MORPHOGENETIC AND PHYTOCHEMICAL CHARACTERIZATION OF KORARIMA (*Affframomum corrorima* (BRAUN) P.C.M. JANSEN) CAPSULES COLLECTED FROM DIFFERENT GROWING REGIONS OF SOUTHWESTERN ETHIOPIA

M.Sc. Thesis

HAIMANOT MITIKU TESSEMA

Jimma University

January, 2013

Jimma, Ethiopia

MORPHOGENETIC AND PHYTOCHEMICAL CHARACTERIZATION OF KORARIMA (*Affframomum corrorima* (BRAUN) P.C.M. JANSEN) CAPSULES COLLECTED FROM DIFFERENT GROWING REGIONS OF SOUTHWESTERN ETHIOPIA

A Thesis Submitted to the School of Graduate Studies,

Jimma University College of Agriculture and Veterinary Medicine,

In partial fulfillment of the requirements for the

Degree of Master of Science (Agriculture)

In

Post Harvest Management

By

Haimanot Mitiku

January, 2012

Jimma, Ethiopia

APPROVAL SHEET

JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

As thesis research advisors we hereby certify that we have read and evaluated the thesis prepared under our direction by Haimanot Mitiku, entitled '**Physico-Chemical Characterization of Korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen) Capsules Collected from Different Growing Regions of Southwestern Ethiopia'.** We recommend that it be accepted as fulfilling the thesis requirement.

Ali Mohammed (PhD)	_____	_____
Major Advisor	signature	date
Digafie Tilahun (MSc)	_____	_____
Co-Advisor	signature	date

As members of Board of Examiners of the M.Sc. Open Defense Examination, we certify that we have read and evaluated the thesis prepared by Haimanot Mitiku Tessema and examined the candidate recommended that the thesis accepted as fulfilling the thesis requirement for the degree of Master of Science in Agriculture (Post Harvest Management)

_____	_____	_____
Chair Person	signature	date
_____	_____	_____
Internal Examiner	signature	date
_____	_____	_____
External Examiner	signature	date

DEDICATION

This thesis is dedicated to my beloved mother, Asresu Meshesha, who passed away without seeing the result of my effort bearing fruits.

“You've been the greatest mother to me, teaching me many things that others never see. And so I write to you this very day that the Lord may bless you in every way. I wanted to write this letter to you and I addressed it to Heaven. I just wanted you to know that having a mother in my life was a blessing; I carry with me all your love, wisdom and precious memories. May your soul rest in heaven. Ameen.”

STATEMENT OF AUTHOR

I declare that this thesis is my original work and all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at Jimma University, College of Agriculture and Veterinary Medicine and put at the University Library to be made available to borrowers under the rules of library.

Brief quotations from this thesis are allowable without special permission provided that an accurate acknowledgment of the source is made. Requests for permission for extended quotation from or production of this manuscript in whole or in part may be granted by the Dean or V/Dean of the college or Coordinator of the Graduate Program or Head of the Department of Postharvest Management, when the proposed use of material is in the interest of scholarship. In all other cases, however, permission must be obtained from the author.

Name: Haimanot Mitiku Tessema
Signature _____
Place: Jimma University collage of Agriculture and veterinary medicine
Date of Submission: _____

BIOGRAPHICAL SKETCH

Haimanot Mitiku, the author, was born at Hosanna town, SNNP regional state, in April, 1984. He attended his elementary school education at Yekatit 25/67 in 1990, and completed his elementary and Junior Secondary education in 1998. He continued his Secondary education at the same School and completed in 2002 G.C. Then, he joined Mekelle University, in 2002, and graduated with B.Sc. degree in Agriculture (Dry land Crop and Horticultural Sciences) in 2006. After graduation, he joined Ethiopian Institute of Agricultural Research (EIAR) Jimma Research center at Tepi Research sub-center (now Tepi National Spice Research Center) as junior researcher and served until he transferred to Jimma Agricultural Research Center (JARC) in 2009. He served JARC as an assistant researcher until he joined Jimma University, School of Graduate Studies for the Degree of Master of Science in Post harvest management in 2011.

ACKNOWLEDGEMENTS

First of all I would like to thank Omnipotent God for providing me his amazing help in all my challenges. I would like to express my sincere gratitude to my Advisor Dr. Ali Mohammed for his guidance, supervision, patience, and support throughout this study. I also wish to express my thanks to my co-advisor Mr. Digafie Tilahun, for his all kind of support and help. I would like to extend great thank to Tepi National Spice Research center for facilitating vehicles during collection of the samples, frankly speaking without their support this study would not have been completed.

