GINGER

Post-harvest Operations

INPhO - Post-harvest Compendium

Food and Agriculture Organization
of the United Nations

GINGER: Post-Production Management for Improved Market Access

Organisation: Food and Agriculture Organization of the United Nations (FAO), AGST
Prepared by Anne Plotto.
Edited by François Mazaud, Alexandra Röttger, Katja Steffel
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1. Introduction

Ginger is the underground stem (rhizome) of a perennial herb, which is used as a spice and as a preserve. The knobby rhizome is dug up when the 1 meter tall leaves and stems of the plant wither, which occurs between 6 and 12 months after planting. It is then prepared for market by either scalding, to produce black ginger, or by scraping and washing to produce white ginger. It is sold in the fresh condition or, more frequently, in a peeled and split dried form. Ginger is utilized widely as a spice, for pickles, candies and as a medicinal herb. It can be produced in many countries but it does best in moist, tropical conditions.

Figure 1: Ginger Plant (Zingiber officinale)[45]

Figure 2: Ginger Rhizome

1.1 Economic and Social Impact of Ginger

In the 1980s, ginger world production was estimated at 100,000 t, but because of the several forms in which it is traded and the fact that a high proportion is consumed in the countries where it is grown or is used to provide seeds for the next crop, it is difficult to get accurate figures[21]. Other sources projected production to grow from 300,000 t in 1980, to 500,000 t in 1990, to 600,000tin 1998 [38]. India, China, Indonesia, Nigeria, the Philippines and Thailand are currently the main producers. India alone produced 232,510 t in 1996-97 on 70,910 hectares, and exported 28,321 t in 1997-9828. However, Indian exports decreased to 6,580 t in 2000-2001, and 8,000 t in 2001-20021. The International Trade Centre [23] data show that China and Thailand were the major exporting countries in 1998-2000. China seems to be the preferred provider for Korea, while Pakistan buys most of its ginger from India. Indonesia also provides ginger to Malaysia, and Hong Kong before it became part the People's Republic of China. Brazil is the third exporter of dried ginger. The three leading exporting countries in 2000 were China, Thailand, and Brazil. [23]

World production of ginger oil, mainly from India and China, was estimated at 30t in 1998[38], and 100-200 t in 2000[42], with the major importing countries being United States, Europe and Japan. Oleoresin production in the 1980s was estimated at 150 t.[38] Most of the oleoresin is produced by the consuming countries, European Union and the United States. In addition, India produces and exports approximately 50 to 100 t annually.[42]

Globally, ginger represents 15-16% of the tonnage of spices imported from 1996 to 2000 (Table 1). In the US, ginger has risen to be among the highest 12 spices consumed, replacing fennel seeds. [12]

Table 1. Global import of ginger from 1999 to 2000 in volume (metric tons)

	1996	1997	1998	1999	2000
Quantity (t)	151,559	167,466	169,454	173,840	192,838
% volume	15.4	16	15.7	15.4	16.6

Source: ITC, 2002

1.2 World trade

1.2.1 Main consumption areas

It is difficult to compare import data because they usually do not distinguish fresh from dried ginger. For instance, Japan is the number one importer of ginger, with 104,379 t in 2000, and no re-export.[23] But Japanese traditionally consume preserve ginger made from a mild fresh rhizome.[21] Therefore, the Japanese import data may be inflated by the weight of fresh ginger, in addition to the weight of dried ginger, and thus may not be comparable to other nations. Other major importing countries are: US (19,035 t), UK (10,337 t), Saudi Arabia (8,248 t), Singapore (import 7,566 t, re-export 2,989 t), Malaysia (import 7,652 t, re-export 1,334 t), Korea (6,805 t), the Netherlands (import 6,981 t, re-export 2,858 t), Canada (4,680 t), Germany, and France (Table 2). Both the Netherlands and Singapore serve as importing countries and re-export to neighboring countries (Netherlands), and other world countries (Singapore).

Table 2: Quantities (metric tons) of ginger imports by country [23]

	1996	1997	1998	1999	2000
Japan	78,969	91,168	91,035	91,684	104,379
United States	14,328	13,836	14,036	15,580	19,035
United Kingdom	8,593	8,592	10,086	9,262	10,337
Saudi Arabia	5,773	6,504	8,398	8,693	8,248
Malaysia	1,442	2,269	2,837	5,671	7,652
Singapore	2,489	1,753	2,760	3,969	7,566
Netherlands	3,920	4,665	5,033	4,732	6,981
Korea Rep.	488	5,635	2,578	1,003	6,805
Canada	3,700	4,731	4,952	4,605	4,680
Germany	1,832	1,721	2,054	2,110	2,310
France	1,438	1,408	1,567	1,331	1,358
Hong Kong	7,822	6,728	3,513	1,631	912
Europe (other countries)	834	1,365	1,396	1,485	1,546
South Africa	343	762	447	520	564
Pakistan	243	857	350	605	446
Australia	185	199	360	259	266
Switzerland	197	211	245	249	264
Russian Federation	34	63	57	299	98
Mexico	84	76	145	65	93
Poland	102	133	171	25	65

