 

# Influence of Harvesting Stages, Drying Structures and Drying Durations on Physical Quality Characters of Korarima (Aframomum Corrorima (Braun) P.C.M. Jansen) Capsules in Ethiopia

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**Abstract**
Korarima *(Aframomum corrorima)* is indigenous spice to Ethiopia used as raw material for consumption. It faces market challenges, due to its inferior quality. Its inferior quality is due to inappropriate harvesting stages, drying structures and durations. Hence, the study was conducted to examine physical quality issues. 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 3*3*3 factorial arrangement using Completely Randomized Design with three replications. Data were recorded and subjected to Analysis of Variance. Interaction of the parameters significantly affected quality of dried capsules. The highest values, for average weight of single dried capsule (9.526g) and dry weight recovery of dried capsule (41.301%) were obtained from mature green capsules and mature deep-red capsules, respectively, both dried on wire mesh for 10 days. The maximum capsule diameter (2.769cm) and maximum seed diameter (5.27mm) were both recorded from mature deep-red capsules dried on wire mesh for 10 days. Therefore, for maintaining better physical quality of the dried capsules, mature deep red capsules dried on wire mesh for 10 days can be recommended.
**Keywords:** Aframomum corrorima, Korarima, Capsules, Harvesting stage, Physical, Quality

## INTRODUCTION

Korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen) is a spice and medicinal plant in the family *zingiberaceae* (Jansen, 1981; Hymete *et al*., 2006) and native to Ethiopia (Jansen, 2002; Eyob *et al*., 2007). 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 (capacity of 1m to 2m height) created by leaf-sheath (Hymete *et al*., 2006). It is a close relative of the widely known Indian cardamom (*Elettaria cardamomum* Maton) (Jansen, 1981; Wondyifraw, 2004). As indigenous spice, *Aframomum corrorima* 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. (Jansen, 1981; Edossa, 1998; Girma and Asrat, 2009 unpublished). Capsules/seeds are the economic parts of the plant (Edossa, 1998; Wondyifraw, 2004; Girma *et al*., 2008). The commercial products of korarima are capsules or seeds.

Ethiopia is a homeland for many spices and stimulants (Parry, 1969 cited from Edossa, 1998). Despite the availability of diverse agro-ecologies in the country to produce many kinds of spices and the significant economical, ecological and social roles of these commodities, the research conducted on spices including *Aframomum corrorima* is very limited and has not been to a level with full production recommendation of these important spices (EARO, 2000; Birhanu, 2010).

*Aframomum corrorima* has very widespread utilization in Ethiopian and Eritrean cuisines. The spice is obtained from the plant's seeds. It has been part of daily Ethiopian dish in preparation of curry powder for culinary purposes. In Ethiopia, the seeds are used to flavor all kinds of sauces locally for which they are ground and usually mixed with other spices (Jansen, 2002; Eyob, 2009). Dried *Aframomum corrorima* capsule 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 *Aframomum corrorima* capsules to the world market, mainly as a substitute for the Indian cardamom (Wondyifraw and Surawit, 2004; Eyob, 2009). Despite of these paramount economic roles of the commodity, the research conducted on this spice is very limited.

Within the existing situation of the spice domestic and export market potential of the country, there is a serious problem of quality on the local and the international markets of the spice. The major reason for this is the absence of recommended technologies pertaining to production, post harvest handling including processing, storage, packaging, transporting and marketing (Jansen, 2002).

