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Determination of Biochemical Contents of Small Cardamom (Elletaria Cardamomum Malton) Grown in Ethiopia as Affected by Stages of Harvesting, Drying System and Drying Duration

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Abstract
Small Cardamom (*Elletaria Cardamomum Malton*) capsules produced in Western Ethiopia face stringent market challenges, due to its inferior Biochemical (oleoresin and essential oil) products. The inferior quality is owed to harvesting stages, drying systems and drying durations. Hence, this study was conducted to address such issues and to enhance Biochemical contents (oleoresin and essential oil) and to generate recommendations. The experiment consisted of three stages of harvesting (Mature Unripe, Mature Semi-Ripe and Mature Ripe), three drying systems (Smoke, Wooden Bed and Wire mesh bed) and three drying durations (05, 10 and 15 days) laid out in 3*3*3 factorial arrangement using Completely Randomized Design with three replications. Data on Biochemical contents (oleoresin and essential oil) content of dried seeds and dried husk were recorded and subjected to ANOVA. The interactions were significantly affected quality of dried capsules. Mature Unripe capsules dried on wire mesh bed for 05 days scored maximum oleoresin (12.535%W/W) and essential oil (7.433%V/W) content of dried seeds. Similarly mature unripe capsules dried on wire mesh bed for 05 days scored maximum essential oil of dried husks (1.283%). On the contrary, mature unripe and mature ripe capsules dried through smoke for 15 days gave minimum oleoresin (7.374%W/W) and essential oil (4.717%V/W)) contents, respectively. Furthermore, mature unripe capsules dried through smoke for 15 days gave minimum essential oil (0.773%V/W)) content of dried husk. Therefore, for extraction purpose, mature green capsules dried on wire mesh bed for 5 days can be recommended for optimum extraction quality.
Keywords: Small Cardamom, *Elletaria Cardamomum***,** Biochemical, Oleoresin, Essential Oil

INTRODUCTION

Small Cardamom (*Elletaria Cardamomum Malton*), known as the 'queen of spices', which belongs to the family of Zingiberaceae, is very important spice crop that originated in the western Ghats of India (Parthasarathy, *et al*., 2008). Cardamom grows abundantly in forests at 760–1500 m (2500–5000 ft) above sea level. It is widely cultivated in India, southern Asia, Indonesia and Guatemala, preferring shady locations and rich, moist, well-drained soil (Murugan, *et al*., 2007).

Cardamom is a perennial bushy herb, growing to about 4.5 m (15 ft) with mauve-marked, orchid-like white flowers and very long, lance-shaped leaves. The tuberous underground rhizome is its real stem and the aerial shoot is a pseudostem formed by the encircling leaf sheaths. The leaves are distichous, long, alternate and lanceolate acuminate in shape. The flowers are borne on panicles and they emerge directly from the underground stem on long floral stalks. The flower-stalk proceeds from the base of the stem and lies on the ground, with the flowers arranged in a panicle (Kachru, 2002).

The fruit is an ovoid, three-celled, loculicidally dehiscent capsule containing many seeds, which are covered by an aril. During drying, it is said to lose three- quarters of its weight. They are hermaphrodite and zygomorphic. The corolla is tubular, 3-lobed, pale green, androecium with petalloid labellum, white in colour with pink or purplish veins, composed of three modified stamens with an undulated edge. There are two further rudimentary staminodes and one functional stamen. The fruits are trilobular, ovoid or oblong, greenish-brown capsules containing about 15–20 seeds attached to an axile placenta. The light reddish- or dark reddish-brown seeds are irregularly 3-sided, transversely wrinkled or furrowed and are covered by a membranous aril. Each pod contains up to 20 aromatic, dark red brown seeds that have a mild ginger flavor. The seedpods are harvested by hand in dry weather during the autumn, just before they start to open. Then they are dried whole in the sun. The main harvest is in October and November of the third year after planting, after which the seeds are sorted according to size, form, color, etc. The basic chromosome number of Elettariais x = 12 and the somatic number of *E. cardamomum* is 2n = 48 or 52 (Peter, 2001).

