete profile of all vanilla extracts.
Market The one with the highest demand for all industries.

Species Vainilla tahitensis
Cultivation areas Exclusively the islands of Tahití and Moorea
Flavor profile A quick release of initial flavor and relatively sweet, with greasy notes and somewhat weak.
Market This flavor has its highest demand in the French and Italian markets, mainly for ice cream manufacturing.

Species Vainilla pompona
Cultivation areas Exclusively in the islands of Guadeloupe and Martinica.
Flavor profile
Market Its main area of application is pharmaceutics and perfumes (Claridades agropecuarias,2002)

e) Cultural practices

Environmental requirements of the crop
Weather. Vanilla cultivation requires a temperature range of 21 to 32 °C, an evenly distributed annual precipitation of 1500 mm or more, 80% relative humidity and altitudes of 0 to 600 m above sea level.
Soil. The main characteristics that soils must meet for vanilla production are: good drainage, abundant organic material and pH values of 6 to 7. It is important to note that intensive production requires tutor trees and then soil depth should be 40 cm or more.
Land orientation
Production sites where slopes predominate, it is better to select lands that are covered by sunlight during the mornings, with an Eastward orientation. This is to avoid moisture reduction in the soil and overdry the plant (leaf burn) and beans by the afternoon sun.
Land preparation
Preparations are made based on the height of the native trees of the site selected for vanilla production.
The land is called forest type if trees taller than 10 m and wider than 50 cm diameter predominate; acahual-type is called if bushes and tress smaller than 10 m and widths smaller than 20 cm predominate; when there are no trees or bushes, the land is called deforested.
Preparation of forest-type land
Weeds must be controlled and branches that extend to less than 4 m from the ground, along with damaged branches, regardless of their height; small trees and bushes located under the shadow of taller trees should be eliminated to improve shadow distribution and ventilation to 50%. Cut plant material is usually shredded and used as mulch as organic matter source, while large pieces of logs are just discarded. When this is done, tutors are planted which will support the vanilla plants.
Preparation of acahual-type land.
As above, weeds need to be eliminated and mulch is prepared from dried branches. Bushes that will provide shadow and support are selected; these bushes should have one stem only, no branches should lay on the ground, with a height of 1.7 m with shadows in excess of 2 m

height. Trees or bushes taller than 2 m should be used as shadow providers only. After this is done, the land is ready for the tutors. Natural conditions of the vegetation should be considered. It is described below the systems employed to plant he tutors in the different types of land.
In forest land. For forest land the system depicted is suggested: 5000 tutors are set by hectare, distributed in rows and with a distance of 1 m between tutors and rows of 2.

Fig. 2 soil type for vanilla (Curti, 1989)

In acahual land. For this type of land, the system depicted in Figure 2 is suggested, comprising 6,600 tutors per hectare in double rows.
The system is based on two single rows where tutors are located 1 m apart. This way, there is a row of tutors, a space of 1 m, another row of tutors, a 2 m space, one row of tutors, a 1 m space, and so on. For tree land (forest and acahual), those trees that do not match the patterns of the rows for tutors must be eliminated as long as the shadow ratio is not greatly affected.

In deforested land. For this type of land tutor planting described in Figure 3 is recommended. In this scheme, 10000 tutors per hectare are established distributed in a 1 m by 1 m frame.

Fig. 3 Tutors (cocuites) for vanilla, (Curti, 1989)

For all three systems, it is recommended to use the “pichoco” Eritrina sp. as tutor. In deforested lands, it is more convenient to use 50% “pichocos” and 50% “cocuites” (Gliricidia sepium), since “pichocos” are not overly abundant. Planting of these two species must be alternated.

Characteristics of tutors

Both “pichoco” as well as “cocuite” trees are propagated by usually straight, one year old, 2 meters long and 3.5 to 5 cm diameter stakes. At planting, stakes should be buried in the ground 30 cm.
Tutors (cocuites and pichocos) establish themselves when leaf shots appear naturally, which happens between March and April in Totonacapan.
In order to decrease erosion of slopes, rows of tutors whenever possible, on leveled curves or across the slope.

Settling of organic matter

For all three systems described it has been suggested to arrange the plot to accommodate walking trails and areas for accumulation of organic matter, in order to reduce the damage to vanilla plants caused by roots stepped on during regular keeping activities as pest control, weed removal or pollination.
According to the type of land, the way organic matter is arranged may be:

In forest lands. If the land is flat or has little slopes, organic matter is placed on 4 m by 50 cm blocks in a way that 25 cm of organic matter on each side of the tutor's rows. If the land contains steep slopes, organic matter is placed on the highest part of the rows to form 4 m by 40 cm blocks. In either case, the blocks must remain 1 m apart along the rows, and 1.5 m between rows if the land is flat or 1.6 m for slopes.
In acahual land. For either flat lands or slopes, organic matter is placed between double rows, forming 4 m by 1 m blocks. These blocks are then separated by 1 m wide clear trails that contain no organic matter, along the double rows and by 2 m wide clear trails between double rows. Clear trails are use for transit within the plot.
In deforested land. Similar to the above types of land, blocks of 4 m by 1 m of organic matter are formed so that 1 m wide trails for transit are set in the plot.
In any type of land that is located on slopes, it is recommended that organic matter blocks should not be aligned in the same orientation as the slope, to prevent organic matter-free trails where water could flow freely. For this reason, trails that separated the blocks along the tutor rows should be arranged in zigzag.
It is important to keep humidity in the organic matter but not to exceed. Thickness of the organic matter layer should be 30 cm and in a decomposition stage, except when branches from pruning and weed are added. The best time to pile organic matter is after the "northerly" season (strong wings from the north), which brings moisture and assures water availability for the dry months of March through May.

Collection of propagation material (bot-cutting)

To avoid propagation of unproductive plants, as it is the case of the vanilla known as "donkey ear", which sheds up to 100% of its fruits after 2 months, it is necessary to follow the following guidelines:

To avoid planting bot-cuttings of unknown origin.
To procure bot-cuttings from plants in full production. For this purpose, suitable plants are selected, marked and located in layouts of the plot. Selected plants must be healthy and bear fruits of at least 3 months old. For bot-cuttings coming from Totonacapan, plant selection must be made between August 14 (three months after pollination) and November 14 (official harvest date).
Obtaining bot-cutting from selected plants. Right after harvest (after Nov. 15), the portion of the plant where fruit were attached is cut and used for propagation material. Bot-cuttings must be healthy, 1 m long and 1 cm thick. .(Fig. 4)

Fig.4. Bot-cutting for vanilla, (Curti, 1989)

Bot-cutting disinfection

Before the bot-cuttings are disinfected, the three leaves from their base must be eliminated with a knife or pruning pliers to facilitate planting. It is important to inspect the material to prevent disease propagation as rotting, anthracnose or mildew.

Bot-cutting disinfection is made with a fungicide as Benomyl, at a concentration of 2 g/L plus an adherent. The preparation is mixed with water in a container large enough to immerse cuttings in bundles of ten to be impregnated.

Planting of bot-cutting

Bot-cutting planting requires established shadows, moist organic matter arranged in blocks, weed-free transit trails and tutors with no branches 1.7 m from the ground level. Cuttings must be disinfected, without the three base leaves and their wounds healed, which usually occurs 1-2 days after the mechanical damage.

Planting season. For seasonal production plots, planting season is May and June, while irrigated plots may be planted more freely, except for September and October, to prevent that winter temperatures burn the young sprouts.

Planting procedure. First, 20 cm depth holes are made on the ground at a 45-degree angle using the bot-cutting. The portion with no leaves is introduced and then a light pressure is applied so the cuttings remain firmly stuck. Then, a section of the cuttings is covered by organic matter, and finally, the rest of the cuttings are tied to the tutor. For this binding, it is recommended to use natural and degradable materials as banana leaves, tree bark stripes or creepers

Plot handling

Shadow. Shadow of a vanilla plot is closely related to plant development; it must be constant and keep an equilibrium throughout the year, so that moisture losses in the surrounding environment and the organic matter are prevented during the dry months; additionally, to protect the beans of low temperatures during the cold months. Too dense shadows produce stem thinning, whereas too little shadows the plant develops burns during the dry season. In either case, the plant weakens and becomes predisposed to attack by pathogens (Fig 5)

Fig 5 Shadow in vanilla plantation, (Curti, 1989)

Shadow handling during the year. Handling depends on humidity and sunlight conditions prevailing through the year, Three critical seasons are recognized: the dry season, the rainy season and the northerlies. Below it is described the amount of shadow required for each season.

Dry season. There are usually very sunny days and it is desirable to keep humidity high of the surroundings and the organic matter. In this case, shadow should be near 80% or similar to the shadow provided by an adult mango tree.