*Aframomum corrorima* with its magnificent uses of for the nation, it has lots of challenges. Till present all production and post harvest processing practices of *Aframomum corrorima* capsules are very traditional which automatically contributed for low quality products. As the spice is collected from inside the wild forest, the capsules are harvested mostly at immature green and mature green stage because of competition among competitive spice collectors from the natural forest and wild animals (Apes, Monkeys, Squirrels, snakes). Similarly, subsequent practice of drying of the capsules also varies among collectors and remained very traditional. In most of the times, the quality of dried capsules is poor to the extent that moulds are developing on the surface of the capsules. Different drying structures are being utilized by producers, 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/smoke are some of the frequent ones. All these practices lead to very poor physical quality parameters of the capsule which is the commercial product. To date, there is no comprehensive study to identify the most quality ensuring structures of drying. Besides, drying duration is another big issue which influences the quality of the final product (Girma *et al*., 2008). Optimization of harvesting stages, drying materials and durations has not been done anywhere in the world as the crop is native to Ethiopia and to our knowledge no commercial production has been started elsewhere. In this context, it is vivid that due to inappropriate harvesting stages, drying structures and drying durations of the spice collectors in Ethiopia, even at the birth place of *Aframomum corrorima*, are not producing quality capsules and hence there is a huge loss of income from the spice. As a mitigation strategy, it is crucial to have recommended harvesting stages, appropriate drying structures and optimum drying durations for good quality production of the spice.

The scenario of the present study focused on harmonizing of harvesting stages, drying structures and drying durations of *Aframomum corrorima* capsules. The objective of this study was therefore to determine appropriate harvesting stages, drying structures and drying durations to improve the physical quality of *Aframomum corrorima* dry capsules in Ethiopia.

## MATERIALS AND METHODS

### Experimental Material and Treatments

*Aframomum corrorima* capsules were harvested from the natural forest of Sheka Zone, Masha Woreda in Southwestern part of Ethiopia. It is located at 7°44′N latitude, 35°29′E longitude and altitude range of 1800-2222 meter above sea level (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 2000mm. The temperature of the region ranges from $12^{o}C$ to $27.50^{o}C$. Forest plots for harvesting were selected from the Woreda that have moderate to good performance of *Aframomum corrorima* 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. The drying operation was performed at Tepi Coffee Plantation Development Enterprise which *is located 611KM from Addis Ababa with almost similar climatic conditions to the harvesting place as discussed on Girma and Kindie (2008).*

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 Analysis of Variance using SAS ver. 9.2, statistical software (SAS Institute Inc., 2008). 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 Least Significant Difference at 5%, when significant treatment effects were observed.

 

Table 4. 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 and drying procedures**

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. Data on physical quality parameters of dried *Aframomum corrorima* capsules; weight of dry capsule (g), dry weight recovery capsules, length of dry capsules (cm), diameter of dry capsules (cm), weight of dry seeds per capsules (g), diameter of seeds (mm), thousand seed weight (g) and seed to husk ratio were recorded. Vernier Caliper (FOWLER0531187, US) was used to measure the length and diameter of dried capsules and a three digit sensitive balance (AF 110L, China) was used for measuring weight.

## RESULTS AND DISCUSSION

### Weight of single dried capsule (g)

The average weight of single dried capsule was very highly significant ($p<0.0001$) as influenced by the interaction among harvesting stages, drying structures and drying durations. The highest value (9.526g) for average weight of single dried capsule was obtained from mature green capsules which statistically resulted in similar values with mature semi-red capsules (9.415g) both of which were dried on wire mesh for 10 days. On the contrary, the lowest weight (5.894g) of dried individual capsules was recorded from mature green capsules dried on cement floor for 20 days which was again statistically at par with mature green capsules dried on cement floor for 15 days (5.998g) (Table 2). During harvest, mature green capsules had higher chemical components which then lead to more loss upon extended drying as compared to mature semi-red and mature deep-red capsules. Comparatively speaking, in the initial drying duration, the mature green capsules dried on wire mesh might have conserved relatively more of their chemical components. Observation during the

experiment revealed that drying on cement floor had raised temperature owing to its high solar heat absorbing nature, thus, the capsules could easily loss their weight while wire mesh drying structure had better aeration. However, with extended drying duration, loss of weight was observed higher in mature green capsules.
Mean of maximum capsule dry weight (g); 9.526, 9.415 and 9.287 obtained from mature green, mature semi-red and mature deep-red respectively, from drying on wire mesh for 10 days duration was a bit higher than a report by Zenebe (2004) and Feleke (2007).