I would like to express my gratitude to my friends Kalkidan Goshu, Hailemariam Abera, Addisu, Dejene, Aweke, Takele Embilo for their unreserved support during data collection. Thanks to my real heart friends Tamirat Dibaba, Habtewold Kifelew, Yohannes Admasu, Eyuel Demis, Gezai Abera and Zekarias Negash for giving me real friendship during the most difficult time of my life. It is not fair if I miss to raise the names of my classmates; Haimanot H/Giorgis, Tirhas Mebratu, Alemayehu, Haileyesu W/Giorgis, Fekia Mohammed, Atikilti Tilahun, Nezif A/Chebsa, Lelise Tilahun, Obse Fikru, Abebe Yimer, Abrar Sualeh and Etaferahu Mulatu for their unlimited support and friendship during the study. I am especially grateful for laboratory workers Kiros, Dembelash, Yirgalem and Abiot for their kind willingness to work with me until all the lab work was completed. I would like to thank all JARC staffs and special thanks to Dr. Taye Kufa, Getachew W/Michael, Tadesse Benti, Melaku Adisu and Tewodros Mulalem for their support and advice from starting to end of this work.

Many thanks go to Professor Tessema Astatkie for his unsaved effort to share his knowledge and for his fast response whenever I needed his help regardless of the limited free time he had. I would like to thank postgraduate students of chemistry department Mulugeta, Edimealem and Sileshi for their gifted kindness and help during laboratory analysis. I would like to thank also Mr. Tefera, Head of chemistry department, for his kind willingness to allow me use his laboratory. I would like to express my deeper appreciation to all, whom I couldn't list here, who participated directly and indirectly for the success of my work

Last but not least, my deep heart gratitude goes to my beloved family for their love, understanding, limitless support and encouragement. I would love to cordially express my gratitude for all of your support.

LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA: - Analysis of Variance

AOAC: - Association of Official Analytical Chemists

ASTA: - American Spices Trade Association

CRD: - Completely Randomized Design

EIA: - Ethiopian Investment Agency

EIAR: - Ethiopian Institute of Agricultural Research

FAO: - Food and Agricultural Organization of the United Nations

IPGRI: - International Plant Genetic Resource Institute

JARC: - Jimma Agricultural Research Center

masl: - meter above sea level

PCA:-Principal Component Analysis

SNNPR: - Southern Nations Nationalities and People Region

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF TABLES IN THE APPENDIX

Page

LIST OF FIGURE IN THE APPENDIX

Page

MORPHOGENETIC AND PHYTOCHEMICAL CHARACTERIZATION OF KORARIMA (*AFFRAMOMUM CORRORIMA* (BRAUN) P.C.M. JANSEN) CAPSULES COLLECTED FROM DIFFERENT GROWING REGIONS OF SOUTHWESTERN ETHIOPIA

ABSTRACT

Korarima (Aframomum corrorima (Braun) P.C.M. Jansen) is indigenous and important cash crop found diversified to various agro-ecologies of the country. However, it has been one of the most underutilized crops and yet minimal research attention was given to it. With an objective of assessing variations in phytochemical qualities, red capsules were collected from four growing regions of the southwestern Ethiopia at peak harvesting time, November and December 2011, using stratified random sampling method. The capsules were evaluated for the different phytochemical parameters at JUCAVM. According to the ANOVA result obtained from analyzing capsules and seeds physical characters significant ($p<0.05$) variations existed in terms of capsule length (CL), diameter and circumference, single fresh capsule weight, number of seeds per capsule, seed:husk ratio, seed length (SL), seed diameter and hundred seed weight. A significant ($p<0.05$) variation was also obtained from seeds quality traits such as volatile oil, oleoresin contents and proximate compositions. The mean values of the capsules and seed physical traits showed that the average CL and SL varied from 4.8 to 6.7cm and 3.56 to 3.89, respectively among the different samples. Fresh capsule weight ranged from 17.2 to 27.4g, seed number per capsule varied from 122.6 to 232.8 and hundred seed weight ranged between 1.39 and 2.34g. The mean values of seed phytochemical traits showed that volatile oil content ranged from 0.9 to 3.2 (v/w%) and oleoresin content ranged from 2.2 to 7.8 (w/w%). The results from proximate analysis revealed that the percentage mean values were within a range of 11.05 to 13.01 moisture, 7.4 to 48.4 crude fiber, 1.25-2.85 crude fat, 3.08 to 15.38 ash, 6.87 to 7.95 crude protein and 26.12 to 61.01 carbohydrate contents. Results from Principal Component (PC) analysis indicated that based on capsule and seed physical traits the first five PCs explained 89% from the total variation from which PC1 and PC2 account for 29.9% and 23.6%, respectively whereas based on seed biochemical characters PC1 and PC2 contributed 25.3% and 18.5%, respectively. Cluster Analysis based on capsule and seed phytochemical traits grouped the samples into four groups. Cluster I, III and IV were formed by less number of samples whereas cluster II contained fifteen samples of various agro-ecologies. Samples from different geographical locations fall under the same clusters. This may be an indication that domestication of korarima from existing gene pool in different areas of cultivation. The overall result showed that there is variability in phytochemical traits among korarima samples of different regions. The variation may be linked to varietal, environmental, edaphic factors and/or management practices. The results obtained may contribute for further breeding and quality improvement purposes. Due to high potential of korarima production in the country, further and concerted efforts would be imperative research including the untouched areas.