Rainy season. In a condition of excess humidity, care must be taken to prevent sunrays to burn the plants, and accumulation of too much humidity in the surrounding environment. A

shadow of 50% is recommended, which is similar to that provided by an adult flowering tree of Delonix regla.
"Northerlies" season. In this season, days are commonly cloudy and there is a persistent and light rain, that produces humidity accumulation. This condition reduce the risk of sun burn. A shadow of 20% is recommended, similar to that provided by an adult "casuarina" (Casuarina equisetifolia) or sweet pine

Shadow regulation (tutors pruning). Shadow regulation of forest or acahual lands starts with pruning of the tutors (pichocos), but if an excess of shadow still remains, lower branches may be cut, together with native brushes. In contrast, if areas with deficit in higher shadows are detected, it is necessary to allow for natural forage development of tutors.
In deforested lands, shadows are controlled by establishing cocuites and pichocos in February or March, and then, pruning is done for pichocos in July or August when sprouts reach 40 to 50 cm and in November and December for cocuites.
This pruning sequence is repeated every year. If only pichocos were planted half of the trees are pruned in July-August in alternate rows in such a way that a pruned pichoco is surrounded by four non-pruned pichocos (Fig 6).

Fig 6. Tutors for vanilla, (Curti, 1989)

In the second pruning season in November-December the other half of tutors is pruned and by that time, those trees that were pruned in July-August had developed shots 40 to 50 cm long. When the plot has not enough shadow and beans may be sun burn, plants may be covered with banana, corn or palm leaves.
Pruning method. Branch cutting is done 40 cm from the tutor's fork (Figure 13). Sharpened pliers are used preferably, but if machetes are to be used, skills must be developed not to damage the tutor or the vanilla plant. Branches cut are placed in the organic matter blocks (Fig. 7).

Fig 7 Method for tutors pruning, (Curti, 1989)

1.1 Economic and social impact of the vanilla crop

A major component of the labor force in Madagascar and Comoros is found in the agricultural sector. In 2000, the vanilla production line in Madagascar employed about 20,000 growers and 5,000 producers. Although we lack data to estimate the population involved in vanilla production in the Comoros, a significant portion of the more than 70% of the active population which works in rural areas, is active in the production of vanilla, one of the country's two export crops. In both countries, vanilla export is monopolized by the government and the associations of vanilla exporters. Likewise, the government sets the final prices, both for the green bean and the final product. Vanilla export represents a large portion of government revenues, thus monitoring vanilla production and vanilla trade in the world became some of the priorities of the governments of Comoros and Madagascar. Policy makers of these countries recognize the effects that a cyclone or a disease on vanilla in disrupting the social safety nets in these developing countries (Alwahti, 2003)
An apparently local shock such as a cyclone can have repercussions that extend over many years and across multiple continents and economic classes. Furthermore, by examining how the effects of cyclones differ from year to year and place to place is not necessarily a fixed state, but instead can change over time based on non-local political and economic forces.For example, poor farmers in many developing nations were lured into the vanilla market in the late 1990s and early 2000s due to shortages in Madagascar's production, shortages that were partially due to cyclones. National campaigns were launched and incentives were provided by

international agencies to promote vanilla production as a way out of poverty, and for many farmers, it did offer gains. While many Malagasy farmers suffered during that period, farmers elsewhere saw their fortunes soar. Yet, later stability in Madagascar's production, due to a relatively cyclone-free few years, led to a sharp decline in demand for vanilla from those emerging regions. Thus, and perversely, good weather in Madagascar can be understood as the "natural disaster" for farmers in other poor countries attempting to establish themselves in the global vanilla market.

Table 3- World country vanilla production (Source: FAOSTAT, 2006)

2006 Top Vanilla Producers

Country	Production (tonnes)	%
Madagascar	6,200	59%
Indonesia	2,399	23%
China	1,000	10%
Mexico	306	
Turkey	192	
Tonga	144	
Uganda	195	
Comoros	65	
French Polynesia	50	
Réunion	23	
Malawi	20	
Portugal	10	
Kenya	8	
Guadeloupe	8	
Zimbabwe	3	
Source: UN Food & Agriculture Organization		

In the early 80's the trend in international markets for natural products sprouted. These products were regarded as safe and posed no threat to human. This trend induced major changes in the way foods are produced, processed and handled, as well as in food safety laws, regulations and procedures of the importing countries intended to protect consumers' health and reduce the cost of health care. In this context, world market for vanilla demands increased availability of the natural product to face the competition by synthetic flavors as vanillin, ethyl vanillin and coumarin. The latter compound has been associated to cancer development. Increased interest for naural vanilla produced increased prices for the produce and prompted vanilla culturing in Mexico and the world (Musalem, 2002).

1.2 World trade

As it has occurred with other products, the main vanilla producing countries are not necessary those where the plant was originated. Usually, producing countries received the plant years after their discovery.
The main vanilla producing countries in descending order are: Indonesia, Madagascar, China, México, and then others, which together supply most of the vanilla consumed in the world, as it is depicted on Figure 1.1

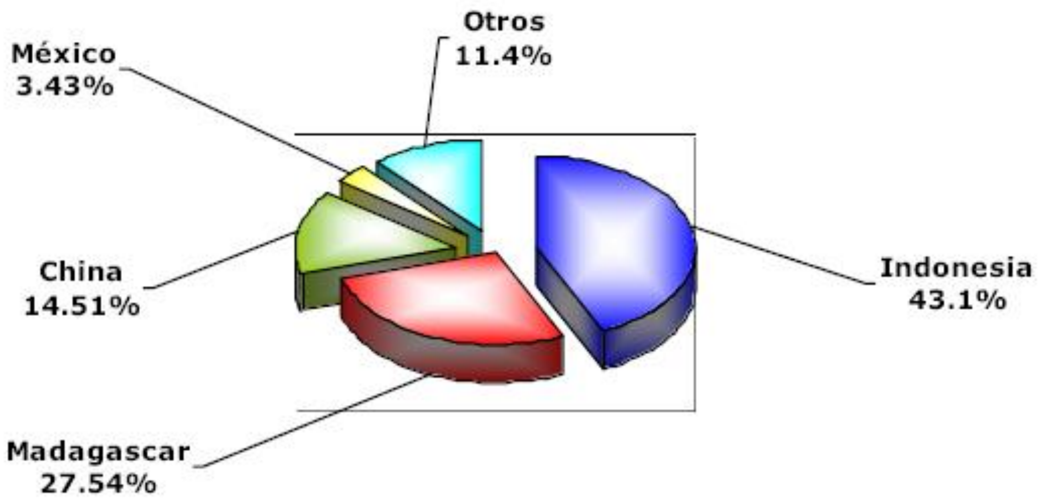

Figure 8 Distribution of vanilla world production in 2003
(source: http://www.apps.fao.org/faostat)

Vanilla production in Indonesia represents nearly 41 to 43 % from the total world production, with an annual volume of 2,060 tones. Indonesia also holds a high productivity of 0.22 tones/hectare, compared to 0.06 ton/ha of Madagascar. However, Indonesia produces varieties Java and Bourbon, both of which are quality vanillas, but do not reach the same trade value as that of Vanilla planifolia from Madagascar and other producing countries (Musalem, 2002).

Comoras islands together with India, Togo, Uganda and French Polynesia make up for most of the rest of the world production. All the latter countries have encouraged vanilla cultivation and trade targeting the main markets of USA and Europe, although their productions do not match those of Indonesia and Madagascar.

In México, vanilla has become important in the Totonacan region of Veracruz, reaching the status of the main agricultural activity in addition of its cultural relevance. In 1956 nearly 9000 hectares were cultivated with a net production of 1,500 tones of green vanilla pods (Musalem, 2002). By the end of that decade, the price of the produce declined due to the following factors:

a) The world market had a surplus in supply, as a result from the elevated productions of African and Asian countries, mainly Madagascar and Indonesia.

b) Introduction of synthetic flavorings with sensory qualities resembling natural vanilla, at lower prices.
c) A major factor was the effect of petroleum drilling and refining that altered and damaged ecosystems where vanilla was produced. This situation made the plantations more sensitive to plagues and illnesses, which led to changes in produce from vanilla beans to oranges, coffee beans, or even cattle production.
Over the past few years prices for this orchid have been concomitant increased as it can be observed in Figure 9