**Dry weight recovery of dried capsule (%)**
Results from the current investigation signified that the interaction effect of the various harvesting stages, drying structures and drying durations significantly ($p<0.0001$) affected average dry weight recovery of korarima (*A. corrorima*) capsules. Maximum value of capsule dry weight recovery (41.301%) was recorded from mature deep-red capsules dried on wire mesh for 10 days , however, statistically the same with the values registered for mature semi-red capsules dried on wire mesh for 10 days whereas the minimum result (22.999%) was recorded from mature green capsules dried on cement floor for 20 days (Table 3).

Irrespective of the drying structure and drying duration, the maximum average percent dry weight recovery was recorded from mature deep-red capsules (35%). The increase in dry weight recovery with ripening may be due to the accumulation of certain assimilates (crude fiber and cellulose). Upon ripening, cellulose and fiber content of capsules increase while moisture content and volatiles decrease. During harvesting, mature green capsules have high moisture content which was subsequently lost upon drying as compared to mature semi-red and mature deep-red capsules. Likewise, as the drying duration is extended, average dry weight recovery decreased as there was high exposure to solar radiation and high loss of constituents from all capsules in general and the mature green capsules in particular. Combined with these, wire mesh drying structure had resulted in high dry weight recovery which might be due to low exposure to solar radiation, good air circulation and slow drying which might result less loss of moisture and volatiles. Drying on cement floor coupled with mature green capsules dried for 15 and 20 days, on the other hand, resulted in low percent dry weight recovery which might be attributed to its solar heat absorbing nature that in turn result in high loss of moisture and volatiles. Recent reports indicate that splitting of capsules which affects quality is less when picked at mature green stage wherein incidence varied from 13.5% in physiologically mature capsules, to 41.50% in ripe capsules (Zachariah and Korikanthimath, 2002).

Peter (2001) and Zachariah and Korikanthimath (2002) reported that the percentage recovery of small cardamom capsules was 29% in ripened stage, 24% in physiologically mature stage and 14% in immature stage. Zachariah and Korikanthimath (2002) had further reported that there was 100% weight gain from immature to mature harvesting stage. The current study showed that irrespective of the drying structures and drying

Table 5.Weight of single dried capsule (g) as influenced by the interaction effect among harvesting stages, drying structures and drying durations

| Drying Structures | Harvesting Stages by Drying Durations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mature Green | | | Mature Semi-red | | | Mature Deep Red | | |
| | 10 Days | 15 Days | 20 Days | 10 Days | 15 Days | 20 Days | 10 Days | 15 Days | 20 Days |
| Cement | 6.840$^{l}$ | 5.998$^{o}$ | 5.894$^{o}$ | 7.010$^{kl}$ | 6.621$^{m}$ | 6.427$^{n}$ | 7.098$^{k}$ | 6.941$^{kl}$ | 6.641$^{m}$ |
| Ground | 8.746$^{de}$ | 7.638$^{i}$ | 6.950$^{kl}$ | 8.334$^{g}$ | 8.028$^{h}$ | 7.450$^{j}$ | 7.949$^{h}$ | 7.769$^{i}$ | 7.760$^{i}$ |
| Wire mesh | 9.526$^{a}$ | 8.816$^{cd}$ | 8.485$^{fg}$ | 9.415$^{ab}$ | 8.752$^{de}$ | 8.537$^{f}$ | 9.287$^{b}$ | 8.927$^{c}$ | 8.637$^{ef}$ |
| Grand Mean = 7.795 | | | LSD (0.05) = 0.171 | | | CV (%) = 1.341 | | | |