Capsules of Small Cardamom have very widespread utilization in Ethiopian and Eritrean cuisines. Small Cardamom has been part of daily Ethiopian dish in preparation of curry powder for culinary purposes. The dried fruit mixture of different clones is sold on almost every Ethiopian market in the production areas; fresh capsules are sold too, rarely only the seeds. The seeds are used in Ethiopia to flavor all kinds of sauces locally for which they are ground and usually mixed with other spices *(*Jansen, 2002; Eyob, **2009)**. Essential oil of Small Cardamom seeds has a typical odor, and is therefore, sometimes called 'nutmeg - cardamom' (Eyob, *et al*., 2007). Thus, the seeds are also used in Ethiopia for medicinal purpose (Wondyifraw, 2004; Hymete, *et al*., 2006).

Dried capsule of Small Cardamom has highly significant economic importance for local and as export commodity in addition to various uses. Previously, Ethiopia was well-known for its considerable exports of Small Cardamom capsules to the world market, mainly as a substitute for the Indian cardamom (Wondyifraw and Surawit, 2004; Eyob, **2009)**. Despite these paramount economic roles of the commodity, the production package of this important spice remained less developed and traditional. Most of the harvest is from natural forest and the identification of the right maturity stage at harvest has not been given due consideration by harvesters merely because of the apparent competition among the collectors for wild Small Cardamom capsules which in turn can lead to poor capsule quality (Girma, *et al*., 2008). According to Jose and Joy (2004), quality of spices is assessed by its intrinsic as well as extrinsic characters. The former consists of chemical quality, *i.e.* the retention of chemical principles like volatile oil, alkaloids and oleoresins while the latter emphasizes physical quality. Physical and chemical characteristics of Small Cardamom vary widely depending on the variety, agro-climatic conditions existing in the area of production, harvest and post-harvest operations. With the demand of current agro-industry development of the country, quality problem has been a big issue to compete local and, especially in international markets. According to Jansen (2002), the major reason for this is the absence of technologies pertaining to production, post harvest handling including processing and value addition, storing, transporting and marketing. On the other hand, investing on essential oil sub-sector in Ethiopia is a serious option as the global demand is increasing. Different drying structures like; drying on bare ground, cement floor, raised beds covered with palm leaves, mat and wire mesh, simple mat spread on the ground and by hanging bunched capsules on cellars near fire places for smoking are some of the frequent practices and also drying duration which is the important quality factor, has not been standardized (Girma, *et al*., 2008).

Therefore, the objective of this study was to analyze Essential Oil and Oleoresin content of Small Cardamom capsules as affected by Stages of Harvesting, Drying System and Drying Duration to improve the extraction or biochemical quality which is the export-oriented product for the country.

MATERIALS AND METHODS

Capsules were harvested from cultivated farms of Small Cardamom (*Elletaria Cardamomum Malton*) from the farmers' field of West Wollega Zone, Gimbi in Western part of Ethiopia. It is located at 9°5′N 36°33′E / 9°00'83''N 36°55'00''E 9°04′60″N latitude, 36°33′00″E longitude and altitude range of 2000 to2100 meter above sea level. The rainfall distribution in the Woreda and/or zone follows a monomodal pattern with annual average rainfall of 2000 mm. The temperature of the region ranges from 13.5^oC to 28.50^oC. Plots for harvesting were selected from the Woreda farmers' field which have moderate to good performance of Small Cardamom. All types of capsules (capsules having various ripening stages) to be harvested were widely available towards the middle of the cultivated plots. Thus the capsules of all the three maturity stages of capsules were harvested and collected to each specific color stage. Capsules were hand-picked by experienced collectors. Capsules were dried at Ethiopian Commodity Exchange Nekemte branch which *is located 350km from Addis Ababa, the capital city of Ethiopia* (Bureau of Agriculture and Rural Development of Nekemte, 2013).

The experiment consisted of three stages of harvesting: Mature Unripe (U), Mature Semi-Ripe (S) and Mature Ripe (R); three drying systems: Smoke (K), Wooden Bed (B) and Raised Bed with wire mesh (M) and three drying durations: Five days (D_{05}), Ten days (D_{10}) and Fifteen days (D_{15}) (Table 1).

The treatments were laid out in a 3*3*3 factorial arrangement using Completely Randomized Design with 3 replications. Data were subjected to ANOVA using SAS ver. 9.2, statistical software (SAS, 2008). The fixed effect model that includes the main effect of stages of harvesting, drying systems and durations together with interaction effects were used. Mean comparison was undertaken with LSD at 5%, when significant treatment effects were observed.

