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Research article

Influence of Harvesting Stages, Drying Structures and Drying Durations on Oleoresin and Essential Oil content of Korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen) Capsules Grown in Ethiopia

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Abstract

Korarima (*Aframomum corrorima*) is an indigenous spice to Ethiopia and serves as an essential raw material for extraction industry. Its quality is influenced by, among others, harvesting stages, drying structures and durations. It faces stringent market challenges, due to its inferior oleoresin and essential oil content, with Indian Cardamom. Hence, this study was conducted to determine appropriate harvesting stages, drying structures and durations to enhance oleoresin and essential oil content of korarima. The experiment consisted of harvesting stages (Mature Green, Mature Semi-red and Mature deep Red), drying structures (Cement, Ground and Wire mesh bed) and drying durations (10, 15 and 20 days) laid out in a 3*3*3 factorial arrangement using Completely Randomized Design with three replications. Data on oleoresin content of dried seeds and essential oil content of dried seeds and husk were recorded and subjected to ANOVA. Interaction of harvesting stages, drying structures and drying durations significantly affected extraction quality of dried capsules. Mature green capsules dried on wire mesh bed for 10 days scored maximum oleoresin (10.04% w/w) and essential oil content of dried seeds (5.53%) and essential oil from husks (0.93% v/w), which surpassed the grand mean by 33.76%, 24.95% and 33.76%, respectively. However, mature green and mature deep-red capsules dried on cement floor for 20 days gave minimum essential oil (2.82% v/w) and oleoresin (4.88% w/w) contents, respectively. Therefore, for extraction purpose, mature green capsules dried on raised wire mesh beds for 10 days can be recommended for optimum extraction quality.

Keywords: Korarima, *Aframomum corrorima*, Postharvest, Oleoresin, Essential Oil

Introduction

Korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen) is a spice and medicinal plant in the family *zingiberaceae* [11] and [9] and native to Ethiopia [11] and [4]. It is a perennial aromatic herb, terrestrial, rarely epiphytic, aromatic, with fleshy, tuberous or non-tuberous rhizomes, often with tuber-bearing roots of usually strong fibrous subterranean scaly rhizomes and with leafy false stems (ca. of 1m to 2m height) created by leaf-sheath [9]. It is a close relative of the widely known Indian cardamom (*Elettaria cardamomum* Maton) [11] and [19]. As indigenous spice, Korarima grows in various parts of the country; Kaffa, Jimma, East and West Wollega, Sidamo, Bale, South and North Omo, Illubabour, East and West Gojam, Gamugofa, etc. [1]. Capsules/seeds are the economic parts of the plant [1], [20] and [8]. The commercial products of Korarima are capsules or seeds.

Capsules of Korarima which possess very different flavor profile from cardamom (*Elettaria cardamomum* Maton) are larger in size and dark reddish brown, brownish black or grayish black and coarsely ribbed. The seeds are darker and have a menthol-like taste. Different reports described the oil composition of Korarima to be qualitatively similar to that of cardamom, except for the reduced content of terpinyl acetate which is the major component of the later. Korarima has 2% essential oil which has more than 70% of 1, 8-cineole [12], [5] and [8].

Capsules of Korarima have very widespread utilization in Ethiopian and Eritrean cuisines. Korarima 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 [12] and [3]. Essential oil of Korarima seeds has a typical odor, and is therefore, sometimes called 'nutmeg - cardamom' [4]. Thus, the seeds are also used in Ethiopia for medicinal purpose [20] and [9].

Dried capsule of Korarima 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 Korarima capsules to the world market, mainly as a substitute for the Indian cardamom [21] and [3]. 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 Korarima capsules which in turn can lead to poor capsule quality [8]. 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 Korarima 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 [12], 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 [8].

Therefore, the objective of this study was to harmonize harvesting stages, drying structures and drying durations of Korarima capsules to improve the extraction or biochemical quality which is the export-oriented product for the country.