***Key words**: Affframomum corrorima, capsule, phytochemical, quality*

1. INTRODUCTION

Korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen) is herbaceous, perennial and aromatic species classified in the monocotyledonous family Zingiberaceae, native to Ethiopia. The plant consists of an underground rhizome, a pseudo stem, and several broad leaves and resembles *Elettaria* species morphologically. Mature korarima can reach a height of 1-2 m. It sets seed after 3-5 years of planting depending on the planting materials used and it continue to bear seeds for a number of decades (Eyob, 2009). The plant is propagated both by seeds and rhizome parts (Ravindran *et al.*, 2002; Girma *et al.,* 2008).

According to Ravindran *et al.* (2002), in Ethiopia, the korarima plant grows naturally at an altitude of 1700–2000 masl. On the other hand, EIAR, (1999) reported that, korarima plant requires 55 to 63% shade level for its proper development and hence grows in the lower strata of natural forests. Usually these areas are located in altitudes ranging from 1000 to 2300 m.a.s.l. furthermore; the areas get 1500mm and more of rainfall per annum. It flowers from January to September and fruits mature in 2–3 months after flowering. Usually bees are the pollinators.

Korarima, also called ‘‘false cardamom’’, spice has been part of daily Ethiopian dish in preparation of curry powder for culinary purposes. It is mainly harvested from wildly grown plants in the forests of many places of south and south western parts of Ethiopia. The dried fruit mixture of different clones is sold on almost every Ethiopian market, and is quite expensive, relative to other spices. In the production areas, fresh fruits are sold too, rarely only the seeds (Jansan 1981). Korarima seeds are used in Ethiopia to flavor all kinds of sauces locally called ‘wot’, for which they are ground and usually mixed with other spices. Another widespread use of the seeds in Ethiopia is flavoring of coffee. Also, butter is flavored with korarima in Ethiopia (Eyob *et al.* 2007; Girma *et al.,* 2008). Also korarima is important plant for soil conservation as the rhizomes and leaves spread on the ground covering and protecting the soil from erosion in hilly areas the year around (Eyob *et al.,* 2008).

Korarima was once important in trade with Europe, and part of the West African coast was then known as the Grain Coast (now Liberia). Its dried fruits of were sold in local markets and exported to other African countries and small quantities were exported to Saudi Arabia, India, Iran and Gulf countries (Lock, 1978; Ravindran *et al.*, 2002). In the early 1978 korarima was sold for 9 USD per kg in the export market (Purseglove *et al*., 1981). Due to shortage of supply in the year 2001 the export market price of korarima reached as high as 23.5 USD per kg (Eyob *et al*., 2009). The actual average yield of dried pods recorded in farmers field in the 1980s ranged from 700 to 950 kg ha^{-1} when the korarima plants received filtered sunlight all day through permanent tree shades. A few hours of direct sun light, 3–5 h seemed to damage the plants. In 2009s the yield was reduced to 250–400 kg ha^{-1} (Eyob *et al.,* 2009). Destruction of the plant's natural habitat for expansion of arable and grazing land, new settlement and forest fire have resulted in low supply and high demand of korarima in local and export markets (Agize and van der Zouwen, 2008: Eyob *et al.*, 2009).

Apart from its commercial and nutritional importance korarima is in demand as a variety of ailments by local people. The fruit pulp around the seed is eaten especially before maturity and is chewed as stimulant (Ravindran *et al*., 2002). It is traditionally used as tonic, carminative and purgative drug. Korarima seeds, pods, leaves, rhizomes and flowers are used in southern Ethiopia as traditional medicine for human and animal ailments caused by unknown agents; and particularly used to treat any part of the animal body upon swelling (Eyob *et al.,* 2008).

Southwestern Ethiopia, where natural (montane) forest can be found, is an important centre of spice production and collection (Agize and van der Zouwen, 2008). As some spices are collected from the forests and many spices need a shady environment and moist soil, spice production can be an incentive to preserve the endangered natural forests in the region. Additionally, in the region major korarima growing administrative zones are found which encompasses different ethnic groups with different cultures, languages, resource levels population density, farming system and agro-ecology (Eyob *et al.,* 2009). Studying phenotypic and genetic variation in heterogeneous environment is key to understanding factors that shape the population structure on which tree domestication, conservation,

management and improvement strategies can be modeled (Bizoux and Mahy, 2007). Therefore, physicochemical characterization of korarima in this region is of vital importance to know the existing variation and to enhance for commercialization.