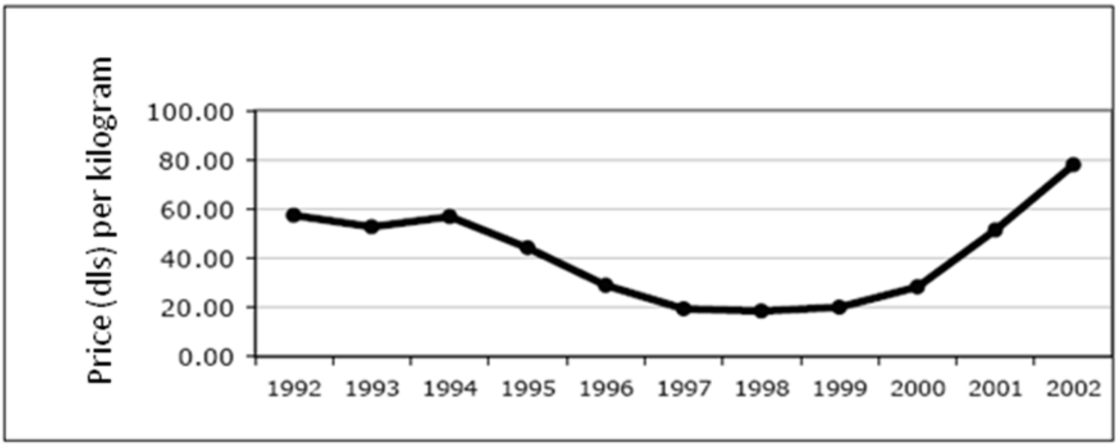

Figure 9 Mean annual international price (in US dollars) for cured vanilla (Source: http://apps.fao.org/faostat)

In the international market, cured vanilla beans are conveniently classified according to their geographical source or origin (Correll, 1953). The principal groupings are: Mexican beans those coming only from Mexico; Bourbon beans – formerly referring only to those produced from the island of Réunion (then named Bourbon) but currently inclusive of all beans from Madagascar and the Mascarene, Comoro and Seychelles islands; Tahiti beans grown in the French group of the Society Islands; and Java beans – derived from Indonesia. From 1990 to 2000, average world production of vanilla beans amounted to 4466 Mt harvested over a total of 38 485 ha (FAO, 2003). Indonesia contributed about 38% of this world produce, slightly higher than Madagascar at around 34%, while Mexico and Comoro Islands had less than 10% share. The annual world import of cured vanilla beans averaged US$545m. In the same decade the USA imported the biggest mean volume of cured beans at 1448 Mt worth US $52m, followed by France at 374 Mt and Germany at 318 Mt. From 1990 to 1995, the price of vanilla bean imported by the USA ranged from US$42 to 74 kg–1 averaging at US$64 kg–1 (USA Vanilla Bean Imports Statistics, 2002). In 1988, marketing estimates by McCormick & Co., Inc. revealed that vanilla extract was largely used by the industrial sector (75% of the total supply), followed by the retail sector (20%) and the food service sector (5%) (Gillette and Hoffman, 1992). Of the total industrial application, 30% was utilized in ice cream preparations, 17% in soft beverages, 11% in alcoholic beverages, 10% in yoghurt and the remaining 7% in bakery items, confectioneries, cereals and tobacco products. (Handbook of Herbs and Spices, 2008).

Countries that cure vanilla and re-export the finished product make important profits without running risks associated with primary production. Thus, the main re-exporting countries are Japan, Germany, France, UK and USA. (Table 4).

Table 4 The main importing countries are included in the following table

Value Imports	1990	1995	2000	2001	2002	2003	2004
United States of America	49,321	60,373	44,644	128,472	162,460	291,279	205,114
France	14,978	13,725	20,357	35,254	52,251	97,976	44,899
Germany	18,881	14,626	11,309	20,079	27,243	29,864	36,606
Canada	6,269	11,708	1,779	1,462	2,327	15,997	17,943
Japan	4,348	4,937	7,202	13,465	15,176	25,184	15,422
United Kingdom	1,986	2,688	6,494	16,620	15,655	16,629	12,982
Singapore	168	1,037	607	1,265	2,145	8,503	9,306
Switzerland	3,511	2,568	2,502	3,729	5,665	7,778	6,180
Australia	443	1,251	949	1,035	2,268	2,952	5,597
Denmark	1,111	1,215	1,480	1,475	2,318	4,772	4,693
Netherlands	2,662	1,592	2,030	2,672	2,016	7,246	4,187
Subtotal	103,678	115,720	99,353	225,528	289,524	508,180	362,919
Rest of the countries	4,774	8,045	9,382	14,619	17,357	27,458	32,085
World total	108,452	123,765	108,735	240,147	306,881	535,638	395,004
% from total	0.956	0.935	0.914	0.939	0.943	0.949	0.919

While the main exporting countries are:

Value Exports (1,000$)	1990	1995	2000	2001	2002	2003	2004
Madagascar	56,958	33,460	21,348	83,348	136,298	121,537	64,188
Papua New Guinea	0	7	0	551	5,170	32,566	31,712
United States of America	1,850	4,353	13,294	10,495	6,603	12,928	26,671
Germany	15,888	9,929	9,780	14,172	19,817	23,047	25,753
France	3,285	5,848	6,873	13,801	19776	37,569	23,826
Comoros	9,406	6,428	4,926	5,660	8,055	11,000	18,764
Indonesia	16,367	17,452	8,503	19,309	19,160	19,275	16,502
Canada	117	4,891	4,749	1,092	1,785	16,510	15,298
Singapore	568	469	1,112	1,644	2,573	12,543	7,407
India	0	10	426	1,190	404	3,156	6,516
Uganda	0	8	1,046	2,210	6,897	2,708	6,119
French Polynesia	674	1,403	171	979	2,071	3,174	2,544
Belgium	0	0	156	310	406	3,821	2,145
New Zealand	0	1	1	0	17	689	1,950
Mexico	609	651	625	1,566	2,773	2,327	1,606
Subtotal	105,722	84,910	73,010	156,327	231,805	302,850	251,001
Rest of the countries	3,266	4,639	8,462	19,631	19,623	26,899	9,116
World total	108,988	89,549	81,472	175,958	251,428	329,749	260,117
% from total	97.0	94.8	89.6	88.8	92.2	91.8	96.5

1.3 Primary product

Green Vanilla

Given the ripening characteristics of the beans it has been considered that a minimum waiting period to start harvest could be nine months from pollination (Fig 10). However in Mexico, it was decided to set the harvest kick off date at Nov. 15. Harvest consists in cutting the beans and pack in bags (Fig 11). Cutting is made by hand with no tools or utensils to avoid physical damage to the beans. This is a major issue for producers and there is a grading system for green product reported by Curti (1989).

Fig 10 pollination of vanilla

Fig 11 Packing of green vanilla

Vanilla fruits are gathered when they are fully mature but before they are too ripe. When picked immaturely, the fruits do not develop the requisite full-bodied aroma and proper colour during processing and are more prone to fungal infection (Correll, 1953). When harvested at the over-ripe stage, the fruits tend to split and lose some of their aroma (Fig 12).

The following serves as harvest indices for vanilla (David, 1950; Purseglove, 1985):

• The thickest portion of the fruit (the 'blossom end') takes on a pale yellow colour.
• Overall pod colour changes from dark green to light green.
• The fruits lose their lustre and become somewhat dull.
• Two distinct lines appear from one end of the fruit to the other.

Since flowering is staggered, harvesting is likewise extended over a period of time (Handbook of herbs and spices, 2008).

Fig. 12 Stages in vanilla maturation, (Curti, 1989)

Grading for green vanilla:
Whole vanilla: Fully mature beans, well developed and with no mechanical or insect damages nor illness.

Spotted and cracked vanilla: Beans with considerable damages by Antrachnose, which produce a spotted apperance, mature fruits with natural longitudinal cracks (Fig 13)

Fig 13 Antrachnose in vanilla, (Curti, 1989)

“Zacatillo” vanilla: Small. Immature malformed fruits, with severe mechanical and insect damages.

Lo más importante del tiempo de corte y de la clasificación de los frutos, es que la vainilla se encuentre en su estado pleno de madurez. Broderick (1956) menciona que las vainas deben ser cosechadas cuando el apical se torna de color amarillo, ya que el fruto se encuentra en el estado de madurez óptimo para su cosecha (Fig 14).
Las vainas cosechadas son casi siempre sin olor y para que desarrollen su aroma característico es necesario un proceso denominado beneficio o curado del fruto, donde los precursores del aroma inducen a la formación de los compuestos aromáticos, siendo la glucovainillina el principal precursor de los principales componentes de las vainas de vainilla.

Fig 14 Vanilla harvest

1.4 Alternative products from vanilla

Vanilla is one of the most recommended products to:
Flavoring
Tobacco, liqueurs, food, beverage, confectionaries
Flavor Enhancer –smoothes and blends
Fruit, citrus, chocolate, savory, dairy
Sweetness potentiator
Bitterness maskant
Reduces burning, biting sensations
Aromatherapy
Pain reduction in women
Calming, reduces the startle reflex
Fragrance
Perfume, candles, air fresheners, incense, household,
Baby, and personal care products
Medicinal
Psychological, Sloane-Kettering reported 63%
reduction in stress level of MRI patients
Reported cure of sexual dysfunction in men
Insect Repellant

Odor Maskant
Paint, industrial chemicals, rubber tires, plastics
a) By- products
Residues from vanilla beans employed to prepare ethanolic extracts is a high fiber by-product that could be utilized in the formulation of functional foods. Fiber-rich foods are known to act as intestinal regulators and laxatives, prevent colon cancer, absorb bile salts, delays absorption and decreases serum glucose and cholesterol
On the other hand, vanilla residues contain precursors which could be converted into vanillin by suitable enzymes. Given the high cost of natural vanilla flavoring, the recovery of flavoring agents from its residues would clearly be of economic interest. Fermentation of vanilla residues yields products with useful aromatic properties. They enhance the flavor of vanilla extract and bring it closer to that of the freshly extracted flavoring. (Pouget, 1990)

1.5 Requirements for export and quality assurance

a) Export grading
After drying, the vanilla sticks are first separated into two categories: in split and non-split fruits. The intact pods are then sorted into four quality grades.