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

***Table 6. Dry weight recovery of dried capsules (%) as influenced by the interaction effect among harvesting stages, drying structures and drying durations***

| Drying Structures | Harvesting Stages by Drying Durations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mature Green | | | Mature Semi-red | | | Mature Deep Red | | |
| | 10 Days | 15 Days | 20 Days | 10 Days | 15 Days | 20 Days | 10 Days | 15 Days | 20 Days |
| Cement | 26.584$^{o}$ | 23.389$^{p}$ | 22.999$^{p}$ | 30.443$^{jk}$ | 28.741$^{m}$ | 27.921$^{n}$ | 31.490$^{i}$ | 30.767$^{ij}$ | 29.478$^{lm}$ |
| Ground | 34.155$^{g}$ | 29.771$^{kl}$ | 27.055$^{o}$ | 36.145$^{e}$ | 34.910$^{fg}$ | 32.390$^{h}$ | 35.237$^{f}$ | 34.583$^{fg}$ | 34.227$^{g}$ |
| Wire mesh | 37.223$^{d}$ | 34.411$^{g}$ | 33.093$^{h}$ | 40.875$^{a}$ | 38.019$^{c}$ | 37.172$^{d}$ | 41.301$^{a}$ | 39.579$^{b}$ | 38.340$^{c}$ |
| Grand Mean = 32.974 | | | LSD (0.05) = 0.766 | | | CV (%) = 1.420 | | | |

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

durations, average dry weight recovery of korarima (*A. corrorima*) capsules, 29.855%, 34.068% and 35% were obtained from mature green, mature semi-red and mature deep-red , respectively. Furthermore, the present study indicated, an overall average dry weight recovery of *Aframomum corrorima* capsules is 19.62% higher than those of small cardamom capsules reported by Peter (2001) and Zachariah and Korikanthimath (2002).

**Length and diameter of dried capsule (cm)**

Interaction effect of various harvesting stages, drying structures and drying durations on average length and diameter of dried korarima (*Aframomum corrorima*) capsule were highly significantly ($p<0.001$) different. The maximum capsule length (5.721cm) and diameter (2.769cm) were recorded from mature deep-red capsules dried on wire mesh for 10 days while the minimum values of capsule length (4.065 cm) and diameter (1.637cm) were obtained from mature green capsules dried on cement floor for 20 days (Table 4 and Table 5, respectively). The observed discrepancy between the maximum and minimum results might be accounted to the chemical changes resulted from ripening which could increase the size of the capsules and maintain the right size up on drying. According to Giovannoni (2001), the changes during ripening generally include modification of cell wall ultra structure and texture (increase cellulose), conversion of starch to sugars, alterations in pigment biosynthesis and accumulation of flavor and aromatic volatiles. Accumulation of carbohydrates (cellulose) contributes to the increase of cell size thereby size of the capsules. Besides, capsules harvested at mature green stage had high moisture content as compared to mature semi-red and mature red capsules. Thus, mature green capsules might have high tendency to lose higher moisture content and shrink at the expense of extended drying duration combined with cement drying structure. Wire mesh drying structure resulted in longer length and diameter of dried capsule which might probably be due to low and moderated exposure to solar radiation that resulted from good air circulation and the loss of moisture and volatiles may be less relatively. On the contrary, cement floor drying structures resulted in shorter length and diameter of dried capsule which could be attributed to its solar heat absorbing nature which in turn might have resulted in a higher loss of constituents of the capsule.

The results conformed the report by Feleke (2007) on length of dried capsule of *Aframomum corrorima* from different growing areas in southern southwestern parts of Ethiopia (Basketo, Gofa, Bonga and Kafa), with capsule length ranges of 4.6cm to 6.3cm. Jansen (1981) as well reported the length and diameter of dried *Aframomum corrorima* capsule collected from market varying from 3cm to 7cm and 1.5cm to 3.5cm, respectively. Furthermore, Hymete *et al*. (2006) reported that the length and diameter of dried capsule varied from 3cm to 6cm and 1.5cm to 3cm, respectively.