Source: ITC, 2002

China and Thailand are the major ginger sources for most importing countries (Table 3). Brazil and Nigeria provide ginger to the United States, the United Kingdom, Germany and the Netherlands. India's exports dropped from 28,268 t in 1997-98 to 6,500 t in 2000-01.[1] Within the last decade China has become a major competitor overtaking some traditional exporting countries. In 1998, for the U.S. alone, ginger imports from China were 2,361 t, which rose to 12,459 t in 2002.[39] Saudi Arabia imported most of its ginger from Indonesia in 1996-1999, but the same amount was imported from China in 2000.[23]

Table 3. Major ginger imports (metric tons) in 2000 by country of origin)[23]

	China	Thai-land	Brazil	India	Malay-sia	Indo-nesia	Ni-geria	Others	Total
Japan	69,448	30,227	-	99	-	730	-	3,626 (Taiwan)	104,379
U.S.A.	10,565	1,808	3,312	323	-	62	310	1,272 (Costa Rica)	19,035
U.K.	1,796	3,804	2,285	244	-	-	800	1,408	10,337
Saudi Arabia	5,120	1,215	-	939	-	536	245	193	8,248
Singa-pore	5,301	897	-	3	1,334	-	-	31	7,566
Malaysia	5,574	536	-	-	-	1,239	-	303	7,652
Korea	6,784	-	-	-	-	-	-	21	6,805
Nether-lands	1,444	1,735	1,436	124	-	-	1,229	1,013	6,981
Canada	2,362	684	474	143	-	-	-	1,017	4,680
Germany	922	307	232	26	-	-	296	527	2,310

Source: ITC, 2002

Most of the International Trade Center (ITC) data report ginger imports overall, without specifying the form, that is fresh, dried, or ground. ITC however does specify "except preserved". On the other hand, the American Spice Trade Association reports import data for "dried plant products used primarily for culinary purposes", data gathered from its members.[12] Therefore, for the United States alone, the difference accounted for 5,000 t of fresh product in 2000 (Table 4).

Table 4: Ginger imports in the US (metric tons; US $1000)

	1998	1999	2000	2001	2002
Ginger, not ground (t)[a]	13,778	15,277	18,682	18,053	20,097
Value (US $1,000)	13,309	13,935	15,251	12,348	11,836
Ginger, ground (T)[a]	258	303	374	1,023	1,018
Value (US $1,000)	567	516	624	1,174	1,004
Ginger, dried spice (t)[b]	2,827	4,336	4,942	-	-

[a]: Department of Commerce, U.S. Census Bureau, Foreign Trade Statistics (United States Department of Agriculture, Foreign Agricultural Service, 2003).
[b]: American Spice Trade Association. Spice statistics 2000. Data not available for 2001 and 2002.

1.2.2 Trends in international prices

Unit prices of ginger slightly decreased in the 4-years 1996-2000, from 1.35 to 0.81 $ per kilogram[23], while other crops such as vanilla, clove and nutmeg have seen their prices inflated by a speculative market.

Table 5: World import value (in US $1,000s) of ginger from 1996 to 2000

	1996	1997	1998	1999	2000
Value	205,081	195,042	149,983	151,316	156,636
(US $1,000)					
% value	10.2	8.5	6.2	5.8	6.2

Source: ITC 2002

Comparison of value by country may be confounded since the product type imported is not specified. One can assume that the bulk of the product is dried whole rhizomes, but as soon as some processing occurs such as peeling, slicing or grinding, differential value is added, rendering the price per unit volume not comparable.

Table 6: Value (US $1,000s) of ginger imports by country

	1996	1997	1998	1999	2000
Japan	129,273	113,854	74,601	74,011	76,961
United States	19,757	17,796	16,446	17,487	19,568
United Kingdom	12,480	13,804	11,481	12,343	13,592
Saudi Arabia	4,067	4,209	5,400	4,648	4,673
Malaysia	839	1,380	1,019	1,811	3,672
Singapore	1,828	1,383	1,942	2,587	4,245
Netherlands	5,600	6,375	5,869	5,240	7,517
Korea Rep.	533	3,270	869	261	1,658
Canada	5,044	5,707	5,684	5,100	5,039
Germany	3,402	3,567	4,249	3,900	4,002
France	2,563	2,233	2,217	1,817	1,839
Hong Kong	5,084	6,372	2,174	1,086	681
Europe (other countries)	2,018	3,001	2,675	2,710	2,442
South Africa	519	1,014	654	490	488
Pakistan	213	967	563	822	484
Australia	379	444	892	391	391
Switzerland	529	507	543	544	536
Russian Federation	62	141	81	151	73
Mexico	220	244	312	139	178
Poland	188	255	285	56	239