1. quality:
juicy, oily, chocolate brown coloured, perfectly formed, vanilla sticks with no blemishes.

2. quality:
somewhat thinner pods with slight defects (flecks or scars).
3. and 4th quality: depending on thickness, color, uniformity, number of flecks and degree of dryness.
After grading, the vanilla sticks are bundled, wrapped in wax paper and packaged in Aluminum or wooden crates.
Other gradings in the trade include Bourbon vanilla (rich, mature aroma, with up to 2.9% vanillin), Mexican vanilla (fine aroma, up to 1.8% vanillin), Tahiti vanilla (sweet, perfume-like aroma, up to 1.5 %vanillin) and Indonesian vanilla (ligneous, strong aroma, up to 2.7% vanillin).
b) Market requirements
The following (Table) is a list of quality characteristics with minimum and maximum values for vanilla sticks that are usually required officially or by importers. Different minimum and maximum values can be agreed between importers and exporters, providing these do not clash with official regulations (Naturland, 2000).

Table 5 Quality characteristics

Quality characteristics	Minimum and maximum values
Taste and smell	Typical for variety, strong, aromatic
Purity	Free of foreign matter, i.e. sand, stones, shell parts, insects etc.
Vanillin	min. 2.0 %
Ash	max. 7.0 %
Hydrochloric acid-soluble ash	max. 0.5 %
Residues	
Pesticides	Not measurable
Bromide Ethylene oxide	Not measurable Not measurable
Micro-organisms	
Mould fungi	max. 100,000/g
Escherichia coli	max. 10,000/g
Bacillus cereus	max. 10,000/g
Sulphite reducing Clostridium	max. 10,000/g
Staphylococcus aureus	max. 100/g
Salmonella	Not measurable in 20 g
Mycotoxins	
Aflatoxin B1	max. 2 Sg/kg
Total aflatoxins B1, B2, G1, G	2 max. 4 Sg/kg

Color is also an important factor of differentiating vanilla sticks. Roughly, the following range can be retained:
Brown vanilla: the most common type. These beans are chocolate brown and present a 18-22% moisture content. They are the most popular among extractors.
Black vanilla: also known as "Gourmet Vanilla". The beans are very dark - almost black - with a higher humidity rate of 25-35%. This grade is most used for restaurants, domestic cooking, etc. (Figs 15, 16, 17, 18 and 19))

Fig 15 Ordinary quality vanilla (Curti, 1989)

Fig 16 Regular quality vanilla (Curti, 1989)

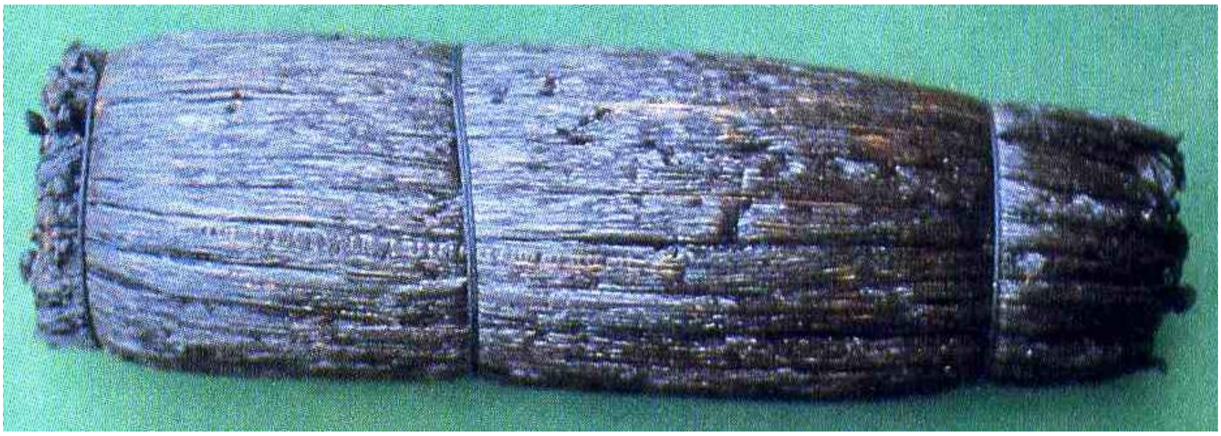

Fig 17 Good quality vanilla (Curti, 1989)

Fig 18 Extra quality vanilla (Curti, 1989)

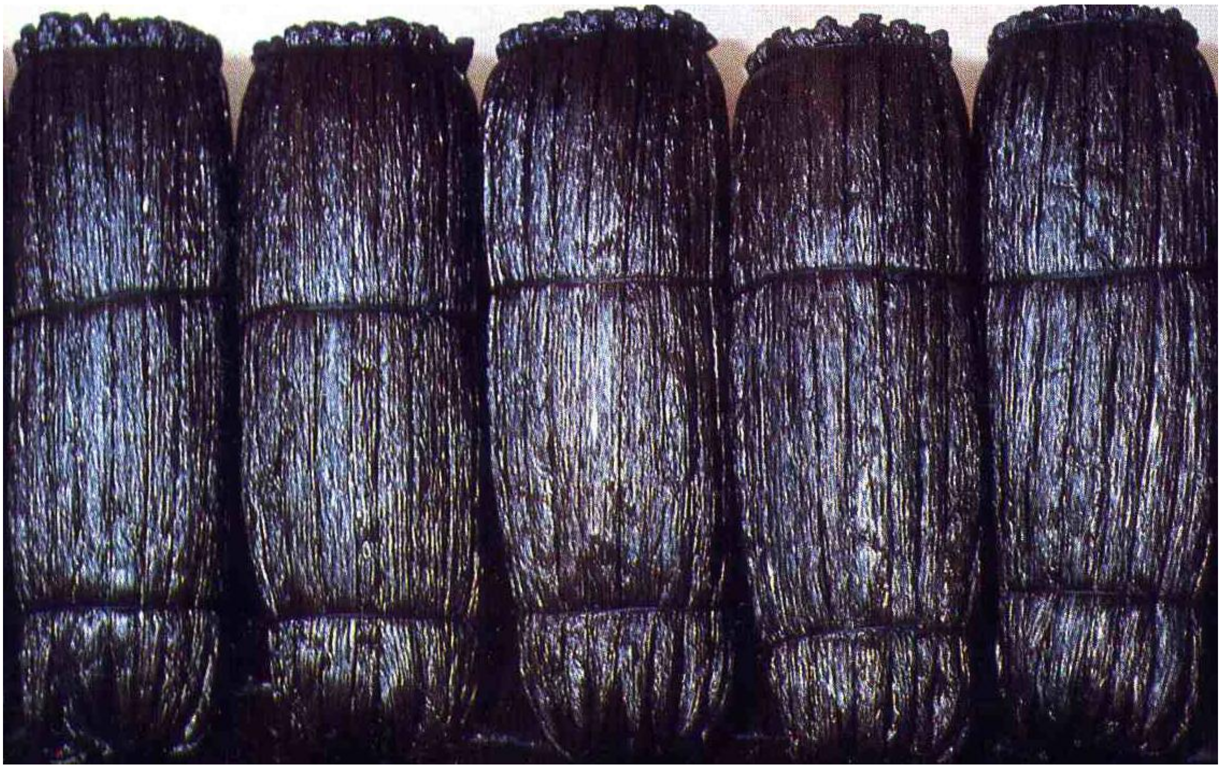

Fig 19 Superior quality vanilla (Curti, 1989)

Consumer preferences

Natural vanilla experiences strong competition on two levels. Within the vanilla flavor category, there is competition from synthetic vanilla, or vanillin. Vanillin is the major flavor constituent of vanilla, but it is produced through various bio-technological processes, which continue to be developed. Although natural vanilla contains many more flavor components than just vanillin –several hundreds have been identified–, the difference in taste with synthetic vanilla is hard to detect in most applications, especially for the untrained "mouth". There is also a production of ethyl-vanillin, but this has a less agreeable taste and is used principally in cosmetics and animal feed.

Vanilla flavor is also in competition with other flavors. At this level, vanilla has a strong position as one of the world's most popular flavors. Vanilla is especially popular in ice creams, beverages, desserts, dairy products, chocolate, confectionery products and pastry. Recent high profile introductions such as Vanilla Coke confirm this popularity.