**Diameter of dried seed (mm)**

The combined effect of the various harvesting stages, drying structures and drying durations resulted in a significant ($p<0.01$) difference in the average diameter of dried seed. The highest dried diameter of seed was recorded from the combined interaction effects of mature deep red capsules dried on wire mesh for 10 days (5.266mm) while the minimum value was recorded from mature green capsules dried on cement floor for 20 days (2.266mm) (Table 6). This indicates that the seeds obtained from mature red capsules dried on wire mesh for 10 days have less tendency to shrink and reduce in diameter may be due to high dry matter accumulation in seeds from fully ripened capsules, short period of exposure to solar radiation, good air circulation and gradual drying characteristic of the drying structure.

The result of this study is in agreement with the report of Jansen (1981) that the dried seed diameter of *Aframomum corrorima* recorded from central market varied from 2mm to 5mm. On the other hand, Aubertin (2002) reported on average diameter of seed of cardamom (*Amomum* spp.) which varies from about 2mm to 3mm. According to these results, it can be concluded that the capsules of *Amomum* and *Aframomum* are much larger in size in comparison with capsules of *Elettaria cardamomum* and it is easy to distinguish them, but the seed size and anatomy are similar in all the three genera.

***Table 7. Interaction effect among different harvesting stages, drying structures and drying durations on length of dried capsule (cm)***

| Drying Structures | Harvesting Stages by Drying Durations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mature Green | | | Mature Semi-red | | | Mature Deep Red | | |
| | 10 Days | 15 Days | 20 Days | 10 Days | 15 Days | 20 Days | 10 Days | 15 Days | 20 Days |
| Cement | 4.350[kl] | 4.193[no] | 4.065[p] | 4.593[i] | 4.293[lm] | 4.184[o] | 4.781[g] | 4.433[jk] | 4.245[mno] |
| Ground | 4.915[f] | 4.485[j] | 4.289[lmn] | 5.109[e] | 4.678[hi] | 4.365[kl] | 5.250[cd] | 4.893[f] | 4.602[i] |
| Wire mesh | 5.339[c] | 5.091[e] | 4.767[gh] | 5.500[b] | 5.185[de] | 4.964[f] | 5.721[a] | 5.450[b] | 5.292[c] |
| Grand Mean = 4.779 | | | | LSD (0.05) = 0.097 | | | | CV (%) = 1.073 | |

Means sharing the same letter(s) are not significantly different at p = 0.05 as established by LSD test.

***Table 8. Interaction effect among different harvesting stages, drying structures and drying durations on diameter of dried capsule (cm)***

| Drying Structures | Harvesting Stages by Drying Durations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mature Green | | | Mature Semi-red | | | Mature Deep Red | | |
| | 10 Days | 15 Days | 20 Days | 10 Days | 15 Days | 20 Days | 10 Days | 15 Days | 20 Days |
| Cement | 1.949$^{lm}$ | 1.768$^{op}$ | 1.637$^{q}$ | 2.054$^{jk}$ | 1.819$^{no}$ | 1.765$^{p}$ | 2.159$^{gh}$ | 1.982$^{l}$ | 1.911$^{m}$ |
| Ground | 2.087$^{ij}$ | 1.805$^{nop}$ | 1.763$^{p}$ | 2.295$^{e}$ | 1.980$^{l}$ | 1.855$^{n}$ | 2.411$^{d}$ | 2.138$^{hi}$ | 2.035$^{k}$ |
| Wire mesh | 2.471$^{c}$ | 2.093$^{ij}$ | 1.965$^{l}$ | 2.662$^{b}$ | 2.251$^{ef}$ | 2.202$^{fg}$ | 2.769$^{a}$ | 2.495$^{c}$ | 2.407$^{d}$ |
| Grand Mean = 2.101 | | | LSD (0.05) = 0.051 | | | | CV (%) = 1.289 | | |