Source: ITC, 2002

1.3 Primary Product

Fresh ginger

Most fresh ginger is consumed locally in Asia. However, due to rising Asian immigrant populations, there has been an increasing demand for fresh ginger in Western Europe and Northern America.[42] The United States brings in fresh ginger produced in Hawaii.[13] Other sources of fresh ginger to the United States are South and Central American countries: Brazil, Costa Rica, Ecuador, Guatemala, Honduras, and Nicaragua.[13]

Figure 3. Fresh ginger[48]

Dried ginger

The country of production determines the types of ginger available to spice importers: Indian (Cochin and Calicut), Chinese, African (Nigeria and Sierra Leone), Jamaican, and Australian[21]. Indian (Cochin) and Jamaican gingers have a reputation of a high quality, with a light color and delicate flavor.38,42 Cochin ginger has a light yellow color while Calicut is more reddish-brown; both have a delicate odor and flavor, with some lemon-like aroma13,21; Indian ginger is mostly exported washed and dried, unpeeled or roughly peeled.

African ginger is darker in color and higher in monoterpene content, giving a more pungent aroma with camphoraceous notes; it has a high oil content and level of pungency, therefore it is usually preferred for the production of oils and oleoresins.[38,42]

Chinese dried ginger is exported as whole peeled with two grades, and sliced unpeeled. It is whiter than the Indian ginger, tends to be more fibrous and more bitter.[13]

Figure 2. Dried ginger[47]

Varieties

Yield and oil characteristic and content vary with cultivar and environmental factors. There are many local varieties grown over the world. More than 400 accessions of ginger are maintained at the Indian Institute for Spice Research in Calicut, Kerala, India, and about 45 are at the research Institute for Spices and Medicinal Crops in Bogor, Indonesia.[38]
The following Indian cultivars are results of selection by the Indian Institute for Spice Research with high yield and high oil content:

Table 7: Characteristics of Improved Cultivars from the Indian Institute for Spice Research [1,2,10,32]

Ginger	Fresh yield (T/ha)	Maturity (days)	Oleo-resin (%)	Essential oil (%)	Crude fiber (%)	Dry recovery (%)
Rejatha[a]	23.2	300	-	1.7	3.3	23
Mahima[b]	22.4	200	-	2.4	4	19
IISR-Varada[b]	22.6	200	6.7	1.8	3.3-4.5	20.7
Suprabha	16.6	229	8.9	1.9	4.4	20.5
Suruchi	11.6	218	10	2	3.8	23.5
Suravi	17.5	225	10.2	2.1	4	23.5
Himagiri	13.5	230	4.3	1.6	6.4	20.6
Rio-de-Janeiro	17.6	190	10.5	2.3	5.6	20

[a] *Rejatha and Mahima are germplasm selections of the Indian Institute of Spice Research, released in 2001. Percent oleoresins not given.*
[b] *IISR-Varada is a germplasm selection of the Indian Institute of Spice Research, released in 1996*

[1] http://www.indianspices.com/html/s1926pac.htm
[2] http://www.iisr.org/varieties/

1.4 Secondary and derived products

Candies and preserves
Chinese ginger has been the standard for ginger preserved in syrup.[38] Australia has also developed a ginger industry, and it exports mostly candied rhizomes[13], reputed to have "superior and consistent quality".[42]
Essential oil and oleoresins
Essential oil is obtained by steam distillation, while oleoresins are obtained by solvent extraction. Therefore, essential oils contain the volatile fraction of the spice, while the oleoresins contain the volatile fraction, as well as components that are soluble in the solvent used in the extraction process.
Oils and oleoresins are preferred to dried spices as flavoring by the food industry, because they are more stable, cleaner, free from contaminations, and can be standardized by blending oils from different sources [32].
Gingerols are responsible for the ginger pungency, with (6)-gingerol being the most abundant[16,19]; however gingerols are decomposed by heat during the distillation process, and thus are found at higher concentrations in the oleoresin extractives.[42] Other compounds with a pungent characteristic are zingerone and shogaols[19], both degradation products of gingerol.[16] Oleoresin production used to be performed in the importing country, but recently, more producing countries see the value-added of making their own extractives.[13] Essential oils are used in the manufacture of soft drinks, ginger beer, and in food preparation.
Ginger paste
With increasing ginger production in Hawaii, canned ginger paste was made experimentally as a value-added product.[14] The instability of flavor components and color of this experimental paste resulted in a product that could not be commercialized beyond 8 weeks. In India, a ginger paste is traditionally made with 50% sliced and macerated ginger, 35% garlic, and 15% salt.[42]
Nutraceuticals
In India, ginger enters in the preparation of many aryuvedic formulations, "aryuveda" being the traditional Indian medical discipline.[28] In the United States and Europe, ginger preparations are sold as nutraceuticals or over-the-counter remedies against nausea, motion sickness, and migraine[26]. It is listed in the *German Commission E Monographs* as an approved phytomedicine against dyspepsia and to prevent motion sickness.