Harvesting of the capsules was done based on visual observation of physical appearance, color and size. In addition, easiness to detach the capsules from mother stalk plant was also taken into account during harvesting. Capsules which were free from insect or physical damage, unbleached, uniform in color for the particular stage were considered during the harvesting time. For each treatment combination, a sample of 4.00kg fresh capsules was prepared. Capsules of the three harvesting stages were randomly placed on the three types of drying systems (Smoke, Wooden Bed and Raised Bed with wire mesh) and then exposed to three different drying durations (Five days, Ten days and Fifteen days) according to the treatment combinations. The drying operation was performed the whole sunny day and covered with water proof plastic sheets from above and sack from beneath the plastic during midday, rain and at night to prevent re-moistening during rain and night as well as over drying during overhead sunlight intensity of the treatments. The extraction process was performed at Wollega University, Organic Chemistry Laboratory (oleoresin extraction) and Addis Ababa University, Nutrition Laboratory (Essential Oil extraction). Accordingly, data were recorded on dried capsule biochemical quality.

Table 1. Details of treatments (Stages of Harvesting, Drying System and Drying Duration) combinations

Stages of Harvesting	Drying system	Drying Durations (Days)	Combination
Mature Unripe (U)	Smoke (K)	05 (D_{05})	UKD_{05}
		10 (D_{10})	UKD_{10}
		15 (D_{15})	UKD_{15}
	Wooden Bed (B)	05 (D_{05})	UBD_{05}
		10 (D_{10})	UBD_{10}
		15 (D_{15})	UBD_{15}
	Wire mesh (M)	05 (D_{05})	UMD_{05}
		10 (D_{10})	UMD_{10}
		15 (D_{15})	UMD_{15}
Mature Semi-Ripe (S)	Smoke (K)	05 (D_{05})	SKD_{05}
		10 (D_{10})	SKD_{10}
		15 (D_{15})	SKD_{15}
	Wooden Bed (B)	05 (D_{05})	SBD_{05}
		10 (D_{10})	SBD_{10}
		15 (D_{15})	SBD_{15}
	Wire mesh (M)	05 (D_{05})	SMD_{05}
		10 (D_{10})	SMD_{10}
		15 (D_{15})	SMD_{15}
Mature Ripe (R)	Smoke (K)	05 (D_{05})	RKD_{05}
		10 (D_{10})	RKD_{10}
		15 (D_{15})	RKD_{15}
	Wooden Bed (B)	05 (D_{05})	RBD_{05}
		10 (D_{10})	RBD_{10}
		15 (D_{15})	RBD_{15}
	Wire mesh (M)	05 (D_{05})	RMD_{05}
		10 (D_{10})	RMD_{10}
		15 (D_{15})	RMD_{15}

ESSENTIAL OIL EXTRACTION

Following the distillation with Clevenger apparatus procedure (ICS-UNIDO, 2008) was used for essential oil extraction of dried seeds and husk. Homogenized 100g coarse powder from dried seed and husk prepared separately was taken for extraction purpose. The steam and oil vapor mixture were passed through a condenser. The essential oil was then extracted from the floral water or hydrolat in the separator. The separator consisted of aroma water below the essential oil, thus the essential oil and water were separated by separator funnel. The essential oils were stored at 1°C to 2°C in test tubes. The distillation process was done at temperature of 80ºC for 5 hours after the mixture started boiling following the method described by (Hymete, *et al*., 2006; Garg, et al., 1999; **Silva, *et al*., 2005)**. Same procedure was followed for the extraction of essential oil from husk. Finally the very transparent or color liquid in the taste tube was quantified to find its percent volume par weight basis.

RESULTS AND DISCUSSION

ESSENTIAL OIL CONTENT OF DRIED SEEDS

Results of the current experiment indicated that the interaction effects among stages of harvesting, drying systems and drying durations on oleoresin content of dried seeds were observed highly significantly different ($p<0.0001$). Maximum oleoresin content (12.535%w/w) was recorded from mature unripe capsules dried on wire mesh for 05 days. In contrast, the minimum oleoresin content (7.374% w/w) was recorded from mature ripe capsules dried through smoke for 15 days (Table 2). It is apparent that the maximum result exceeded 41.172% and 26.812% from the minimum result and grand mean, respectively.