Materials and Methods

Experimental Material and Treatments

Capsules were harvested from wild Korarima (*Aframomum corrorima*) from the natural forest of Sheka Zone, Masha Woreda in Southwestern part of Ethiopia, particularly at Beto kebele. It is located at 7°44′N latitude,

35°29′E longitude and altitude range of 1800 to2222 meter above sea level (Figure 1) (Bureau of Agriculture and Rural Development of Masha Woreda, 2010). The rainfall distribution in the Woreda and/or zone follows a bimodal pattern with annual average rainfall of 2000 mm, the wet seasons being between April/May and October/November. The temperature of the region ranges from 12**°C** to 27.50**°C**. Forest plots for harvesting were selected from the Woreda that have moderate to good performance of Korarima and with minimum human and wild animal disturbance. The forest plots were selected towards the middle of the forest (50m from boundary of the forests). All types of capsules (capsules having various maturity stages and colors) to be harvested were widely available towards the middle of the forests. Thus the capsules of all the three maturity stages of capsules were harvested and collected to each specific color stage from the middle of the forest within a day. Capsules were hand-picked by experienced collectors. Capsules were dried at Tepi Coffee Plantation Development Enterprise which is located 611km from Addis Ababa with almost similar climatic conditions to the harvesting place as discussed by [7].

The experiment consisted of three harvesting stages: Mature Green (MG), Mature Semi-red (MS) and Mature Deep-Red (MR); three drying structures: Ground (G), Cement floor (C) and raised beds with wire mesh (W) and three drying durations: Ten days (D_1), Fifteen days (D_2) and Twenty days (D_3) (Table 1).

Experimental Design and Statistical Analysis

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 [18]. The fixed effect model that includes the main effect of harvesting stages, drying structures and durations together with interaction effects were used. Mean comparison was undertaken with LSD at 5%, when significant treatment effects were observed

Table 1. Details of treatments (drying structures, harvesting stages and drying durations) combinations

Drying structures	Harvesting stages	Drying durations (Days)	Treatment combination
Cement floor	Mature Green	10 (D_1)	$CMGD_1$
		15 (D_2)	$CMGD_2$
		20 (D_3)	$CMGD_3$
	Mature Semi-red	10 (D_1)	C MSD_1
		15 (D_2)	C MSD_2
		20 (D_3)	C MSD_3
	Mature Deep Red	10 (D_1)	$CMRD_1$
		15 (D_2)	$CMRD_2$
		20 (D_3)	$CMRD_3$
Ground	Mature Green	10 (D_1)	$GMGD_1$
		15 (D_2)	$GMGD_2$
		20 (D_3)	$GMGD_3$
	Mature Semi-red	10 (D_1)	$GMSD_1$
		15 (D_2)	$GMSD_2$
		20 (D_3)	$GMSD_3$
	Mature Deep Red	10 (D_1)	$GMRD_1$
		15 (D_2)	$GMRD_2$
		20 (D_3)	$GMRD_3$
Wire mesh	Mature Green	10 (D_1)	$WMGD_1$
		15 (D_2)	$WMGD_2$
		20 (D_3)	$WMGD_3$
	Mature Semi-red	10 (D_1)	$WMSD_1$
		15 (D_2)	$WMSD_2$
		20 (D_3)	$WMSD_3$
	Mature Deep Red	10 (D_1)	$WMRD_1$
		15 (D_2)	$WMRD_2$
		20 (D_3)	$WMRD_3$

Collection, Drying and Extraction Procedure

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 and complete dry up of the capsule upper tip (straw) were 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 3kg fresh capsules was prepared. Capsules of the three harvesting stages were randomly placed on the three types of drying structures and then exposed to three different drying durations according to the treatment combinations. The drying operation was performed during the sunny days starting from 9:00AM to 5:00PM and covered with water proof two fold plastic sheets from above and sack from beneath the plastic during midday, rain and at night to prevent re-r moistening of samples.

The extraction process was performed at Jimma University, Organic Chemistry and Nutrition Laboratories. Data were recorded on dried capsule chemical quality.

Oleoresin Extraction

A hot continuous extraction (Soxhlet) method was used in the laboratory to extract oleoresin following the method described by [10]. As outlined by Krishnamurthy *et al*. (1976) cited from Parthasarathy *et al*. (2008), oleoresin was determined by the solvent extraction method using acetone (95%) as organic solvent for 4 to 5 hours. First dried seeds were extracted from capsules cleaned and ground in to fine powder using pistil and mortar. Sample of 100g of powder, 500ml 95% aqueous acetone and thimble were taken for extraction purpose. The extraction process was carried out at a temperature of 56^{o}C for 4 hours. Solvent removal from the miscella was carried out using reduced pressure Rotary Vacuum Evaporator at 40^{o}C and 90RPM. Finally, the viscous colored liquid (oleoresin) was measured and quantified as percent weight-weight basis.