1.5 Requirements for export and quality assurance

1.5.1 Cleanliness specifications for spices

In 1969, the U.S.-Food and Drug Administration has come to an agreement with spice importers in the United States that the industry would control spice sampling and analysis prior to entering the food consumer market. Since then, the American Spice Trade Association (ASTA) has established standards for Cleanliness Specifications and assured through its approved laboratories that no spices enter the food market if not meeting the criteria. Contaminated or adulterated spices would need proper sanitation and reconditioning, or would be returned to the exporting country. The standards were changed over the years to also reach FDA requirements for foods. The ASTA Cleanliness Specification have become a standard for most exporting countries, who have built their facilities to meet those requirements. Importing countries that do not have specified standards may use ASTA's specifications.

Table 8: ASTA Cleanliness Specifications for Ginger[11]

Whole insects, dead	Excreta, Mammalian	Excreta, Other	Mold	Insect Defiled/Infested	Extraneous Foreign Matter1
by count	by mg/kg	by mg/kg	No more than 3% moldy pieces and/or insect infested pieces by weight		% by weight
4	6.6	6.6			1.00

[1] *extraneous matter includes but is not restricted to: stones, dirt, wire, string, stems, sticks, non toxic foreign seeds, excreta, manure, and animal contamination.*

ASTA sampling guidelines are as follows: precisely weighed samples are passed through a sieve (U.S. Standard No 8, or standard pepper sieve No 9) with a white paper underneath to observe foreign matter, insects and mammalian excreta. Rhizomes are examined for mold and defiling insects. Foreign matter is reported by count for insects or by weight [1].
EU-member countries such as the U.K., Germany and the Netherlands have their own specifications. The European Spice Association (ESA) has a set of "quality minima for herbs and spices", but has yet to finalize the cleanliness specification standards for spices and spice products.

Table 9: European Spice Association (ESA) Minimum Quality Standards for Ginger

Total Ash(% w/w) max	Acid Insoluble Ash(% w/w) max	Moisture(% w/w) max	Volatile oil(v/w) min
(ISO 928)	(ISO 930)	(ISO 939)	(ISO 6571)
8:00 [a]	2 [b]	12 [a]	1.5 [a]

[a]*:Indian Standards Institute*
[b]*:European Spice Association*

Extraneous matter and foreign matter should not exceed 1% and 2%, respectively. Should be free from live and/or dead insects, insect fragments and rodent contamination visible to the naked eye (corrected if necessary for abnormal vision).
Microbiology: Salmonella must be absent in (at least) 25 g of material. Yeast and mold: 10^5/g (target), absolute maximum: 10^6/g. E.Coli: 10^2/g (target), absolute maximum: 10^3/g.
The European Union has fixed limits for aflatoxin, which should not exceed 10 ppb (total aflatoxins), and 5 ppb for aflatoxin B1. Individual European Union member countries have their own limits varying from 1 to 20 ppb. In the United States, it should not exceed 20 ppb[2].

1.5.2 Essential oil specifications

The Food Chemical Codex standards for ginger oil are the following:

Table 10: Food Chemical Codex Standards for Ginger Oil

Standard	Value	ISO method
Relative density at 20 ºC	0.870-0.882	ISO 279-1981
Refractive index	1.488-1.494	ISO 280-1976
Optical rotation	-47º to -28º	ISO 592-1981
Saponification number	Not more than 20	

Oleoresins standards as defined by the U.S. Essential Oil Association are as follows:

Table 11: Oleoresins standards as defined by the U.S. Essential Oil Association

Volatile oil content	18-35 ml per 100 g
Refractive index	1.488 – 1.498
Optical rotation	-30º to -60º

Ginger oil and oleoresins may be standardized to meet specific product requirements. However, when this procedure is done, the product must be labeled WONF (With Other Natural Flavors), with the added natural flavor identified[3].

1.5.3 Requirements for organic spices and products

To be sold as "organic", a product must be certified by an accredited certification body. There are slight differences in standards between countries. IFOAM, the International Federation of Organic Agriculture Movement, has established organic production, processing and trading standards, and tried to harmonize certification systems worldwide.[36] National and regional governments are also trying to work under a compatible minimum set of standards. The European Union (EU) has established basic regulations for organic products in 1991 (Council Regulation 2092/91), which apply to all products marketed as "organic", "biologic", "ecologic", "biodynamic", or similar terms. Imports may be accepted through procedures conforming to the exporting country's regulations, or by review of the certification documents, which accompany each shipment.

The EU regulation sets a minimum standard, and member states or private certification bodies may certify to standards that meet or exceed EU regulation 2092/91. In the United States, the Organic Food Production Act (OFPA) was passed into law in 1990, and since October 2002 has made organic production and processing uniformly regulated across all of the United States. The Agricultural Marketing Service (AMS) branch of the U.S. Department of Agriculture is administering the National Organic Program [4].