While vanilla flavor experiences strong and growing demand, within the larger category real vanilla is increasingly being substituted with synthetic vanillin. This substitution was catalyzed by the limited availability and extreme price increases in 2002 and 2003, but also responds to longer-term factors, including:

• consumer preferences for natural products;
• technological developments, especially in vanillin production;
• changes in regulation.

The consumer trend of demanding natural products is a positive factor. Demand for natural vanilla showed continuous growth throughout the 1990s, in spite of the price difference that was huge even then. On the other hand, this trend is balanced with an increasing price-consciousness consumer and other concerns. The demand for the natural variety of vanilla is probably only decisive in the gourmet segment. In the mainstream segments, there is a strong tendency to "cheat", i.e. to use more economic vanilla substitutes, especially since this is not

easily noticed by the average consumer. But this is where the government steps in (Epopa, 2005).
A recent study by David Michael & Company (2006), reported that vanilla flavor was preferred after chocolate flavor in ice cream by European, American, South American, Asian and Australian consumers.
A tremendous shift has occurred among home fragrance consumers, as people realized that having a pleasant smelling home is not just for holidays or special occasions anymore. People expect their homes to smell great year around, thus buying and using home fragrance products has become an everyday necessity for more Americans. Fragrances reflect individual personalities within the home and choosing the right fragrance has become increasingly important to home fragrance consumers.
Citrus notes such as lemon, orange, lime a n d grapefruit, which were traditional perceived as functional, are now blending with sophisticated floral, fruity and vanilla notes to create a fresh, clean sensation. Gourmand fragrances continue to be top sellers in the candle market and have grown substantially in the air freshener segment as well. Vanilla and vanilla based fragrances continue to be top sellers.

1.7 Varieties and commercial cultivars

Cultivars

Bourbon vanilla or Bourbon-Madagascar vanilla, produced from V. planifolia plants introduced from the Americas, is the term used for vanilla from Indian Ocean islands such as Madagascar, the Comoros, and Réunion, formerly the Île Bourbon.
Mexican vanilla, made from the native V. planifolia, is produced in much less quantity and marketed as the vanilla from the land of its origin. Vanilla sold in tourist markets around Mexico is sometimes not actual vanilla extract, but is mixed with an extract of the tonka bean, which contains coumarin. Tonka bean extract smells and tastes like vanilla, but coumarin has been shown to cause liver damage in lab animals and is banned in the US by the Food and Drug Administration.
Tahitian vanilla is the name for vanilla from French Polynesia, made with the V. tahitiensis strain. Genetic analysis shows that this species is possibly a cultivar from a hybrid-cross of V. planifolia and V. odorata. The species was introduced by French Admiral François Alphonse Hamelin to French Polynesia from the Philippines, where it was introduced from Guatemala by the Manila Galleon trade . [16]
West Indian vanilla is made from the V. pompona strain grown in the Caribbean, Central and South America.
The term French vanilla is not a type of vanilla, but is often used to designate preparations that have a strong vanilla aroma, and contain vanilla grains. The name originates from the French style of making ice cream custard base with vanilla pods, cream, and egg yolks. Inclusion of vanilla varietals from any of the former or current French dependencies noted for their exports may in fact be a part of the flavoring, though it may often be coincidental. Alternatively, French vanilla is taken to refer to a vanilla-custard flavor.[16] Syrup labeled as French vanilla may include hazelnut, custard, caramel or butterscotch flavors in addition to vanilla (Wikipedia, 2008).

2. Harvesting and Post-production operations

Traditional and improved picking operations

2.1 Harvesting

Harvesting:

Vanilla beans are ready for harvest in six to nine months after pollination. The beans are harvested one by one when they are fully-grown and as they begin to ripe. At this stage, beans change their color from dark green to light green with yellow tinge. Immature beans produce an inferior product and, if picked too late, the beans start splitting. Bunch or broom harvesting should be avoided. The well-ripened ready beans detach easily from the bunch just by lifting them in reverse direction. Immature beans do not detach easily from the stalk; but, on the other hand, leave behind a bit of the bean in the bunch. Hence, to pick the beans at right stage, the plantation should be visited two or three Times a week. The green beans do not possess any aroma. Processing and curing should commence within a week of harvest. The main variable to consider to decide harvest time is for the beans to have reached full maturity (Broderick, 1956). Beans must be harvested when the apex turns yellow, which indicates optimal maturity. Beans are mostly odorless and further processing or curing is necessary to develop their characteristic aroma, whereby precursors induce production of aroma compounds, of which glucovanillin is the main precursor of the main components of processed vanilla beans.

Arrangement of vanilla beans in the transport boxes:

Beans are placed horizontally inside the specialized boxes making layers of 25 to 30 cm. thick and allowing enough air circulation to avoid crushing and lack of air. Each box must contain its net weight outside (Figs. 20 and 21)

Fig 20 Vanilla plastic box transport

Fig 21 Vanilla wood box transport

Transport from the boxes to the processing facility:
Harvest must get started in the early morning hours, once the fruits are naturally dry Boxes should be placed near a path where a vehicle can pick them up and take them to the processing facility.
The harvesting of the beans demands substantial labor efforts. The vanilla harvest lasts two months and farmers should preferably pick beans a few times a week. Beans that are not harvested in time turn black and are then overripe for processing (ADC, 1998).
All in all, each production cycle includes two labor peaks: one during the flowering stage (two months) and one at the harvesting stage (two months). In Mukono (Uganda), the centre of vanilla production, the rainfall pattern allows two production cycles per year. Vanilla vines start flowering after a dry season of two to four months, and Mukono has two such dry seasons. Thus, vanilla production in Mukono is characterized by four labor peaks a year totaling 8 months. Vanilla is indeed a labor-intensive crop.
The number of available household members (adults and children) determines to a large extent the number of vanilla vines that can be handled successfully. Children participate especially in the pollination exercise as their small fingers and sharp eyes are well suited for the job. The pollination cannot be done after school as it has to be carried out in the morning to be successful. This leads to high school-truancy levels during pollination periods.
In addition to family members, casual laborers may be mobilized. In Mukono, communal or group labor, whereby people mutually assist each other without payment, has died out (Kyabangi, 1995; Kasente et al., 1998).

Therefore, households can only call on casual laborers if they have money to pay them. This is a major restriction although in 1998 more than half of the vanilla smallholders utilized hired labor (ADC/IDEA, 1998).

There is a difference between male-headed and female-headed smallholder households in their use of hired labor. In 1998, more male-headed households hired labor than female-headed ones (Table 6). In male-headed households substantially more of the total labor requirements were met by hired labor. The number of family members engaged in vanilla production was the same for male and female-headed households. The male-headed households had, however, on average a larger area under vanilla than the female-headed ones. Although female-headed households owned less land than male-headed households, land was not the limiting factor in vanilla production. Therefore the figures suggest that male-headed households with a larger area under vanilla could handle this crop because they were able to hire more labor. As hired labor has to be paid, these households must have had more financial resources.

Table 6 Labor and land characteristics of male and female-headed households in vanilla production, 1998

	Male-headed households	Female- headed households
Labour:		
-Number of family members Engaged in vanilla	4	4
-% of farmers utilizing Hired labour	60	50
-% hired labour of total labour Requirements	25	10
Land:		
-Average area owned	8	5
-Average area under vanilla	0.7	0.5

Source: ADC/IDEA, 1998
*includes plantations producing and new

Vanilla farmers wanting to expand production by hiring labour face a growing problem due to the increasing scarcity of labour for hire especially in the central region of Uganda. In the past, Rwandan refugees who were living in Uganda came to the farms to work. They have, however, either returned to Rwanda or bought land themselves. While the local supply of casual labor is declining in rural areas, demand is increasing. Casual laborers are still available in large numbers in the west and north-west of Uganda, but it is too expensive for an individual smallholder to relocate them. Moreover, these people do not have experience with vanilla. Casual laborers from the central region have experience, but they are expensive. Mechanization is not a solution. Vanilla is interplanted with other crops and grows on support trees. Therefore, land preparation prior to vanilla planting has to be done by hoe and cannot be done by tractor. Once planted, weeding also has to be done by hoe. Vanilla plants have shallow roots and even a small tractor would easily damage their root system if used for weeding. A tractor might also damage the foot of a vanilla stem leading almost inevitably to the death of the plant. (Dijkstra, 2001)

2.2 Yield

The result of vanilla harvest is largely determined by the level of the soil fertility, its cultivation, fertilization, and the plant's variety. The optimum result of vanilla of Vanilla planifolia type, with a good cultivation technique is 3 kg of fresh vanilla per plant. In each hectare, therefore, fresh vanilla which can be produced reaches 3.000 kg. For Indonesian situation, such a result is still far to obtain since until the present time, the average yield obtained in each hectare is only 140 kg of fresh vanilla fruit.