Mature deep-red capsules dried through smoke for longer time have got low oleoresin content at the expense of high sweating from the continuous application of smoke and depletion of the volatiles and non-volatiles which resulted in decreased oleoresin content in this experiment. It is unambiguous that when harvesting stage extended, oleoresin content decreased owing to the commencement of ripening which require expenditure of volatiles and non-volatiles. Following the same trend, as the drying duration extended, oleoresin content found to be decreased which might be due to depletion of volatiles and non-volatiles of dried seeds resulted from prolonged exposure to solar exposure.

ESSENTIAL OIL CONTENT OF DRIED SEEDS

Results of the current experiment revealed that the interaction effect among stages of harvesting, drying systems and drying durations on essential oil (EO) content of dried seeds was very highly significant ($p<0.0001$). According to the result presented in Table 3, the maximum value for EO content of dried seeds was recorded from mature unripe capsules dried on wire mesh for 05 days (7.433%v/w). On the other hand, the minimum EO content was recorded from mature unripe capsules dried through smoke for 15 days (4.717^{mo}%v/w). Mature semi-ripe capsules dried through smoke for10 days and 15 days both recorded the same result (4.950%v/w). Similarly mature ripe capsules dried through smoke for10 days and 15 days both recorded the same result (5.100%v/w). Early harvested mature and unripe capsules and dried on wire mesh for short drying duration (05 days) had high EO content due to low exposure of capsules to solar radiation and high air circulation in wire mesh drying structure while smoke drying structure scored low results due to longer exposure smoke and excessive sweating. As late harvesting stage (mature semi-ripe and mature ripe) exercised, the EO content of dried seeds decreased and this reconfirmed that harvesting at a given stage of maturity is a significant factor affecting quality of spices (Purseglove, *et al*., 1981). It is apparent that as ripening commenced, metabolic activity will take place which may result in reduction of EO of dried seeds as it could be used exhaustively. Leela (2008) Proved this fact which stated that in all small cardamom genotypes, the highest mean EO yield was obtained at immature stage, which was at par with that of physiologically mature stage whereas the least oil yield was recorded at fully ripe stage. In the same way, when the drying duration extended the EO content of dried seeds decreased may be due to the volatility nature and heat sensitivity of the oils. Purseglove, *et al*., (1981) also elaborated that in most of the spices essential oils are maximum at earlier harvest stages and under the fruit maturation process the fruits undergo a physic-chemical changes and this definitely affect the quantity of essential oils.

Lawrence (1970) cited from Ravindran, *et al*. (2002) as well as Endashaw (2007) reported that the EO of Small Cardamom which was 3.50% volume by weight. Hymete, *et al*. (2006) Further reported that dried seeds of Small Cardamom contain 3.77% EO, with 1, 8-cineole as the main constituent. On the other hand, Parthasarathy, *et al*. (2008) reported that EO of small cardamom (Indian) and large cardamom (Nepal) was 5.50% to 10% and 2.80%, respectively. Likewise, Peter (2001) had reported that EO of small cardamom (Indian; cultivars, Mysore and Malabar) and large (Nepal) cardamom was 6.60% to 10.60% and 2.80%, respectively.

ESSENTIAL OIL CONTENT OF DRIED HUSK

The result of the current investigation exhibited that the interaction effect among stages of harvesting, drying systems and drying durations on essential oil (EO) content of dried Small Cardamom husk was very highly significantly affected ($p<0.0001$). The result presented in Table 4, illustrated that the maximum result was recorded from mature ripe capsules dried on wire mesh for 05 days (1.283%v/w) while the minimum values were attained from mature unripe capsules dried on smoke for 15 days (0.773%v/w) (Table 4). Smoke drying combined with late harvesting stage (mature semi-ripe and mature ripe) and extended time smoke resulted in low EO content of dried husks which might be due to excessive sweating coupled with the volatility nature of the oils led to high reduction of EO in the sample. It is obvious that when harvesting stage extended, EO content decreased perhaps due to the volatile nature besides to the expenditure of these chemicals during metabolic activity for ripening which may result in reduction of high EO content. Likewise, as there is extended period of exposure, EO content of dried husks decreased.

Eyob, *et al*. (2007) Reported that the EO yield of pod was 0.83% (v/w) on dried basis. Hymete, *et al*. (2006) further reported that the EO content of dried husks of Small Cardamom purchased from Merkato, the largest open market in Africa, separated, powdered and undergo distillation had contained 0.27%. On the other hand Parthasarathy, *et al*. (2008) reported the essential oil for large cardamom husk as 0.18%. However, the average result of the current study is higher than the finding of (Hymete, *et al*., 2006).