Essential Oil Extraction

Distillation with Clevenger apparatus 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 80^{o}C for 5 hours after the mixture started boiling following the method described by [9], [6] and [19]. 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

Oleoresin Content of Dried Seeds

The results of the present study indicated that the interaction effects among various harvesting stages, drying structures and drying durations on oleoresin content of dried seeds were observed highly significantly different ($p<0.001$). Maximum oleoresin content (10.04% w/w) was recorded from mature green capsules dried on wire mesh for 10 days and next to this oleoresin content (9.16% w/w) was obtained still from seeds of mature green capsules dried on the ground for 10 days. In contrast, the minimum oleoresin content (4.87%) was recorded from mature deep-red capsules dried on cement floor for 20 days (Table 2). It is apparent that the maximum result exceeded 51.49% and 33.76% from the minimum result and grand mean, respectively.

Mature deep-red capsules dried on cement floor for longer time have got low oleoresin content at the expense of high exposure to solar radiation 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 the various harvesting stages, drying structures 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 green capsules harvested and dried on wire mesh for 10 days (5.53%) which was statistically at par with mature semi-red capsules dried on wire mesh for 10 days (5.35%). On the other hand, the minimum EO content was recorded from mature green capsules dried on cement floor for 20 days ($CMGD_3$) (2.82% v/w). Mature semi-red capsules dried on cement floor for 15 days and 20 days both recorded the same result (3.05%) which was statistically similar to the result of $CMGD_3$. About 49.11% difference was recorded between the maximum and minimum results of EO content of dried seeds. Furthermore, the maximum result was found to be 24.95% higher than the grand mean. Early harvested mature and green color capsules and dried on wire mesh for short drying duration (10 days) had high EO content due to low exposure of capsules to solar radiation and high air circulation in wire mesh drying structure while cement floor drying structure scored low results due to longer exposure to higher solar radiation. As late harvesting stage (mature semi-red and mature deep-red) 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 [16]. 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. [13] 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. [16] 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.

[4] Stated that steam-distilled dried fruits gave about 3.50% pale yellow EO with a flat cineolic odor. Lawrence (1970) cited from [17] as well as [2] reported the same result of EO of Korarima which was 3.50% volume by weight. [9] Further reported that dried seeds of Korarima contain 3.77% EO, with 1, 8-cineole as the main constituent. On the other hand, [14] reported that EO of small cardamom (Indian) and large cardamom (Nepal) was 5.50% to 10% and 2.80%, respectively. Likewise, [15] 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. In comparison of these reports with the current study, the average EO content of Korarima was about 48.25% less and 42.03% greater than the average EO content of small cardamom and large cardamom, respectively. However, the result of the current study more likely agreed with the finding of [16] that the maximum EO content of Korarima is 4.50%. Essential oil content was 20 to 30 percent more in the physiologically mature and immature stages compared to ripe stage and half ripe stage [22].

Essential Oil Content of Dried Husk

The result of the current investigation exhibited that the interaction effect among various harvesting stages, drying structures and drying durations on essential oil (EO) content of dried Korarima husk was very highly significantly affected ($p<0.0001$). The result presented in Table 4, illustrated that the maximum result was recorded from mature green capsules dried on wire mesh for 10 days (0.933%) while the minimum values were attained from mature green capsules dried on cement floor for 20 days (0.42%), mature semi-red dried on cement floor for 15 days and 20 days resulted (0.46%) and (0.48%), respectively and showed no statistical difference to each other (Table 4). Cement floor drying structure combined with late harvesting stage (mature semi-red and mature deep-red) and extended drying duration resulted in low EO content of dried husks which might be due to high exposure to solar radiation 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 the drying duration extended, EO content of dried husks decreased as there was extended duration of exposure.

[4] Reported that the EO yield of pod was 0.83% (v/w) on dried basis. [9] further reported that the EO content of dried husks of Korarima purchased from Merkato, the largest open market in Africa, separated, powdered and undergo distillation had contained 0.27%. On the other hand, [14] reported the essential oil for large cardamom husk as 0.18%. However, the average result of the current study (0.62%) exceeded about 55% from the finding of [9] which might be due to harvesting stages, drying structures and drying durations.