To be labeled "organic", a product must be grown following organic agricultural practices. Post harvest handling and processing must be done in certified facilities, whether on the farm or in food packing or processing facilities. Only mechanical, thermal or biological methods can be used in organic processing. The use of genetically modified organisms (GMO) (plants, animals or bacteria) and products of GMO are prohibited in organic production. Likewise, ionizing radiation and sewage sludge are prohibited from organic agricultural practices. Labels of organic products must identify the certification body.

In general, the Japanese organic standards (Japan Agricultural Standards, JAS) follow the U.S. NOP standards. However, JAS does not allow organic labeling on products that contain less than 95% organic ingredients (the EU and NOP allow labeling "made with organic ingredients" for products that contain between 70% and 95% organic ingredients).

In addition to standards pertaining to the production of organic products, IFOAM basic standards include environmental and social justice requirements. For example, IFOAM basic standards[6] include "2.1.1: operators shall take measures to maintain and improve landscape and enhance biodiversity quality"; "8.1: operators shall have a policy on social justice"; "8.5: operators shall provide their employees and contractors equal opportunity and treatment, and shall not act in a discriminatory way"; and "8.6: children employed by organic operators shall be provided with educational opportunities".

IFOAM, EU and U.S. organic standards include lists that allow the use of specific synthetic, non-agricultural or non-organic agricultural substances. If a substance does not appear on those lists, it must not be used on an organic product, in the process or as an ingredient. Those lists differ slightly, and operators producing for export markets to Europe, United States and Japan should consult and compare those lists carefully to assure compliance in each country [5] [6].

To comply with organic standards and practices, the operator must document all farming and post-harvest activities. The following records must be maintained: farm field map, field history, activity register, input records including purchases, output records including sales, harvest records, storage records, pest control records, movement records, equipment cleaning and labeling. All such documentation must meet specific standards that are enumerated in directives issued by the certification agencies.

In the processing plant, the operator must present an "organic handling plan" that will show how contamination from prohibited materials and commingling with non-organic products will be prevented. This includes a detailed description of the process, receiving and storage of ingredients and finished products, cleaning and sanitation of the processing equipment, facilities pest management, and a documentary "paper trail" that must permanently record all of the above.

For the spice and oleoresins production, ionizing radiation and the use of volatile synthetic solvents are prohibited for use in the processing of organic products.

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[1]Percent calculation formula are given in the ASTA Cleanliness Specifications manual, method 14.1, page13-17[11]

[2]Detailed specifications for quality standards, pesticide residues and aflatoxin levels for some individual European countries may be found at: http://www.indianspices.com/html/s1490qua.htm

[3]For further details, see CFR 21, Part 101.22: http://vm.cfsan.fda.gov/~lrd/CF101-22.html

[4]see final rules in the Federal Register (7 CFR Part 205, 2000).

[5]For reference, the IFOAM lists are contained in Appendices 1, 2, 3, and 4 of the IFOAM basic standards6. The USDA National List for allowed non organic (non agricultural and agricultural) ingredients is under § 205.605 and § 205.606 of the Federal Register, Vol. 65, No 246, and can be found at: http://www.ams.usda.gov/nop/NationalList/FinalRule.html

[6]EU lists for processing are under Annex VI-A, VI-B, and VI-C. EC 2092/91 regulation and amendments may be found by searching Euro-lex, at: http://europa.eu.int/eur-lex/en/search/search_lif.html, using the year descriptor "1991" and document number "2092".

2. Post-Production Operations

2.1 Harvest

The time of harvest after planting depends on the end-use. For fresh products and preserves, one should harvest rhizomes while they are still tender, low in pungency and fiber content, therefore before they are fully mature.[38] Harvest for dried spices and oil is best at full maturity, when the leaves turn yellow; leaving the rhizomes in the ground past that stage may reduce pungency and oil content, and increase the fiber content.[38,42] Maximum oil and oleoresin contents are between 150 and 170 days after planting under Kerala's conditions.[3] In Hawaii, (6)-gingerol, the pungent constituent of ginger, increased over time in rhizomes of 'Hawaiian' cultivar as measured on a fresh-weight basis, while it reached a peak 16 weeks after planting on a dry-weight basis, decreased and increased again to reach a second peak at 24 weeks.[15] Likewise, the maximum oleoresin content was reached after 28 weeks on a fresh-weight basis. Time from planting to maturity may be highly affected by the type of soil in which ginger is grown.[42]

In summary, the best harvest time for each end-use is:

For fresh consumption: 5 months

For preserved ginger: 5-7 months

For dried ginger: 8-9 months, when leaves start yellowing

For essential oil production: 8-9 months

Harvest for planting material is further delayed until the leaves are completely dried out.[21] Rhizomes may be left in situ, with the leaves cut serving as a mulch, and dug when needed.[38] Alternatively, they may be dug out, treated with fungicide and insecticide, dried in the shade, and stored in pits covered with sand.[10,21]

Harvest is by manually lifting the rhizomes from the soil, that may have been loosen at first.[21,42] In some countries such as Australia, harvest may be fully mechanized using special equipment; the crop must be planted in such way that interspacing between rows is adapted to equipment.[42] Care should always be taken to assure integrity of the rhizomes during harvest and postharvest handling.