The production pattern of vanilla plants is not always the same from year to year. If it is well cultivated, a vanilla plant can produce an optimum result in the age of 3-4 years. After that the product will continue to decrease until the sevents harvest, then the plant will die. The number of optimum production of fresh during its productive period is shown in Table 7

Table 7 Production of vanilla plants

Year	Vanilla plant wet (Kg)
1	
2	
3	
4	0.36
5	0.72
6	1.08
7	1.44
8	1.08
9	0.90
10	0.72

Source: http://www.bi.go.id

Sorting and Grading: Size and appearance get the primary importance here, since; there is a direct relationship between the aroma (or vanillin content) and these factors. The beans are classified according to their length as follows:

Table 8 Size classification of vanilla beans

Length of beans	Grade of beans
15 cm and more	I
10-15 cm	II
10 cm	III
Splits, cuts and damaged beans	IV

Source: http://www.bi.go.id

2.3 Packing

After sorting, the beans are tied into bundles, usually 70 to 130, weighing between 150 and 500 g. (Fig 22). These are then packed into cardboard or tin boxes lined with waxed paper. The beans are now ready for shipment.

Fig 22 Bunches of vanilla to be packed

Bulk packaging

In order to be exported to Europe, the graded vanilla sticks are generally sealed in units of 20-30 bundles (8-10 kg) in metal tins lined with wax paper to avoid drying out.

Consumer packages

If the vanilla sticks are not to be packaged in bulk containers in the country of origin, but sealed in consumer packages, then this packaging should fulfill the following functions:

· Protect the vanilla sticks from loss of aroma and against undesirable smells and tastes from its surroundings (aroma protection).

· Protect the contents against damaging.

· Offer sufficient conservation properties, especially against loss or gain of moisture.

· Provide a surface area for advertising and product information.

· Prominent notification of the vanilla's ecological origin

· Easy to open and re-seal, so that those vanilla sticks remaining in the case stay fresh.

The following materials can be used as product packaging:

· Plastic tubes with screw-tops

· Single-layer plastic bags (polyethylene or polypropylene) (Naturland, 2000).

Storage

Beans should be kept in a tightly-closed container in a refrigerated area where they should last up to six months. Pure vanilla extract has an indefinite shelf-life, and actually improves with age. Vanilla powder is also available, which should also be kept tightly-sealed, in a cool, dry place away from sun and heat. Whole beans that have been used in sauces or other liquids can be rinsed, thoroughly dried, and stored for reuse.

2.4 Packinghouse operations

a) Inspection

When properly cured vanilla is a fairly stable product to store, if adequate conditions are maintained.

Carefully packed beans should be kept under regulated temperature (10° to 15°C/50° to 59°F) and controlled humidity ratio (60-65%).

The beans are shipped either in metal or cardboard boxes, lined with a plastic bag and wax paper to preserve the quality

The bundles of vanilla sticks, sealed in metal tins or wax paper can be stored for up to 1 year at a temperature of ca. 5°C.

This is best achieved using the following methods:

· Training and informing of warehouse personnel

· Explicit signs in the warehouse (silos, pallets, tanks etc.)

· Color differentiation (e.g. green for the organic product)

· Incoming/dispatched goods separately documented (warehouse logbook)

It is prohibited to carry out chemical storage measures (e.g. gassing with methyl bromide) in mixed storage spaces. Wherever possible, storing both organic and conventional products together in the same warehouse should be avoided (Naturland, 2000).

b) Killing: Graded beans are transferred to a bamboo basket and immersed in hot water at a temperature of 70oC for periods as indicated in Table 9

Table 9 Killing of vanilla beans

Grade of beans	Period of immersion (minutes)
I	5
II	4
III	2
IV	1.5

Source: Varanashi Research Foundation (VRF), Karnataka, India

c) Sweating: The treated beans are then transferred immediately to a wooden box lined with blanket, for sweating and kept for 36-48 hours. The temperature initially is to be 48-50oC. By then, the beans will attain light brown color and start imparting aroma.

Sun drying: Later on, the beans are spread in hot sun (from 12 noon to 3 pm) over wooden loft on a clean black blanket. The temperature of the bean, at this time should raise to 50oC. Later on, the bundles are transferred to the sweating box. Sun drying and sweating is continued grade-wise, as indicated in Table 10

Table 10 Sun drying of vanilla beans

Grade	Period (days)
I	12-14
II	7-10
III and IV	5-7

Source: Varanashi Research Foundation (VRF), Karnataka, India

At the end of this period, the beans lose half of initial weight, turn to a shining dark brown color and develop wrinkles. Also, their aroma improves.
Slow drying: The next step involves the spreading of the beans in racks kept in well-ventilated room maintained around a temperature of 35oC and relative humidity of 70 %. The duration of slow drying is as indicated in Table 11

Table 11 Slow drying of vanilla beans

Grade	Period (days)
I	20-35
II	10-20
III	3-10
IV	2-8

Source: Varanashi Research Foundation (VRF), Karnataka, India

On completion of slow drying, the vanilla beans get heavy longitudinal wrinkles, turn lustrous with brownish black color and become supple. They offer a soft leathery touch; can be rolled around finger easily and on release, becoming straight. The moisture content at this stage may be around 30-35 per cent.
Conditioning: The dried and classified beans are bundled (150 - 250 gm each), tied with a thread and kept for conditioning inside wooden or metal boxes lined with wax paper for two months. By this time, there is a further loss of three to four per cent moisture with the full development fragrance. Finally, the bundles are wrapped in wax papers and stored in airtight containers. The reduction in weight from green to conditioned beans ranges from 4.5:1 to 6:1, depending on the grade.
On the whole, meticulous care has to be taken during the curing process, as otherwise the quality of the beans may get deteriorated due to fungal, bacterial or other pest damage.

Points to remember
To get quality and sustainable yield, organic farming technique is to be adopted.
Curing of green beans is to be commenced within a week of harvest.
Matured, light green with tinge of yellow colored beans are to be harvested individually, avoiding broom harvesting.
For heat killing, temperature of water should not exceed 65-70oC.
Initial sweating is to be for 24 to 48 hours. Extension of this period will initiate rotting.
Daily sun drying is to be followed by proper sweating for controlled fermentation.
The beans are to be examined everyday during sun drying and slow drying for avoiding infection.
Moulds, if noticed, has to be removed from time to time. These beans are kept away from other beans.
As in the previous steps, beans are to be checked regularly, during conditioning too; to avoid any infection.

d) Packing and packaging materials
The transport packaging should display details of the following:
Name and address of the manufacturer/packer and country of origin
Description of the product and its quality class
Year harvested
Net weight, number
Batch number
Destination, with the trader's/importer's address (Naturland, 2000)
e) Containers
Refrigerated containers operate with the refrigerated air supplied across the t-section floor, circulating around the container and returning to the system via the top of the cargo. The "temperature set point" is the temperature entered into the controller, or microprocessor, of a temperature controlled container. This determines the air temperatures supplied to the container. However good the container, and however well cooled, packed, and stowed the cargo, there is of necessity a temperature gradient within the container, which is dependent on outside conditions. Such gradients are known and understood by container operators and the reason for temperature variations include: effects of ambient temperature, container thermal properties, air circulation rate, air flow patterns, refrigeration control system and loading temperatures.
Integral containers in chilled mode control the air temperatures via the supply air probe. Modern integral units are fitted with dehumidifiers and in-built data-loggers measuring temperatures, relative humidity and events. Digital displays allow visual monitoring of temperatures. The software installed in these integrals also prevents fans from blowing warm, moist air into the container until the refrigeration system has restarted, and the evaporator coil has cooled. This helps maintain the integrity of the temperature chain. Air must circulate around the cargo to absorb the small amount of heat that enters the container through the insulated walls, ceiling, and floor. It is imperative that cargo is not loaded above the load limit line on the walls, to ensure air circulation occurs. Air must be allowed to flow between the door and the rear cargo stow, which must not extend beyond the end of the t-section floor. Space (chimneys) must not be left between pallets, or cartons, ensuring air does not short circuit back to the refrigeration unit. Gaps must be plugged with dunnage material to ensure that the maximum volume of air flows around the door area. Shippers of very small cartons sometimes cover the floor of the container with a form of hardboard that is covered with pinholes.
Cargo stability is important and shippers must ensure the cargo is well braced before closing the container's doors. Care must be taken when opening containers in case cargo has been displaced, thus creating a safety hazard. Each country has its own maximum load weight regulations, as do the containers; we can advise shippers of the relevant requirements. Shippers must ensure they take full advantage of the available cube space in a container, re-designing the packaging may improve the utilization of available volume and thus reduced transport costs.
Container Preparation
The procedure involves a physical and technical inspection of each unit to make sure the unit performs as required. Cleaning of the container involves removal of any solid matter, using hot water, detergent wash, and steam as required. The container needs to be dry before being moved to the stuffing point. Shippers must inspect and accept that each container has been supplied clean and odor free (P&O Nedlloyd, 2001).