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

Drying Structures	Harvesting Stages by Drying Durations								
	Mature Green (MG)			Mature Semi-red (MS)			Mature Deep Red (MR)		
	10 Days	15 Days	20 Days	10 Days	15 Days	20 Days	10 Days	15 Days	20 Days
Cement	7.341^{g}	6.073^{m}	5.455^{o}	6.635^{j}	5.528^{o}	5.158^{p}	6.048^{m}	5.177^{p}	4.874^{r}
Ground	9.159^{b}	7.430^{g}	6.416^{k}	7.742^{e}	6.253^{l}	5.812^{n}	6.859^{i}	5.526^{o}	5.027^{q}
Wire mesh	10.035^{a}	8.443^{c}	7.549^{f}	8.284^{d}	7.074^{h}	6.491^{k}	7.069^{h}	6.214^{l}	5.777^{n}
	Grand Mean = 6.646			LSD (0.05) = 0.112			CV (%) = 1.035		

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

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

Drying Structures	Harvesting Stages by Drying Durations								
	Mature Green (MG)			Mature Semi-red (MS)			Mature Deep Red (MR)		
	10 Days	15 Days	20 Days	10 Days	15 Days	20 Days	10 Days	15 Days	20 Days
Cement	3.833^{ijk}	3.133^{l}	2.816^{m}	4.050^{fghi}	3.050^{lm}	3.050^{lm}	4.283^{ef}	3.200^{l}	3.200^{l}
Ground	5.116^{b}	4.533^{d}	4.033^{ghi}	4.866^{c}	4.283^{ef}	3.766^{jk}	4.450^{de}	4.200^{fg}	3.683^{k}
Wire mesh	5.533^{a}	5.116^{b}	4.533^{d}	5.350^{ab}	4.583^{d}	4.116^{fgh}	4.866^{c}	4.283^{ef}	3.950^{hij}
	Grand Mean = 4.144			LSD (0.05) = 0.242			CV (%) = 3.567		

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

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

Drying Structures	Harvesting Stages by Drying Durations								
	Mature Green (MG)			Mature Semi-red (MS)			Mature Deep Red (MR)		
	10 Days	15 Days	20 Days	10 Days	15 Days	20 Days	10 Days	15 Days	20 Days
Cement	0.526^{ijklm}	0.516^{jklm}	0.423^{n}	0.576^{ghij}	0.463^{mn}	0.476^{lmn}	0.640^{fg}	0.520^{ijklm}	0.493^{klm}
Ground	0.773^{bc}	0.713^{cde}	0.533^{ijkl}	0.720^{cd}	0.553^{ijk}	0.523^{ijklm}	0.650^{ef}	0.583^{ghi}	0.533^{ijkl}
Wire mesh	0.933^{a}	0.770^{bc}	0.630^{fg}	0.833^{b}	0.673^{def}	0.626^{fgh}	0.766^{c}	0.626^{fgh}	0.563^{hij}
	Grand Mean = 0.616			LSD (0.05) = 0.067			CV (%) = 6.593		

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

CONCLUSION

Results of the current investigation indicated that the influence of interaction effect of drying structures, harvesting stages and duration of drying on biochemical qualities (oleoresin and essential oil content) of dried Korarima (*A. corrorima*) seeds and husk was very significant.

Mature green capsules dried on wire mesh for 10 days scored maximum oleoresin content of dried seeds (10.04%w/w), EO content of dried seeds (5.53%v/w) and husk (0.93%v/w). About 51.49%, 49.11% and 51.61% differences were recorded between the maximum and minimum results of oleoresin and essential oil of dried seeds, respectively. And as the maturity group of the capsules extended to mature semi-red and mature deep-red (equivalent to late harvest in this case) oleoresin content of the seeds and essential oil content of seeds and husks showed a decreasing pattern. Likewise, extended drying durations also resulted in lower values of oleoresin and essential oil. These results are very supportive to the reports of [16].

Therefore, it can be concluded that the result of the current study showed that the combined effect of the various harvesting stages, drying structures and durations have sound and promising impact on oleoresin content of dried seeds and essential oil content of dried seeds and husks of Korarima. Generally, drying on Wire mesh structure was found to be consistently superior in resulting of better chemical quality attributes and can be recommended for higher oleoresin and essential oil production. Hence, when the capsules are intended for immediate extraction purpose, mature green capsules dried on wire mesh for 10 days can be recommended for high oleoresin and essential oil production. Thus, collectors/producers in all Korarima growing areas of Ethiopia better to be aware of the quality issues and may use the recommendations for better oleoresin and essential oil.

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