Table 2. Interaction effect among different stages of harvesting, drying structures and drying durations on oleoresin content of dried seeds (%W/W)

Stages of Harvesting	Drying Duration by Drying System								
	Smoke (K)			Wooden Bed (B)			Wire mesh (M)		
	05 Days	10 Days	15 Days	05 Days	10 Days	15 Days	05 Days	10 Days	15 Days
Mature Unripe (U)	9.842^{g}	8.574^{m}	7.955^{o}	11.659^{b}	9.930^{g}	8.917^{k}	12.535^{a}	10.943^{c}	10.049^{f}
Mature Semi-Ripe (S)	9.135^{i}	8.029^{o}	7.658^{p}	10.242^{e}	8.753^{l}	8.313^{n}	10.784^{d}	9.574^{h}	8.991^{k}
Mature Ripe (R)	8.548^{m}	7.678^{p}	7.374^{r}	9.359^{i}	8.026^{o}	7.527^{q}	9.569^{h}	8.714^{l}	8.278^{n}
	CV (%) = 0.732			Grand Mean = 9.125			LSD (0.05) = 0.105		

Means sharing the same letter(s) are not significantly different at p = 0.05 according to LSD test.

Table 3. Interaction effect among different stages of harvesting, drying structures and drying durations on essential oil content of dried seeds (%V/W)

Stages of Harvesting	Drying Duration by Drying System								
	Smoke (K)			Wooden Bed (B)			Wire mesh (M)		
	05 Days	10 Days	15 Days	05 Days	10 Days	15 Days	05 Days	10 Days	15 Days
Mature Unripe (U)	5.733^{ijk}	5.033^{l}	4.717^{m}	7.017^{b}	6.433^{d}	5.933^{ghi}	7.433^{a}	7.017^{b}	6.433^{d}
Mature Semi-Ripe (S)	5.950^{fghi}	4.950^{lm}	4.950^{lm}	6.767^{c}	6.183^{ef}	5.667^{jk}	6.017^{gfgh}	6.483^{d}	7.183^{b}
Mature Ripe (R)	6.183^{ef}	5.100^{l}	5.100^{l}	6.350^{de}	6.100^{fg}	5.583^{k}	5.850^{hij}	6.183^{ef}	6.767^{c}
	CV (%) = 2.425			Grand Mean = 6.033			LSD (0.05) = 0.255		

Means sharing the same letter(s) are not significantly different at p = 0.05 according to LSD test.

Table 4. Interaction effect among different stages of harvesting, drying structures and drying durations on essential oil content of dried husks (%V/W)

Stages of Harvesting	Drying Duration by Drying System								
	Smoke (K)			Wooden Bed (B)			Wire mesh (M)		
	05 Days	10 Days	15 Days	05 Days	10 Days	15 Days	05 Days	10 Days	15 Days
Mature Unripe (U)	0.877^{ijklm}	0.867^{jklm}	0.773^{n}	1.123^{cb}	1.063^{cde}	0.883^{ijkl}	1.283^{a}	1.120^{cb}	0.980^{fg}
Mature Semi-Ripe (S)	0.927^{ghij}	0.813^{mn}	0.827^{lmn}	1.070^{cd}	0.903^{ijk}	0.873^{ijklm}	0.977^{fgh}	1.023^{def}	1.183^{b}
Mature Ripe (R)	0.990^{fg}	0.870^{ijklm}	0.843^{klm}	1.000^{ef}	0.933^{ghi}	0.883^{ijkl}	0.913^{hij}	0.977^{fgh}	1.117^{c}
	CV (%) = 4.219			Grand Mean = 0.959			LSD (0.05) = 0.060		

Means sharing the same letter(s) are not significantly different at p = 0.05 according to LSD test.