2.2 Washing, "killing", drying

Fresh rhizomes should be washed, and cleaned from debris, shoots and roots. When available, pressure washing is preferred as it is more efficient and tends to reduce the microbial load[33]. Traditionally, rhizomes are killed by a 10 min. immersion in boiling water, which also inactivates enzymatic processes, then sun-dried.[38, 42] Another method is to scrape, peel, or slice rhizomes prior to drying. Peeling or scraping is advised for reducing drying time, thus minimizing mold growth and fermentation.[33] However, while this process decreases the fiber content by removing the outside corky skin, it also tends to remove some of the oils constituents, as they are more concentrated in the peel, and therefore reduces some of the pungency.[38,42] The peeled rhizomes may be bleached to improve appearance.

After peeling and washing, rhizomes are first soaked in water for 2 to 3 hours, then steeped in a solution of 1.5 to 2.0% lime (calcium oxide) for 6 hours, then drained and sun-dried[33]. This procedure is used when a light bright color is desired. The Indian Spice Board recommends the following sequence for preparing dry spices: soaking in water overnight to loosen the soil, peeling/scraping with pointed-end bamboo splinters, washing off the residual peel, sun drying for one week, soaking in 2% lime for 6 hours, and final drying (www.indianspices.com/html/s1926pac.htm).1 Drying should be done to 8-10% moisture, and should not exceed 12%.21 Expected weight loss during drying is 60-70%.[42]

Cleaning and drying procedures should be done as fast as possible after harvest to ensure minimum loss from microbial contamination, mold growth and fermentation. Mechanical washers, slicers, and solar or hot air driers may help minimize contamination from dust during post harvest handling operations.[42] Sun-drying peeled ginger takes 7 to 9 days to reach a moisture content of 7.8% to 8.8%.[33] If the ginger is sliced, it takes only 5 to 6 hours by using a cross-flow drier, while it takes 16 to 18 hours to dry scraped whole ginger using the same equipment and conditions. Mechanical drying will ensure a more homogenous and cleaner product. When drying with hot air, care should be taken to adjust air flow and temperature. Drying should not exceed the critical temperature of 60 ºC to avoid flesh darkening and discoloration.[33]
Specific equipment is suggested for optimum cleaning of the dried rhizomes.[33] An air screen separator will help remove dead insects, excreta and extraneous matter, while a rotary knife cutter with a screen separator will help remove residual insects and other extraneous matter.

2.3 Grading and packaging

Quality specifications are imposed by the importing country, and pertain to cleanliness specifications rather than quality of the spice (see cleanliness specifications in 1.5.1below). Proper care must be taken to meet minimum requirements, otherwise a lot may be rejected and need further cleaning and/or disinfection with ethylene oxide or irradiation.
Bulk rhizomes may be packed in jute sacks, wooden boxes or lined corrugated cardboard boxes for shipping[42]. The following terms are used to describe the various forms of dried rhizome.
Peeled, scraped, uncoated: whole rhizome with the corky skin removed
Rough scraped: whole rhizome with the skin partially removed
Unpeeled or coated: whole rhizome with skin intact
Black ginger: whole rhizomes scalded before being scraped and dried
Bleached: whole rhizome treated with lime or diluted sulfuric acid
Splits and slices: unpeeled rhizomes, split or sliced
Ratoons: second growth rhizomes, small, dark and very fibrous."[42]
Dry slices or powder are packaged in Kraft multi-wall laminated bags.[21,22] Some laminates may be better than others due to film permeability. Whichever film is used, storage in a cool and dry environment is crucial for dry spices.

2.4 Storage

Dried spices
Dried rhizomes, slices, or splits should be stored in a cool environment (10-15°C). When stored at room temperature (23-26 ºC), losses of up to 20% oleoresin (dry weight) were observed on dry ginger after 3 months, and the content of (6)-gingerol decreased [29] [7]. It is therefore recommended to extract or distill dried ginger rapidly, if cold storage is not available, when oil or oleoresin is the final product. The importance of a dry storage for dried ginger destined for distillation can only be emphasized because additionally, mycotoxins from mold may be co-distilled with the essential oil.
Mold and bacteria developing on dried rhizomes may be efficiently controlled with ^{60}Co gamma-irradiation at doses of 5 to 10 kGy, with minor changes in the quality of ginger oil [20,30]. Ethylene oxide is also used as a fumigation treatment on spices.[21,22] The U.S. Environmental Protection Agency (EPA) has a maximum tolerance residue for ethylene oxide of 50 ppm on spices [8]. Both disinfection by irradiation and ethylene oxide treatments require specially built and highly secured facilities.