Means sharing the same letter(s) are not significantly different at p = 0.05 as established by LSD test

**Thousand dried seed weight (g)**

Thousand seed weight of *Aframomum corrorima* was affected significantly ($p<0.0001$) by the interaction effects of the harvesting stage, drying structure and drying duration treatments. Accordingly, the combined effects of at mature green stage capsules dried on wire mesh for 10 days gave highest (30.824g) thousand seed weight of dried seeds. On the other hand, the least value (18.240g) was obtained from mature green capsules dried on cement floor for 20 days (Table 6). This may be due to the presence of high moisture content in mature green capsules at harvest joined with the nature of wire mesh drying structure having good aeration. Coupled with these, it is evident that as the drying duration is prolonged, the reduction in dried seed weight is increased, particularly in the mature green capsules due to greater loss of moisture as compared to capsules with advanced maturity. According to the report of Holm and Slinkard (2002), thousand seed weight of selected progenies of small-fruited and large-fruited coriander cultivar varied from 8.1g to 10.4g and 9g to 12.4g, respectively.

**Dried seed to husk ratio**

The interaction effect among the various harvesting stages, drying structures and drying durations showed a significant ($p<0.01$) difference in respect of dried seed to husk ratio. Accordingly, the highest average dried seed to husk ratio was recorded from mature green capsules dried on wire mesh for 20 days ($WMGD_3$) (3.36:1). However, mature semi-red capsules dried on ground (3.36:1) for 20 days recorded statistically the same result with $WMGD_3$. In contrast, the lowest values were obtained from mature green capsules dried on cement floor for 10 days (2.42:1), mature green capsules dried on cement floor for 15 days (2.56:1) and mature semi-red capsules dried on cement floor for 10 days (2.58:1) (Table 6) which were statistically at par with each other. Wire mesh and ground drying structures recorded the highest average dried seed to husk ratio while capsules dried on cement floor achieved lower seed to husk ratio. About 27.98% difference was observed between the highest and the lowest values of dried seed to husk ratio.

Seed to husk ratio decreased in cement floor drying structure due to heat built up after exposure to solar radiation which in turn resulted in greater weight loss of seeds per capsule. Combined with this, as the drying duration and harvesting stage extended, dried seed to husk ratio was increased owing to higher weight loss in husks than that of seeds. Lower seed to husk ratio is not recommended because the husk consumes much of the capsules' composition and the reverse is true and very preferred that high seed to husk ratio indicates the seed consumes much of the capsule composition during maturation, harvest and processing steps. In short it implies that within the capsule the photosynthates were partitioned in such a way that seeds had more of the share.

***Table 9. Interaction effect among different harvesting stages, drying structures and drying durations on diameter of seed, thousand seed weight and seed to husk ratio of dried capsules***