CONCLUSION

Small Cardamom (*Elletaria Cardamomum* Malton), it is also so called queen of spices is a warm season, shade obligate, high value spice. India is a homeland of Small Cardamom and other different indigenous species. Small Cardamom *is* one of the few under-exploited plant species with promising economic value for the country. The seeds have medicinal value as carminative, tonic agent, purgative as well as laxative; however, there is a problem of quality of Small Cardamom products on markets due to the absence of recommended post harvest practices pertaining to processing, value addition, packaging, storing, transporting and marketing. Most often capsules are harvested at mature/immature green stages. The drying system and drying durations are also variable and have equal consideration with the stages of harvesting on quality. Due to the presence of inappropriate stage of harvesting, drying structure and drying duration, it was assumed that there is a huge loss of income from the spice. Hence, it was found crucial to do a research on harvesting stages, drying systems and drying durations of Small Cardamom capsules.

In this study, the influence of the treatments on biochemical quality of dried Small Cardamom capsules and seeds was investigated. The combined effect among the various stages of harvesting, drying systems and drying durations showed significant effects on the biochemical quality parameters. The interaction effect between harvesting stages and drying structures as well as the main effect of drying durations were significantly affected dried capsule.

Mature unripe capsules harvested and dried on wire mesh for 05 days scored maximum oleoresin content of dried seeds (12.535%w/w), essential oil content of dried seeds and husk (7.433%v/w and 1.283%v/w, respectively). On the other hand, mature unripe and mature ripe capsules dried through smoke for 15 days gave minimum oleoresin (7.374%w/w) and essential oil (4.717%v/w)) contents, respectively. Furthermore, mature unripe capsules dried through smoke for 15 days gave minimum essential oil (0.773%v/w)) content of dried husk.

As drying duration extended from 05 days to 10 days and then to 15 days, harvesting prolonged from mature unripe to mature ripe and drying systems concerned moving from wire mesh to wooden bed and then to smoke, oleoresin content of dried seeds and essential oil content of dried seeds and husks showed decreasing trend. This may be due to the fact that long time exposure to solar radiation and smoke combined with prolonged stages of harvesting and nature of the drying system. As the harvesting stage is prolonged, expenditure of chemical constituents (volatiles and non-volatiles) takes place during ripening. Alongside, extended drying duration might result in depletion of the chemical constituents because of long period exposure to solar radiation and smoke. Coupled with these, smoke drying system with sweating nature for the spices, contributes to excess loss of the biochemical, resulting to high loss of volatiles and non-volatiles.

Therefore, it can be concluded that the result of the current study showed that the interaction of various drying systems, stages of harvesting and drying durations have sound impact on biochemical quality of Small Cardamom. Generally, wire mesh drying system was found to be consistently superior in resulting majority of the quality parameters and can be recommended for production of good quality dried Small Cardamom capsules. Considering overall quality of the spice, the recommendations may be based on the purpose of the capsules intended for final use. If the capsules are intended for immediate extraction purpose, mature unripe capsules harvested and dried on wire mesh for 05 days can be recommended for high oleoresin and essential oil production. Thus, collectors and/or producers in all Small Cardamom growing areas better to be aware of the biochemical quality issues and may use the recommendations of this research work for maintenance of good quality of capsule,

depending on the intended use.

Provided that equal opportunity in research and development, Small Cardamom can be another gift of Ethiopia and undoubtedly it can be the best candidate to rival with other commercial commodities, example coffee, both in the domestic and export markets. Thus, it appears to be worthy of considering further investigations in the aspects of storage shelf life of capsules, quality comparison of Small Cardamom capsules dried in shade, packaging and packaging materials as well as quality comparison of Small Cardamom collected from different growing agro ecologies and with the other Small Cardamom and *Amomum* species. Furthermore, there has not been any significant work done so far on the crop in Ethiopia with regard to conservation, sustainable research and extension. Along with the shade loving nature of the crop, well oriented development policy of agricultural investment towards agro ecological sustainability and giving adequate concern for the ever increasing habitat degradation of the natural forest that threatened the available diversity and its other properties also request a top urgent action from the research and biodiversity institutes.

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REFERENCES

Endashaw, B., 2007. Study on Actual Situation of Medicinal Plants in Ethiopia. Prepared for Japan Association for International Collaboration of Agriculture and Forestry. Ethiopia. Pp. 48-65.

Eyob, S., 2009. Potential of Small Cardamom (*A. corrorima*) as a crop plant in Southern Ethiopia", is dealing with such a promising plant species. Ph.D. Dissertation, Hawassa, Ethiopia.

Eyob, S., M. Appelgren, J. Rohloff, Tsegaye A. and Messele G., 2007. Chemical composition of essential oils from fresh plant parts of *A. corrorima* cultivated in the highland of Southern Ethiopia.