Girma *et al.* (2008) reported that as this crop is indigenous to Ethiopia there could be high genetic diversity in the country. Moreover, the presence of *Aframomum zambezicum sp*. Puberulum 'monkey's korarima' in the same habitat with *Aframomum corrorima* indicates that there is a high diversity and hence greater chance for further genetic improvement works, which have not yet started. *Aframomum corrorima* is a spice only known from Ethiopia. It certainly deserves more attention, as its seeds have a milder, sweeter flavour than those of the better known West African species *Aframomum melegueta.* However, Compared to other Aframomums *(A. melegueta),* the seeds of korarima have a less peppery pungent taste; they have a milder flavour.

Characterization of fruits in the tropics can never be over-emphasized; particularly the concept of domestication which is highly pertinent and extremely important in determining the commercial potential of the local tree species at local, regional and international markets (Oyebade *et al*., 2011). Though korarima is indigenous and important cash crop having a good export potential, it has been one of the most mishandled crops which a less research attention has been given. A very few authors have addressed some issues on korariam plant; indigenous practices and farm based biodiversity (Eyob *et al.,* 2009), micropropagation methods (Teffera and Wannakrairoj, 2004, 2006; Eyob, 2009), antioxidant and antimicrobial activities (Eyob *et al*., 2008). The essential oil yield and compositions from leaves, rhizomes, pods and seeds of was done by Eyob *et al.* (2007, 2008). However, nothing has been reported concerning the physicochemical variation in capsule and seed of korariam from different growing regions. Furthermore, Physico-chemical characteristics are influenced by genetic and environmental factors (Ahmed *et al.* 2011). Therefore, evaluating physicochemical characteristics korarima collected from major growing areas became so important.

So far there is no released variety of korarima plant which can have superior quality except few collected accessions have been maintained at Tepi and Jimma research centers (Girma *et*

al., 2008). Further, as a cash crop korarima capsule and seed physical and biochemical characteristics have not been yet characterized for the accessions found in major growing regions which are, therefore, very crucial in assessing for commercialization. A study of physicochemical variation of this indigenous crop from different growing regions will give as a range of variability in terms of important quality traits so that further research and improvement becomes easier. Therefore this study was carried out based on the following objectives:

Objectives

General objective

- ✓ To investigate variation on the phytochemical characteristics of korarima capsules growing in various regions of Ethiopia

Specific objectives

- To identify physical quality variations of korarima capsule and seeds collected from different growing regions
- To compare the biochemical parameters of korarima collected from different growing regions
- To identify the association among various phenotypical and phytochemical traits of korarima capsules and seeds

2. LITERATURE REVIEW

2.1. Spices production in Ethiopia

Ethiopia is one of the richest genetic resource centers in the world in terms of crop diversity. This is principally attributed to the diverse farming systems, socio-economics, cultures and agro-ecologies. The flora of Ethiopia is estimated to be between 6,500 and 7,000 species, of which 10-12 percent is considered to be endemic (FAO, 2007). Endemism is reportedly high on the plateaus, mountains, in the Ogaden region and in the western and south western woodlands.

The cultivated spice plants of Ethiopia reflect the long period of isolation in which the country found itself. Most of the spices that belong to the American and South Asia complexes were probably introduced by the Portuguese in the 16th and 17th centuries. Some plant names of South Asian origin are easily recognized by Europeans, suggesting that they may have been introduced recently, e.g., "*lomi*" for lime and "*jinjibil"* for ginger. *Rhamnus prinoides* (gesho) and *Aframomum korarima* (korarima) appear to be indigenous (Fullas, 2009). As a result, the history of spice use in Ethiopia is an ancient one and spices have always been and remain as basic food items in the diet of the Ethiopian people (EIA, 2010).

There are several important spices which are of Ethiopia origin. The most important species include *Aframomum corrorima*, *Trachyspermum ammi*, *Coriandrum sativum*, *Nigella sativa*, *Capsicum spp*., *Cuminum cyminum*, *Diplolophium abyssinicum*, *Anethum graveolens*, *Ocimum basilicum*, *Allium cepa*, *Foeniclum vulgare*, *Ruta chalapensis* and *Piper longum* (Anonymous, 2008; EIA, 2010). However, as compared to field crops research has been less in spices and medicinal plants including native plants of Ethiopia although these plants are widely used in traditional dishes, and sold at higher prices in the local markets than cereal grains (Eyob *et al.,* 2008). Although spices are considered as minor crops their significance for Ethiopia can hardly be overestimated. Spices are needed every day in considerable amounts for the preparation of the main dish of the day. Most of the spices needed in Ethiopia are grown as field or garden crops, although some are frow in the wild (Goettsch, 1991)

According to EIA (2010), the cultivation of spice for centuries is predominantly stayed traditional by small scale land holding farmers. Recently the average land covering by spices has been a 222,700ha and the production reached 244,000 ton/annum. The seed spices potentials area are Amhara and Oromia regions while for the low land spices dominantly produced and potential in SNNP and Gambela regions. In general the total potential for the low land spices is estimated to be 200,000 ha.