Alternatives to irradiation or synthetic chemicals were investigated by the Indian Institute of Spices Research. They found that leaf powder of G*lycosmis pentaphylla and Azadirachta indica* added to dried ginger rhizomes in sealed polyethylene bags were effective at preventing damage from the cigarette beetle (*Lasioderma serricorne*) (http://www.iisr.org/department/cropprod/hhigh.htm).[2]

Fresh ginger

Fresh ginger should be stored in a cold and humid environment. However, cold storage may not always be available in the producing areas. A "zero energy" cool chamber was experimentally designed at the Peruvannamuzhi IISR farm to store fresh ginger, maintaining the temperature 6 to 7 ºC below the outside temperature (http://www.iisr.org/cropprod/postharvest.htm).[2]

Fresh ginger rhizome shelf life may be extended by storage at 10-12ºC and high humidity. In a study on Hawaiian ginger, quality was stable during 28 weeks when stored at 12.5ºC and 90% relative humidity (RH) as determined by dry weight, fiber content, oil content, sugars and phenols.[31] In comparison, storage at 22 ºC and 70% RH shortened rhizome commercialization to 20 weeks due to excessive water loss and fiber contents.[31]

Irradiation at 0.05-0.06 kGy may be used to inhibit sprouting and extend shelf life of fresh ginger [27,43]. However, irradiation at these low levels decreased volatile content of fresh ginger, which was perceived by sensory analysis after 5 months in storage.[43]

A combination of biocontrol with Trichoderma sp. and storage in polyethylene bags at 25-30ºC controlled storage rot due to the fungus Sclerotium rolfsii and prevented weight loss from dehydration. [27] The Indian Institute of Spices Research recommends storage of fresh ginger in polyethylene bags with 2% ventilation prevents both dehydration and mould development (http://www.iisr.org/department/cropprod/hhigh.htm). [2]

2.5 Distillation

Ginger oil may be produced from fresh or dried rhizomes. Oil from dried rhizomes will have less of the low boiling point volatile compounds since they tend to evaporate during the drying process[41]. The difference between oils produced from fresh and dried rhizomes can be seen in the citral content, usually lower in the oil from dried plant material.[25] Additionally, unpeeled or coated rhizomes are preferably used for oil or oleoresin extraction to improve yield.[38,42]

For steam distillation, dried rhizomes are ground to a coarse powder and loaded into a still.[42] Live steam is passed through the powder, thus entraining the volatile components, which are then condensed with cold water. Upon cooling, the oil separates from the water. Cohobation, or re-distillation, is practiced in India to increase oil yield.[42] Oil yield from dried rhizomes is generally from 1.5% to 3.0%42. Indian (Cochin) ginger yields 1.5% to 2.2 % of an oil rich in citral.[13] The rhizome powder stripped from its oil (marc) is made of about 50% starch and may be used as livestock feed[42]. It may also be further dried and powdered to produce an inferior spice.[42]

Major components in ginger essential oil are zingeberene (20-37%), ar-curcumene (5-20%), - and -farnesene, -bisabolene and -sesquiphellandrene.[25] The low boiling point monoterpenes a-pinene, cineole, borneol, geraniol, geranial and neral are less abundant and present in various proportions, and they impart aromas characteristic to the products. For instance, citral with its two isomers geranial and neral, is especially high in the Brazilian-grown cultivars 'Capira' (6.6-7.0% citral) and 'Gigante' (14.3-20.7% citral), while it is only 1.9-4.3% in some Chinese oils[25]. Australian oils also have a high citral content, up to 27%, averaging 19%, imparting a lemony aroma to the final product.[18, 41]

2.6 Extraction: oleoresin production

Gingerols (6-, 8-, and 10-gingerol) are the compounds responsible for ginger pungency[16,19]; however, because they are readily decomposed to the less pungent shoagols and zingerones upon heating, oleoresins obtained by solvent extraction are preferred when pungency is desired. Commercial solvents include ethanol, acetone, trichloroethane or dichloroethane[42], although the latter two are known carcinogenic and ethyl acetate or hexane are preferred.[40] Dried powdered rhizomes are extracted by percolation, and the extract is then cold-distilled at 45-55 °C to remove all the solvent, while assuring integrity of gingerols by not overheating. Hydrophilic solvents such as ethanol, and acetone also extract water-soluble gums, which may need to be further separated by centrifugation. However, water-soluble solvents may be preferred to prepare extractive to be used by the beverage industry to assure water solubility. Supercritical fluid extraction uses carbon dioxide (CO2) under high pressure and cold temperature. This extraction technique is preferred for higher quality extracts because there is no thermal degradation, and the aromatic profile is therefore closer to the profile in the plant.[42]

Zingerone, shogaol and gingerol were present in cold pressed oil and supercritical extract of Chinese ginger, and were absent from the steam distilled oil.[44] Geranial and citral were 10.9 and 2.0% in supercritical extract, as compared to 0.63 and 1.31% in steam distilled oil, respectively.[44]

The use of steam or CO2 is environmentally preferred over hydrocarbon or halohydrocarbon solvents since they generate little or no hazardous wastes. Kim et al. (1992) reported extracts yield of 6.9% with CO2.