2.5 Pre-treatments

a) Curing

After harvesting, the pods of vanilla need to be cured to develop the characteristic natural flavor associated with the product. Curing can be defined as the sum total changes that occur during the primary processing of a given raw material to a desired finished product, which is ready for market (Jones and Vicente, 1949a). Curing stops the various natural vegetative processes in the harvested beans and promotes the metabolic reactions involved in the generation of the aromatic flavoring constituents in the cured material (Arana, 1944).

It can be broadly classified into two: (1) changes that involve a simple loss of water, achieved through drying, and (2) changes that involve chemical transformation, which is usually accompanied by hydrolytic and oxidative changes with or without the aid of enzymes. In vanilla, the latter changes are more critical.

Vanillin, the main flavoring chemical of vanilla, is present only in trace amounts in the green mature beans; upon curing, however, vanillin content increases (Arana, 1943). The chemical compound from which vanillin is derived occurs in the uncured pods in the form of a glucoside called glucovanillin (Arana, 1945). During the curing process, this glucoside is hydrolyzed to form vanillin and glucose through the action of a β-glucosidase. The activity of this enzyme changes with the maturity of the vanilla beans, being negligible in the green beans and highest in the split, blossom-end yellow beans. Spatially, all of the enzyme is located in the fleshy portion or thick wall of the pods, where most of the glucovanillin is also concentrated (Arana, 1943). Along the bean length, 40% of glucovanillin has been detected in the blossom end, another 40% in the middle and the remaining 20% in the stem end. Other flavor constituents such as p-hydroxybenzoic acid, p-hydroxybenzaldehyde and vanillic acid are also present in the green beans in their glycosidic forms and are released through enzymatic hydrolysis during curing (Ranadive, 1992).

The splitting of vanillin from the glucoside is initiated during the early part of the curing process, but the full development of flavor and aroma occurs only after a considerable period of pod preparation and conditioning (Arana, 1943; Jones and Vicente, 1948).

Treatment of cured beans with β-glucosides enhances vanillin content, suggesting incomplete hydrolysis, probably as a result of (a) insufficient amount of native enzyme, (b) inadequate enzyme–substrate interaction or (c) inactivation of enzymes by oxidized phenols liberated during curing (Ranadive, 1992). Chemical changes other than enzymatic hydrolysis may also contribute a great deal to the quality of cured vanilla. Balls and Arana (1941) suggested the possible role of a peroxidase system in the oxidation of vanillin to quinine compounds. These substances possess more complex structure with presumably different aroma that can add to the total flavor of the cured product. Wild-Altamirano (1969) reported that proteinase activity declines with pod growth while the activities of glucosidase, peroxidase and polyphenoloxidase increase with pod age, being maximum near or at ripening. The trend in enzyme activities is indicative of the potential role of the various products derived from catalyzed reactions in the full development of the characteristic flavor and aroma of cured beans (Handbook of herbs and spices, 2008).

In general, vanilla curing follows four successive steps:

(1) killing or wilting

(2) 'sweating'

(3) drying, and

(4) conditioning.

Killing or wilting is the initial step in inhibiting the natural changes in vanilla beans. It is achieved through various techniques, depending upon the producing country (Arana, 1945; Theodose, 1973). In Mexico and Indonesia, the most popular method is sun wilting. In this method the beans, which are contained on racks covered with dark woolen blankets, are simply heated under the sun. Wilting with the use of an oven maintained at 60ºC is alternatively practiced in Mexico. (Fig 23 and Fig 23a).

Fig 23 Oven killing of vanilla beans

Fig 23a Oven killing of vanilla beans

In Madagascar, Réunion and Comores, beans are killed by dipping in hot water for a few minutes (scalding technique) (Fig 24)

Fig 24 Hot wáter killing of vanilla beans

On the island of Guadeloupe, beans are gently scratched on the surface with the use of a pin embedded in a cork ring prior to sun exposure. Wilting by freezing has been developed in Puerto Rico for experimental purposes only. In this technique the beans are refrigerated until frozen and then thawed naturally at room temperature. Some of the advantages and disadvantages of these types of wilting are presented in Table .

The successive steps after killing are more or less similar for the different countries exporting vanilla. 'Sweating' or heating is done to develop the proper texture and flexibility. This is accomplished through either of two ways: (1) daily sun exposure for about six hours, with the beans covered with woolen blankets for the remainder of the day, incubation in ovens at 45ºC at high relative humidity (Arana, 1944, 1945). The significant change in color of the bean to chocolate brown is manifested at this stage (Balls and Arana, 1941). Sweating is terminated when beans become pliable. The next step is slow drying, which is normally carried out at room temperature. Drying is needed to lower the moisture content of the beans to a desirable level, usually 15–30% (Jones and Vicente, 1948). Finally, in conditioning the product is kept in closed containers at room temperature for several months to allow the complete development of aroma. In this last stage beans are frequently examined for the presence of moulds. At the minimum, conditioning lasts for three months (Arana, 1944).

An improved curing process using drying tunnels has been developed in Madagascar (Theodose, 1973). This method relies on hot air, instead of heating by the sun, and produces homogeneous, good quality beans in large quantities (40 tones dry vanilla in one season). Gillette and Hoffman (1992) depicted a very good comparison of the curing process associated with the different types of vanilla beans. The nature of curing procedures adopted affects the quality of cured beans. Aside from the influence of method of wilting, Arana (1945) pointed out that non-uniformity in drying, sweating and drying under the sun, use of dirty blankets and improper ventilation in curing rooms, all contribute to the susceptibility of beans to mould infection, which in turn lowers the quality of the product. He further noted that the moisture content of cured beans should
be properly controlled to obtain the full development of the vanilla aroma. The aroma of cured beans with 50–54% moisture is characteristically fermented; those with 24–27% moisture, sophisticated and well developed; while those with 31–34% moisture, just desirable.
Factors other than those related to curing protocol are also known to influence the quality of the final product. Vanilla beans that ripen early in the harvesting season yield higher quality cured beans than those gathered at mid-season or late in the season (Jones and Vicente, 1949b). The best cured material comes from pods harvested when the blossom-end section is yellow. When picked prior to this stage, beans give an undeveloped vanilla flavor; when beyond, a full but undesirable flavor is obtained (Broderick, 1955a). Immature beans when processed are also readily attacked by fungi (Arana, 1945) (Handbook of herbs and spices, 2008).

Table 12 Advantages and disadvantages of different methods of killing vanilla beans

Method of wilting.	Advantages	Disadvantages
Sun killing	Method is simple Does not require additional equipment	High degree of bean splitting beans mould easily
Oven killing	Short period of time for sweating and drying. Fewer split beans High vanillin content	High percentage of moldy beans
Hot-water killing	Few moldy beans and medium degree of splitting. Easiest and most satisfactory for the inexperienced curer.	Longer period of drying Low vanillin content
Scratching	Short period of time for sweating and drying. Low degree of splitting	High susceptibility to mould poor flexibility of the beans in the stem end Dependent on the skill and care of the curer
Freezing	Practically no mould Sophisticated aroma Beans are picked at the best stage of maturity and kept in the refrigerator until enough beans are accumulated.	Medium values for phenol, vanillin content and percentage splitting

(Handbook of herbs and spices, 2008).

b) Mexican processing method

The harvested vanilla sticks are placed in large heaps, so that they begin to sweat (Fig 25), wither and ferment. After a few days, they are laid out in the sun for a couple of hours (Fig 26) and then covered with a blanket around midday (Fig. 25). In the evening, the blankets and vanilla are rolled together and placed in sealed boxes to sweat further. Depending on the condition of the vanilla sticks, the process is repeated for around 8 days to a month. Regular checks are made remove moldy sticks, the sweating –which gives rise to considerable heat– begins the aroma forming process. The vanillin is contained in the balsam-like, oily liquid that develops in the inner layer of the pod. During the process, the liquid oozes out into the capsule's interior and evenly covers the pod. Each vanilla stick is individually stretched and smoothed out in order to ensure that the seeds and oily liquid from the fleshy interior are evenly spread throughout the pods. Drying, which takes place afterwards (Fig. 27), needs to be interrupted at precisely the right time (learned from experience), as the amount of aroma present –and thus the vanilla's value– is dependant on this. After processing, the vanilla sticks are typically dark brown in color, soft, pliable and smelling strongly of vanilla (Naturland, 2000).

Fig 25 Sweat of vanilla beans

Fig 26 Sun drying of vanilla beans

Fig 27 Conditioning of vanilla beans

c) Flavor constituents

The flavor famously associated with vanilla results from a complex and varied mixture of chemical compounds. About 170 volatile constituents, most of which occur below 1 ppm, have been reported in vanilla by Klimes and Lamparsky (1976). Vanillin serves as the major flavor backbone, occurring in levels from 1.52 to 2.42% of bean dry weight (Cowley, 1973). Other major components are p-hydroxybenzoic acid, p-hydroxybenzaldehyde, vanillic acid, p-hydroxybenzyl alcohol (Fig.28) and vanillyl alcohol. (Anwar, 1963; Smith, 1964; Herrmann and Stockli, 1982).