According to result of the survey conducted by Agize and van der Zouwen (2008), the main spices produced and collected by farmers in sowthwestern Ethiopia include Ethiopian cardamom (*Aframomum corrorima*), rue (*Ruta chalepensis*), basil (*Ocimum basilicum*), birdseye chili (*Capsicum frutescens*), chili pepper (*Capsicum annuum*), garlic (*Allium sativum*), onion (*Allium cepa*), turmeric (*Curcuma domestica*), ginger (*Zingiber officinale*), black pepper (*Piper nigrum*), timiz (*Piper capense*) and cardamom (*Elettaria cardamomum*). Few produced coriander (*Coriandrum sativum*), cinnamon (*Cinnamomum verum*), cumin (*Cuminum cyminum*), mint (*Mentha longifolia)*, thyme (*Thymus*) and lemon grass (*Cymbopogon citratus*). Not all spices are used in the same intensity.

2.2. Description and production of korarima

Korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen) also called Ethiopian cardamom, is native to Ethiopia. It is mainly grown in southern, south-western and western Ethiopia, and belongs to the family Zingiberaceae, the genus Aframomum (Eyob *et al.,* 2008). Korarima is a perennial, tropical shade loving, aromatic herb, often of large size, bearing flowers either terminally on aerial leaf shoots or from the ground level. It is usually self-pollinated. The position of stigma in the flower is below or against the base of the thecae of the anther. Most probably the flowers are open for 1 day only, but there is no experimental evidence. Occasionally cross-pollination by insects is possible due to the presence of large nectaries at the top of the ovaries (Eyob *et al*, 2009). According to Jansen (2002) the chromosome number of *Affframomum corrorima* is not yet recognized (2*n* = unknown). It grows usually with strong fibrous subterranean scaly rhizomes and with leafy stems reaching 1–2 m height. Korarima is one of the aromatic medicinal plants used in traditional medicine by the people of southern

Ethiopia. The study done by Eyob *et al*. (2007 and 2008) indicated that almost all parts of the plant is aromatic including leaves, rhizomes pods and seeds.

Ethiopian cardamom (*A. corrorima*) is being collected from natural forests as well as being cultivated in home gardens and on farm fields. This is typically done by farmers who either sell the fruits on local markets or to intermediary traders who visit them. Usually the fruits are sold freshly, but in some cases the farmers dry them before selling. The intermediary traders who collect the fruits from farmers sometimes add their own production to the collected volumes, dry the fruits or further dry them if they bought fruits which were not completely dry yet and then sell to local wholesalers by quintal. These wholesalers add up the volumes in their shops and wait until they have sufficient amounts to take the Ethiopian cardamom to Addis Ababa and other major places in Ethiopia profitably. These activities take place all year round, but are strongly concentrated in the harvesting season (Agize and van der Zouwen, 2008).

2.3. Diversity of *Affframomum species*

The genus *Aframomum* comprises about 60 species in tropical Africa with a centre of diversity in the rainforests of Gabon where 25 species could be recorded (Dhetchuvi and Fischer, 2006). Species of the genus *Aframomum* range from Senegal to Ethiopia in the north and Angola to Madagascar in the south. It is also found in the Gulf of Guinea islands, Sao Tome and Principe (http://botany.si.edu). Lock (1978) reported as he has examined collections of Aframomum from many herbaria, but only two species of *Aframomum* from Ethiopia have been seen among them. According to Eyob *et al.* (2009) when compared with other native plants of Ethiopia such as enset, tef and sorghum, the diversity indices for korarima were lower implying low farm based biodiversity.

2.4. Importance of characterization of quality traits

Characterizing accessions, an activity that is typically regarded as the responsibility of the gene bank curator, involves determining the expression of highly heritable characters, ranging from morphological features to seed proteins and possibly including molecular markers. Such

characters also enable easy and quick discrimination among phenotypes and allow simple grouping of the accessions, as well as a check on the trueness-to-type of homogeneous samples, frequently according to criteria used by breeders and other germplasm users (Engels and Visser, 2003). Adequate characterization for agronomic and morphological traits is necessary to facilitate utilization of germplasm by breeders (Upadhyaya *et al.,* 2006).

The assessment and description of trait variation is important in the initiation of programs aimed at the selection of genotypes providing high yields and which have qualitative traits acceptable to consumers (Bozokalfa *et al.,* 2009). Several techniques have been used to classify and measure the patterns of phenotypic diversity in the relationships of species and germplasm collections for a variety of crops. However, morphological characterization is the first step in the description and classification of germplasm. Further information can then be obtained using DNA markers and molecular techniques.