| Drying structures | Harvesting Stages | Drying durations | Diameter of dried seed (mm) | Thousand dried seed weight(g) | Dried seed to husk ratio |
|---|---|---|---|---|---|
| Cement | Mature Green | 10 Days | 3.000[n] | 20.148[q] | 2.420[l] |
| | | 15 Days | 2.433[p] | 19.382[s] | 2.567[kl] |
| | | 20 Days | 2.266[q] | 18.240[t] | 2.676[ijk] |
| | Mature Semi-red | 10 Days | 4.033[i] | 21.732[o] | 2.585[jkl] |
| | | 15 Days | 3.533[k] | 20.248[q] | 2.849[fghi] |
| | | 20 Days | 3.233[m] | 19.674[r] | 2.731[ghijk] |
| | Mature Deep Red | 10 Days | 3.466[k] | 23.143[lm] | 2.686[ijk] |
| | | 15 Days | 3.033[n] | 23.628[k] | 2.769[ghi] |
| | | 20 Days | 2.766[o] | 21.186[p] | 2.715[hijk] |
| Ground | Mature green | 10 Days | 4.033[i] | 28.558[c] | 2.958[def] |
| | | 15 Days | 3.466[k] | 23.313[l] | 2.847[fghi] |
| | | 20 Days | 3.333[l] | 20.086[q] | 3.160[bc] |
| | Mature Semi-red | 10 Days | 4.733[c] | 26.054[e] | 2.891[efg] |
| | | 15 Days | 4.433[f] | 23.062[m] | 3.105[bcd] |
| | | 20 Days | 4.166[h] | 22.034[n] | 3.360[a] |
| | Mature Deep Red | 10 Days | 4.333[g] | 25.847[h] | 2.946[def] |
| | | 15 Days | 4.133[h] | 24.181[j] | 2.999[cdef] |
| | | 20 Days | 4.000[i] | 23.162[lm] | 3.176[b] |
| Wire mesh | Mature green | 10 Days | 4.533[e] | 30.824[a] | 2.758[ghij] |
| | | 15 Days | 4.033[i] | 27.247[d] | 3.048[bcde] |
| | | 20 Days | 3.633[j] | 23.093[m] | 3.361[a] |
| | Mature Semi-red | 10 Days | 5.000[b] | 28.981[b] | 2.903[efg] |
| | | 15 Days | 4.933[b] | 26.195[g] | 3.080[bcd] |
| | | 20 Days | 4.600[de] | 24.110[j] | 3.042[bcde] |
| | Mature Deep Red | 10 Days | 5.266[a] | 27.252[d] | 2.890[efgh] |
| | | 15 Days | 4.666[cd] | 26.539[f] | 2.953[def] |
| | | 20 Days | 4.266[g] | 25.229[i] | 2.947[def] |
| Grand Mean | | | 3.901 | 23.820 | 2.905 |
| LSD (0.05) | | | 0.186 | 0.214 | 0.176 |
| CV (%) | | | 0.477 | 1.533 | 3.693 |

Means within a column followed by the same letter(s) are not significantly different at $p = 0.05$ according to LSD tests.

The result of the present study is in alignment with the finding of CFTRI (2008) who reported that husk to seed ratio of large cardamom of Ramla variety was 2.49:1. Similarly, Parthasarathy *et al*. (2008) reported 2.2:1 seed to husk ratio from *Amomum subulatum* grown in western regions of Sikkim, India. On the other hand, there are reports on comparative physical and chemical parameter on seed to husk ratio of Indian (3:1), Sri Lankan (1.7:1) and Guatemalan cardamoms (2.1:1) by Kizhakkayil *et al*. (2006).

## CONCLUSION AND RECOMMENDATION

The effect of drying durations and the combined effect among and/or between the various harvesting stages, drying structures and drying durations showed significant effect on the physical quality of dried *Aframomum corrorima* capsules and/or seeds. Results revealed that the combined effect among various harvesting stages, drying structures and drying durations have sound and promising impact on physical quality of dried *Aframomum corrorima* capsules.

Mature green (MG) capsules dried on wire mesh for 10 days scored maximum weight of single dried capsule and dried thousand seed weight. Similarly, capsules dried on ground for 10 days scored maximum average seed to mucilage ratio. On the other hand, mature semi-red (MS) capsules dried on wire mesh for 10 days and on ground for 20 days scored maximum average weight of seeds per capsule and average seed to husk ratio, respectively. Likewise, mature deep red (MR) capsules dried on wire mesh for 10 days scored maximum dry weight recovery, length and diameter of dried capsule. This paragraph seems a paragraph for result, need to shape to conclusion.

On the contrary, the combined effect of MG capsules dried on cement floor for 20 days scored minimum average weight of single dried capsule, dried thousand seeds weight and average weight of dried seeds per capsule. Similarly, MG capsules dried on cement floor for 10 days, mature deep red capsules dried on cement floor for 20 days, also gave minimum average seed to husk ratio and average seed to mucilage ratio, respectively.