Garg, S. N., R. P. Bansal, M. M. Gupta and S. Kumar, 1999. Variation in the rhizome essential oil and cucurmin contents and oil quality in the land races of turmeric Curcuma longa of North Indian plains.

Girma, H. and Kindie T., 2008. The effects of seed rhizome size on the growth, yield and economic return of ginger *(Zingiber officinale* Rose.). Asian Network for Scientific Information, *Asian Journal of Plant Sciences 7(2): 213-217.*

Girma, H., Digafe T., Edossa E., Belay Y., and Weyessa G., 2008. Spices research achievements, Revised Edition. Ethiopia Institute of Agricultural Research, Addis Ababa.

Hymete, A., J. Rohloff and T. H. Iversen, 2006. Essential oil from seeds and husks of *Small Cardamom* from Ethiopia. *Flavor and fragrance Journal, 2006; 21: 642-644.*

ICS-UNIDO, 2008. Extraction Technologies for Medicinal and Aromatic Plants. Earth, Environmental and Marine Sciences and Technologies International Centre for Science and High Technology ICS-UNIDO, AREA Science Park Padriciano 99, 34012 Trieste, Italy

Jansen, P.C.M. 2002. "*A .corrorima* (Braun) P.C.M. Jansen) ". Record from Protabase. Oyen, L.P.A. and Lemmens, R.H.M.J. Editors. PROTA Plant Resources of Tropical Africa, Wageningen, The Nethelands.

Jose, K. P. and C. M. Joy, 2004. Postharvest Processing of Spices in Relation to Export Quality. Everyman's Science, Vol. XXXIX, No. 4., Kerala, India.

Kachru, R. P. 2002. Agro-Processing Industries in India—Growth, Status and Prospects, *Indian Council of Agricultural Research, New Delhi*

Korikanthimath, V. S. Handbook of herbs and spices, Indian Institute of Spices Research, Karnataka

Leela, N.K., D. Prasath and M.N. Venugopal, 2008. Essential oil composition of selected cardamom genotypes at different maturity levels. *Indian Journal of Horticulture 65(3), September 2008: 366-369.*

Murugan, M., Backiyarani, S., Josephrajkumar, A., Hiremath1, M.B. and Shetty, P.K., 2007. Yield of small cardamom (*Elettaria cardamomum* M) variety PV1 as influenced by levels of nutrients and neem cake under rain fed condition in southern western ghats, India. *Caspian J. Env. Sci. 2007, Vol. 5 No.1pp. 19~25*

Parthasarathy, A. V., B. Chempakam and T. J. Zachariah, 2008. Chemistry of Spices. Indian Institute of Spices Research Calicut, Kerala, India.

Peter, K.V., 2001. Hand book of herbs and spices. Wood head Publishing Limited. Cambridge, England. Volume I: 326: 150-159.

Purseglove, J.W., E.G. Brown, C.L. Green, and S.R. Robins, 1981. Spices: Volume 1 and 2. Longman group limited, London.

Ravindran, P.N., M. Shylaja and K. N. Bab, 2002. False cardamom, *Aframomum* sp. (Small Cardamom cardamom: *Small Cardamom* (Braun). Syn., *A. melegueta* (Roscoe) Schum. (Meleguetta pepper, grains of paradise or alligator pepper). Pp. 330-340.

SAS Institute Inc. 2008. SAS/STAT. 9.2 User's Guide. Cary, NC: SAS Institute Inc, USA.

Silva, L.V., D.L. Nelson, M.F.B. Drummond, L. Dufossé, and M.B.A. Glória, 2005. Comparison of hydro-distillation methods for the deodorization of turmeric. Belo Horizonte, MG, 31270-901, Brazil.

Wondyifraw T. E., 2004. *Invitro* propagation and polyploidy induction of Small Cardamom (*A. corrorima* (BRAUN) JANSEN) and krawan (Amomum krervanh PIERRE). Dissertation for Doctor of Philosophy. Kasetsart University, Thailand.

Wondyifraw, T. and W. Surawit, 2004. A Micropropagation Method for Small Cardamom (*Small Cardamom* (Braun) Jansen). Department of Horticulture, Kasetsart University, Kampaengsaen campus, Nakhon Pathom 73140, Thailand. Research Article, Science Asia, 30: 1-7.