In domesticated crop species, populations of different geographical origin show that there is a selection pressure in a particular environment and less selection pressure in other environments. This is especially true in countries like Ethiopia where there are many nations and nationalities which in turn lead to high cultural diversity. This cultural versatility results selection of different crops at different localities as a source of food and for other applications. Thus, this variation in selection pressure finally, causes inherent variation among different populations of the same species (Hawtin *et al.,* 1997). An understanding of fruits characterization and variation help in identifying and giving silvicultural advice to local farmers against the traditional method of propagation for sustainable food and nutritional security (Oyebade *et al*., 2011).

Many of these traits are heritable and can be passed on to their progeny. In practicing selection, plant breeders choose plants with desirable traits for further propagation and discard plants that are inferior for that trait. By doing so, plant breeders can select and reselect for the trait through successive generations, shifting the population in the desired direction (Oyebade *et al*., 2011).

Fruit qualities are decided largely before harvest and depend on the variety grown, crop management (fertilization, irrigation, etc.), environment [climate (excessive rainfall causes major problems with flowering, pests, diseases and fruit quality) and soil] and other preharvest factors (Cavalcante *et al*., 2012). Previous reports show that destruction of the plant's natural habitat for expansion of arable and grazing land, new settlement and forest fire have resulted in low supply and high demand of korarima in local and export markets (Eyob *et al*., 2009). Equally, scientific information that characterizes these species in relation to quality of fruits is important to develop market opportunities. In this sense, the determination of physical and chemical fruit characteristics constitutes an important reference for studies about the maturation and quality of fruits, with the ultimate aim of determining consumer acceptance requirements (Cavalcante *et al*., 2012).

2.5. Phytochemical characteristics

Analysis of human consumable fruits become necessary to the students and researchers of fruit science, horticulture, food technology, plant biochemistry, botany, applied botany, forestry, ayurved, pharmaceutics and some other disciplines. Necessity of such analysis is also felt in fruit preservation factories or training centers and to the agricultural marketing personnels in making grading of fruits. It needs pointing out in this context that to assess the quality and nutritive status or compositional features of a fruit, not only the chemical constituents but also many physical components of it become necessary to be determined (Mazumdar and Majumder, 2003).

2.5.1. Phenotypic characteristics of korarima capsule and seeds

Little has been reported on the characteristics and variations of korarima capsule and seed. Fruit (capsule) is 6-7 cm long when dry, including a solid sterile beak c. 2 cm long and a persistent calyx c. 2 cm long; when fresh, red, and smooth and ampulliform. Seeds are c. 2-3 mm long, depressed-spherical, dark brown, finely striates (Lock, 1978). Jansen (1981) reported as capsule of korarima was indehiscent, fleshy, sub-conical up to ca 6 cm long and 3.5 cm diameter; shiny green when immature, turning bright-red at maturity, usually showing

3 longitudinal furrows (the 3 carpel), sometimes more furrows are present. Dried fruits (as often sold on markets) flask shaped, ca 3-6 cm long and 1.5-3cm diameter, with a beak ca 1-2cm long, brown to grey brown, with a tough, strong fibrous wall, usually showing irregular ribs and furrows due to shrinkage; fruit with 3 clusters of ca 45-60 seeds each. And seeds are subglobose in outline, usually somewhat angular, ca 2-5mm diameter with a glossy, light to dark-brown, glabrous, finely lined testa and a circular, whitish hilum; aril thin, a bit fleshy, finely lined, completely covering the seed, becoming papery after drying; the seeds have a strong spicy smell and taste.

2.5.2. Chemical Compositions of korarima

2.5.2.1. Essential oil of korarima

Essential oils are volatile, natural, complex compounds characterized by a strong odour and are formed by aromatic plants as secondary metabolites (Bakkali *et al*, 2008). They are liquid, volatile, limpid and rarely coloured, lipid soluble and soluble in organic solvents with a generally lower density than that of water. They can be synthesized by all plant organs, i.e. buds, flowers, leaves, stems, twigs, seeds, fruits, roots, wood or bark, and are stored in secretory cells, cavities, canals, epidermic cells or glandular trichomes (UNIDO and FAO, 2005; Bakkali *et al*, 2008). An essential oil may contain up to several hundred chemical compounds and this complex mixture of compounds gives the oil its characteristic fragrance and flavour. An essential oil may also be fractioned and sold as individual natural components (UNIDO and FAO, 2005). Jansen (1981) reported the seeds of korarima contain *ca* 1-2% of an essential oil. However, Hymete *et al.* (2006) studied essential oil of seeds of dried korarima and found 3.77% by steam distillation method. In another study the essential oil yield of fresh seeds of *Affframomum corrorima* was found to be 4.30% (Eyob *et al.,* 2007). In addition to this, the essential oil yield of leaves, rhizomes and pods were found to be 0.46, 0.69 and 0.83% on a w/w dry basis, and 0.09%, 0.07% and 0.15% on a w/w wet basis, respectively (Eyob *et al.,* 2007).