Therefore, it can be concluded that the result of the current study showed that the various harvesting stages and the interaction of various drying structures, harvesting stages and drying durations have sound impact on physical quality of *Aframomum corrorima* capsules. Generally, Wire mesh drying structure was found to be consistently superior in resulting majority of the physical quality parameters and can be recommended for good quality production of dried *Aframomum corrorima* capsules. Considering overall quality of the spice, Mature Red capsules dried on wire mesh for 15 days may be recommendable. Thus, collectors or producers in all *Aframomum corrorima* growing areas better to be aware of the quality issues and may use the recommendations of this research work depending on the purpose of the capsules for maintenance of good quality of capsule.

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**REFERENCES**

Aubertin, C., 2002. Cardamom (Amomum spp.) in Leo Leo People's Democratic Republic (PDR): the hazardous future of an agro forestry product.

Birhanu, M., 2010. Determination of Some Major and Trace Metals Levels in Korarima (*A. corrorima*) Cultivated in the Southern and Southwestern Ethiopia. An M.Sc. Thesis presented to the School of Graduate Studies of Addis Ababa University, Ethiopia. 72p.

CFTRI, 2008. Physicochemical analysis of large cardamom (Amomum Subulatum Roxb). University of Mysore Karala, India.

EARO, 2000. National research strategy for spices, medicinal and other essential oil bearing plants. EARO, Addis Ababa, Ethiopia.

Edossa, E. 1998. Spices research achievements and experiences, Research report No. 33. Institute of Agricultural Research, Addis Ababa Ethiopia.

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

Eyob, S., 2009. Potential of Korarima (*A. corrorima*) as a crop plant in Southern Ethiopia", is dealing with such a promising plant species. Ph.D. Dissertation, Hawassa, Ethiopia. (http://www.umb.no/ipm-en/article/new-crop-plants-2) (Accessed on 18 February 2011).

Feleke, W., 2007. The rich and the poor sources, quality and typicality of the grains of paradise from Ethiopia. Bernard Roussel (MNHN/IRD UMR "local Heritage", Paris). University of Arba Minch, Ethiopia.

Giovannoni, J., 2001. Molecular Biology of Fruit Maturation and Ripening. USDA-ARS Plant, Soil and Nutrition Laboratory and Boyce Thompson Institute for Plant Research, Cornell University, Ithaca, New York. Plant Physiology. Plant Mol. Biol. 2001. 52:725-49.

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, Ethiopia.

Holm, F. A. and A. E. Slinkard, 2002. Spice Breeding and Agronomic Research. Crop Development Centre, Saskatchewan Herb and Spice Association, University of Saskatchewan.

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

Jansen, P.C.M. 1981. Spices, condiments and medicinal plants in Ethiopia, their taxonomy and agricultural significance. Joint venture of the college of Agriculture AAU, Ethiopia and the Agricultural University Wageningen, the Netherlands. Laboratory of plant taxonomy and plant geography, agricultural university Wageningen, the Netherlands. Agricultural Research Reports 906, Center for Agricultural Publishing and Documentation, Wageningen, Netherlands, 327: 10-20.

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.

Kizhakkayil, J., E. Thomas, T. J. Zachariah, S. Syamkumar and B. Sasikumar, 2006. A comparative quality appraisal of exported cardamoms of India, Sri Lanka and Guatemala. Division of crop improvement and Biotechnology, Indian Institute of Spices Research, Kerala, India. Vol. 5(5).

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.

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

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

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

Zachariah, J. T. and S. V. Korikanthimath, 2002. Harvesting and processing of cardamom, Kerala, India.

Zenebe, W., 2004. Forest resource of Ethiopia: Status, Challenges and Opportunities. Institute of Biodiversity Conservation (IBC) and German Development Cooperation (GTZ), Addis Ababa, Ethiopia.