For certifiable organic production, synthetic solvents are not allowed [9]. Therefore, solvents derived from petrochemicals such as hexane, pentane, di- and tri-chloroethanes, acetone, cannot be used in organic production. The International Federation of Organic Movement (IFOAM) specifies that only ethanol, water, edible oils or carbon dioxide are allowed (see IFOAM standards, Appendix 4).

[7] A similar range of decrease in oleoresin content was reported earlier by Richardson (1967).

[8] (CFR 40, Part 180.151)

[9] (Federal Register, 7 CFR Part 205)

ANNEX 1: Useful Sites

1. Indian Spice Board:
http://www.indianspices.com
2. Indian Institute of Spice Research:
http://www.iisr.org/
3. Indian Institute of Spice Research, Agricultural Technology Information Center:
http://www.iisr.org/atic/
4. Indian Ministry of Food Processing Industry:
http://mofpi.nic.in/technologies/rural/spices&plantation/spi_dehydraginger.htm
5.Organic Trade Association
http://www.ota.com
6. International Federation of Organic Movements
http://www.ifoam.org
7. American Spice Trade Association
http://www.astaspice.com
8. Plant Resources of South-East Asia
http://www.prosea.nl
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10. IFOAM N O R M S: IFOAM Basic Standards for Organic Production and Processing IFOAM Accreditation Criteria for Bodies certifying Organic Production and Processing including Policies related to IFOAM Norms
http://www.ifoam.org/standard/norms/cover.html

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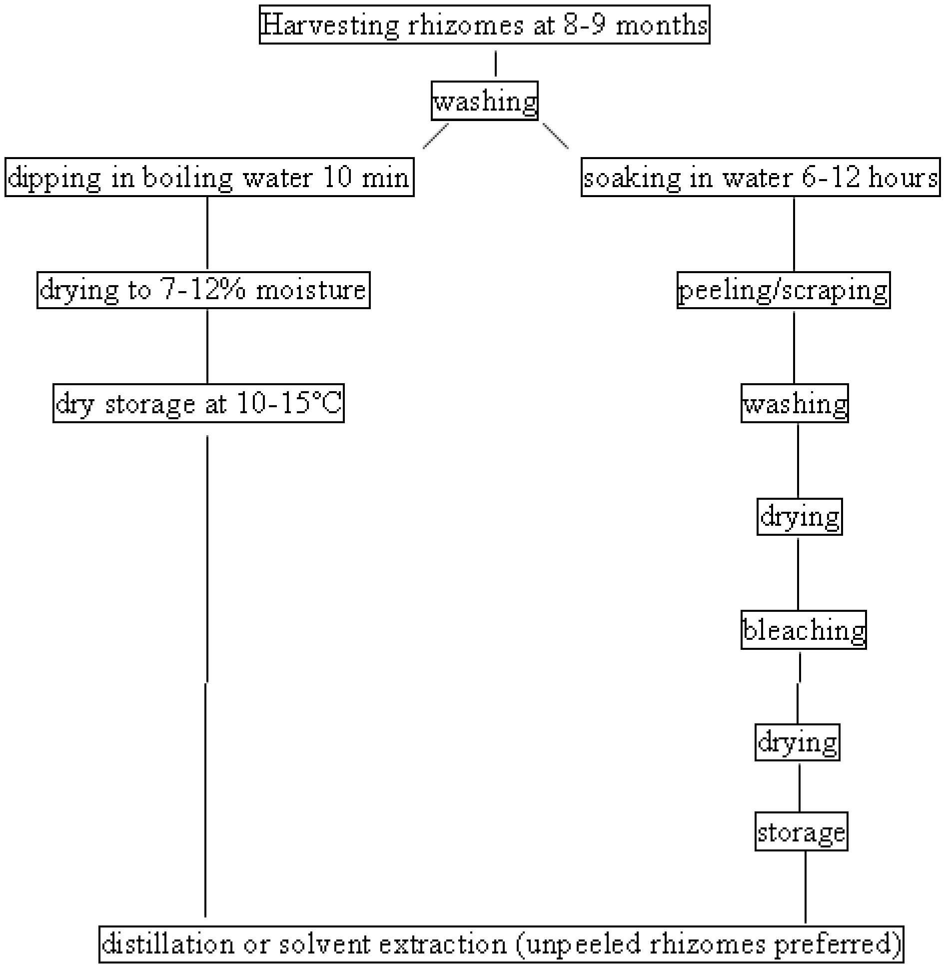
ANNEX 3: List of Figures and Tables

ANNEX 4: Flow Chart for Dried, Preserved Ginger and Essential Ginger Oil Production

Ginger dry spices or essential oil production



Fresh of preserved ginger