There is great variability in the yield and chemical composition of essential oils obtained from spices. Factors that determine the composition and yield of the essential oil obtained are

numerous. In some instances it is difficult to segregate these factors from each other, since many are interdependent and influence one another. Such variability depends on several factors including climatic, season, geographical location, geology, part of the plant and the method used to obtain the essential oil (Viuda-Martos *et al.,* 2007; Figueiredo *et al.,* 2008; Hussain, 2009). In order to fully recognize the best time of plant collection in terms of oil composition and/or yield, it is important to know the factors that influence production, and to know, for each particular case, their specific requirements (Figueiredo *et al.,* 2008).

The different factors responsible for variation in essential oil from spices were reported by many authors. Genetic variation (Figueiredo *et al.,* 2008; Hussain, 2009), agro-ecological variation (Viljoen *et al.*, 2006; Curado *et al.,* 2006), harvesting stage (Girma *et al*., 2006 and 2009; Leela *et al.*, 2008), seasonal variation (Jercovic *et al*., 2001; Emara and Shalaby, 2011) and processing conditions (Jercovic *et al.,* 2001; Ravindran *et al.,* 2002; Díaz-Maroto *et al.,* 2003; Ashafa *et al.*, 2008; Girma *et al.*, 2008).

2.5.2.2. Oleoresin content of korarima

Plant parts can be extracted with organic solvents to produce oleoresins, concretes and absolutes or extracted with a near or supercritical solvent such as carbon dioxide to produce very high quality extracts. These oleoresins and extracts contain not only the volatile essential oil but also the concentrated non-volatile flavour components and these have wide application in the food and pharmaceutical industries (UNIDO and FAO, 2005). So far nothing has been published regarding oleoresin contents of *Affframomum corrorma*.

2.5.3. Proximate compositions cardamom and *Affframomum* species

Proximate and nutrient analysis of edible fruit and vegetables plays a crucial role in assessing their nutritional significance (Pandey *et al*., 2006). Actually the specific uses of spices tend to vary considerably among cultures and countries: medicine, religious rituals, cosmetics, perfumery, and foods. As food, they have been shown to play an important role in health partially as sources of nutrients (Takruri and Dameh, 1998). Ibekwe and Orok, (2010) studied proximate compositions of *Affframomum melegueta* seeds and found 3.37% moisture, 4.81

crude protein, 13.88% crude fiber 6.17 ether extract, 2.61% crude ash and 72.53% carbohydrate. To date no result has been reported concerning the proximate compositions of *Affamomum corroima*. Amma *et al.* (2010) studied chemical compositions of four cardamom varieties and found within a range of 9-11% moisture content, 42.14-49.05% carbohydrate, 11.40-13.53% protein, 6.97-8.52% ash and 8.50-13.16% crude fiber contents. The proximate composition of cardamom from different growing regions of India was reported by Chempakam and Sindhu, (2008).

The variation in respect of proximate composition of Indian, Guatemalan and Sri Lankan cardamom was reported by Thomas *et al.* (2006). The study revealed that variation was obtained in terms of moisture, crude protein, carbohydrate, crude fiber and ash contents. The spice, *Affamomum danielli* on contained 10.5% moisture and protein content of 8.2% (Adegoke and Skura, 1994). Variation in terms of biochemical compositions of pistachio (edible nut) collected from different growing regions of Turkey was reported by Seferoglu *et al.* (2006). The result from percentage of proximate composition showed that crude protein ranged from 23.2-31.7%, fat (46.8-66.5%) and ash content varied from 3.1-3.9% across the locations.

2.5.4. Phytochemical characteristics of plants growing under different agro-ecology

The physical and chemical parameters of fruits are important indicators of their maturation and internal and external quality, decisive factors for accomplishment of market demands, that have encouraged the initiation of a lot of researches under different conditions overseas (Cavalcante *et al*., 2012). Fruit quality is related to some intrinsic characters (appearance, colour, acids, sugars, etc.) and since they change during handling research data can give us information on the way a product should be handled post harvest. Inherently, the demand of fruit quality, physically and chemically talking, by industries, depends on fruit species and the product processed by each one of them.

Physicochemical characterization of crop species from different agro-ecologies is reported by many authors. Thomas *et al*. (2006) reported variation in terms of capsule physical quality

characters such as weight of capsules, seed to husk ratio, color of capsule, length and circumference of capsules of Indian, Guatemalan and Sri Lankan cardamoms. Edim *et al*. (2011) studied the consumption preference, mineral contents and proximate composition of *Gnetum africanum* Welw. from five ecotypes of Northwest Cameroon and Southeast Nigeria. As a result, variation was observed Ikom and Umuahia samples for proximate compositions, however, no significant variation was found in other samples. The authors reported that, the results could be attributed to the geographical area where the samples were obtained. Apart from the Ikom and Umuahia samples, the others were obtained from within the same ecological area. This showed the absence of any significant difference in their proximate composition. Comparative analysis of the chemical composition of spices commonly consumed in Nigeria such as *Allium sativum* L. *Zingiber officinale* Rosc. and *Capsicum frutescens* L. were done by Otunola *et al.* (2010). According to result of the study significant variation was found in respect of moisture, crude protein, fat, and fiber and carbohydrate contents.