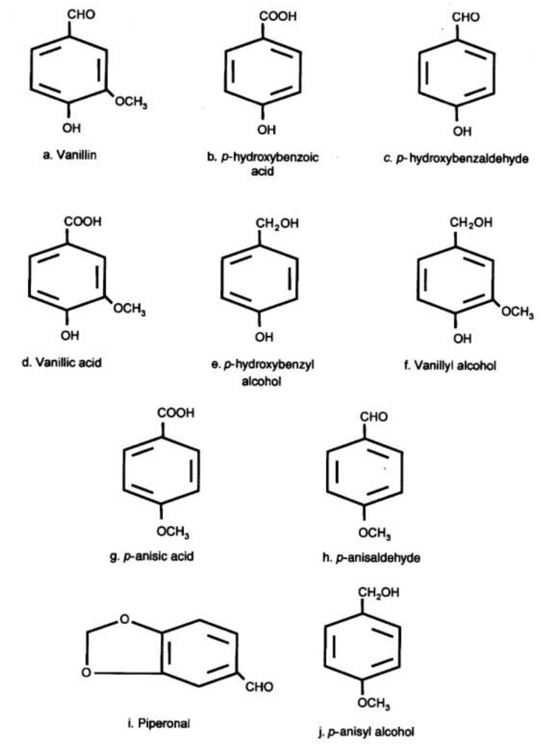

Fig 28 Chemical structures of the major flavoring constituents of vanilla

The type and levels of the major flavoring components vary depending upon the species and geographical source. Tahiti vanilla stands out among the different types of beans for exhibiting higher levels of p-hydroxybenzoic acid. Other components present in V. tahitensis that are not detected in V. planifolia are p-anisic acid, p-anisaldehyde and piperonal (heliotropin) (Ranadive, 1992). Vanillons (V. pompona, Guadeloupe vanilla) contains vanillin, p-hydroxybenzoic acid, vanillic acid, p-hydroxybenzaldehyde, panisic acid, p-anisaldehyde and p-anisyl alcohol, but not piperonal (Ehlers and Pfister, 1997).
The hydrocarbon profile of the lipidic fraction, which also contributes to flavor, of different types of beans has also bean investigated by Ramaroson-Raonizafinimanana et al. (1997). Hydrocarbon content varies between 0.2 and 0.6%. A total of 25 n-alkanes, 17 branched alkanes and 12 alkenes have been identified. Distinction between types of vanilla is also evident. Vanilla fragrans from Réunion is rich in n-alkanes (46%) and n-1-alkenes (26%), while V. tahitensis from Tahiti contains predominantly branched alkanes (47% for 3-methylalkanes and 33% for 5-ethylalkanes). Also present in the lipophilic fraction before saponification in the two vanilla species are three new γ-pyrones:2-(10-nonadecenyl)-2,3-dihydro-6-methy-4H-pyran-4-one; 2-(12-heneicosenyl)-2,3-dihydro-6-methyl-4H-pyran-4-one and 2-(14-tricosenyl)-2,3-dihydro-6-methyl-4H-pyran-4-one (Ramaroson-

Raonizafinimanana et al. 1999). γ-Pyrones are intermediates in the synthesis of biologically important compounds. A review of other flavor components as a function of vanilla species can be found in Richard (1991).
Werkhoff and Guntert (1997) characterized for the first time in Bourbon vanilla beans 15 esters that are derived from cyclic and acyclic terpene alcohols and aromatic acids. Among those isolated, pentyl salicyl important compounds. A review of other flavor components as a function of vanilla species

3. Pest species and pest control and decay

a) Diseases

A range of fungus diseases occur on vanilla cultivations, the most important of which are:

Fungus	Description of disease and cause
Fusarium oxysporum	Is the most frequent disease of roots and shoots. Infection results from wounds in the roots, which can be caused by stepping on them, or when the plants are pruned.
Anthracnose (Colletotrichum vanillae)	Affects leaves, shoots and fruits. Irregular brown flecks, the affected parts die and fall off, leaving indentions. Occurs most often on poorly maintained plantations with proper shading control (Fig 29)
Puccinia sinamononea (honguillo, roya)	Small, prominent, dark yellow blisters on the bottom of the leaf. When the blisters join up, large, dark irregular flecks form, and the plant eventually dies off. Occurs mostly on poorly maintained plantations during the wetter seasons

Fig 29 Anthracnose in vanilla leaves (Curti, 1989)

b) Pests

Generally, pests barely play a role on organic vanilla cultivations. Occasionally Clysia vanillana, a butterfly, may appear, whose caterpillars eat the capsules, also, bugs (Spinas floridulos, Nezara spp.), beetles and dwarf cicadas can cause a certain amount of damage. Snails that damage shoots and leaves turn up in some regions of Mexico.

Recommendations to prevent and counteract diseases
Choice of site (no water-logging, abundance of organic material);
· Plant vanilla only after tutors and support vegetation have been established;
· Gaps between plants must be large enough;
· Only plant healthy plants; plant seedlings after wounds have healed; eventually disinfect
· Remove diseased plants
· Management of light/shade and enrichment of organic material through tree trimmings;
· Avoid damaging the vanilla plants' roots by not stepping in their vicinity;
· Constant rejuvenation of the plantation (see below);
· Lignin-rich mulch material stimulates the actinomycetes in the soil, which are in turn antagonists of Fusarium;
· Do not pollinate too many blossoms, as this will weaken the plant .(Naturland, 2000)
The occurrence of a wilt disease caused by Fusarium oxysporum has been observed. (Fig 30)

FIg 30 Wilt disease in vanilla (Curti, 1989)

C) Recommendations to prevent and control diseases

For control of wilt disease adopt the following measures:

1. Remove diseased plants along with surrounding soil where the disease is observed.
2. Remove weeds around the plants.
3. Mulch the base of the vine with dry leaves before and after monsoon.
4. Avoid injury to roots during cultivation
5. Drench soil around the base of vine with 1% Bordeaux mixture (combination of copper sulfate and hydrated lime).

Fungal diseases like shoot tip rot, stem and bean rot caused by Phytophthora sp. as well as immature bean drop are noticed. The disease-affected portions are to be removed regularly and 1% Bordeaux mixture should be applied on the affected plants. (KAU, 2002) (Fig 31)

Fig 31 Fungal disease in vanilla stem and leave (Curti, 1989)

Gender aspects: Role of the men and women in post harvest operations
Vanilla production is gender sensitive. The pollination exercise has to be done with care and used to be women's (and children's) work but the division of labor is changing. Initially the male head of the household would decide to grow the vanilla, and expect his wife or wives to do the pollination. He would control the money earned from the sales of the 'family plot'. Nowadays in many vanilla-producing households both husband and wives have their own vanilla plots. During the flowering seasons the women will first work on their husband's plot (the family plot) and then concentrate on their own vines. Although the land belongs to the husband, the wives can usually keep the money they earn by growing their own crops.

Mature women may go one step further and decide that they do not have time to work on their husband's vanilla plot and tell him to look after his own crop. The man has no choice but to do the pollination himself, hire laborers to do the job or forget about vanilla. In some households the latter does indeed happen and one of the wives may grow vanilla while the husband does not.

In summary, vanilla production is changing the labour division in households giving women some financial autonomy. According to a survey among vanilla farmers in Gonve, a village in Mukono District, 40 per cent of the interviewed farmers said the wife authorised expenditure of the money from sales of vanilla, while 60 per cent pointed to the husband (Kasente et al., 1998).

Over the years, vanilla-growing women have formed clubs. Although education about vanilla growing was the prime objective, they appeared to have also a general emancipatory aim. According to Kyabangi (1995), such clubs ‘have helped women learn how to express themselves, how to address different issues in their homes, especially issues concerning their relationships with their husbands’.

Women have also learnt how to use banking institutions. Club members opened individual accounts with a local branch of the Uganda Commercial Bank. They put their earnings from vanilla sales into these accounts, which made it more difficult for their husbands to access the money (Dijkstra,2001).

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5. Glossary (List of Terms)

%	percent
m	meter
cm	centimeter
mm	millimeters
ft	feet
ppm	parts per million
g	gram
mg	milligrams
µg	micrograms
kg	kilograms
MT	metric tons
lbs	pounds
psi	pounds per square inche
ml	milliliter
mL/L	milli liter/liter
º C	degrees Celcius
°F	degrees Farenheit
Kcal	calories X 1000
min	minutes
FFA	free fatty acid
° Bx	degrees Brix
EU	European union
USA	United States of America
$	US dollars

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