Okello (2010) studied morphological and nutritional characteristics of Tamarind (*Tamarindus Indica*) fruits from three agro-ecological zones of Uganda and found variation in terms of physical characters such as pod length and diameter, seed number per pod, fresh pod weight and seed weight; biochemical traits like moisture, ash, protein, fibre, oil, carbohydrates contents. The study also indicated that the differences in the morphological characteristics between agro-ecological zones and land use type call for the recommendation of both pulp and seeds for consumption, domestication, commercialization and species improvement.

In general, information pertaining to the physicochemical qualities of *Afframomum corrorima* is very scanty. This is perhaps attributed to the indigenous nature of the crop to Ethiopia and its limited sphere of cultivation and use in the world. Therefore, it is so pertinent and timely issue to put a concerted effort to characterize the available germplasm and document finds for future improvement.

3. MATERIALS AND METHODS

3.1. Description of the study area

The samples were collected from four korarima growing administrative zones, Kaffa, Bench Maji, Konta Special woreda and South Omo Zones from Southern and southwestern parts of Ethiopia.

Table 1. Description of the administrative zones

Variables	Administrative Zones			
	Kaffa	**Bench Maji**	**South Omo**	**Konta special woreda**
Altitude (m.a.s.l)	500–2,50	500-2,500	500–3,500	514-3305
Temperature (°C)	15.10–27.50	15.10-27.00	10.1–27.50	15.1-27.50
Rainfall (mm)	1001–2,000	400-2000	601–1,600	1401-1800
Latitude	6.24–7.29°	5.33-7.21°	5.36–6.19º	6.30-7.25º
Longitude	35.92–36.40°	34.88- 36.14°	36.23–37.07º	36.15-36.55º
Area (km^2)	2929.80	19965.90	4107.10	2,196.80

Sources: Eyob *et al*. (2009); Bekalo *et al*. (2009) and http://www.snnprs.gov.et

3.2. Survey and sampling method

Each woreda was selected in consultation with agricultural bureaus of the administrative zones using stratified random sampling method. Under each woreda, the sampling sites (kebeles) were selected randomly.

3.3. Collection of plant materials

Korarima samples were collected from twenty two kebeles of the four administrative zones of SNNPRS, Ethiopia (Table 1 and 2). Fully mature red ripe korarima capsules were collected from each area during the peak harvesting time (November and December). The collected

capsules were transported to Tepi National Spices Research Center (TNSRC) where the drying process was accomplished.

Table 2. List of kebeles, zones, woredas and altitudes considered for korarima sampling

No.	Sampling sites (kebeles)	Zones/special woredas	Woredas	Altitude (masl)
1	Michiti	Keffa	Gimbo	1800
2	Keja Araba	Keffa	Gimbo	2100
3	Bita Chega	Keffa	Gimbo	1800
4	Boba Gecha	Keffa	Decha	1350
5	Shapa	Keffa	Decha	2100
6	Eremo	Keffa	Decha	1952
7	Dukara Weshi	Keffa	Chena	1700
8	Kuta Shory	Keffa	Chena	1950
9	Wana Bola	Keffa	Chena	1650
10	Baita	Bench Maji	Shewa Bench	2350
11	Golish	Bench Maji	Shewa Bench	2250
12	Maz	Bench Maji	Shewa Bench	2100
13	Gisu	Bench Maji	Debub Bench	1725
14	Gaus	Bench Maji	Debub Bench	1800
15	Adisu Zemikn	Bench Maji	Debub Bench	1750
16	Gachit	Bench Maji	Menit Goldya	1900
17	Girsha	Bench Maji	Menit Goldya	1650
18	Kobut	Bench Maji	Menit Goldya	1625
19	Metser	South Omo	South Ari	1500
20	Zenba	South Omo	South Ari	1650
21	Pelpa	South Omo	South Ari	1750
22	Seri Shewa	Konta	Konta	1500

Source: kebele offices of each sampling sites during sample collection

3.4. Pre-drying treatment

Washing: - Harvested capsules were thoroughly washed with pure water to eliminate impurities such as soil, dirt and other unwanted plant parts. Washed capsules were allowed to drain water for some time.

3.5. Drying of the korarima capsules

Sun-drying of the samples was done on raised bed made of wire mesh at Tepi National Spices Research Center. Frequent mixing up of capsules was done to ensure uniform drying of the samples. Immediately after drying, the samples were removed from the drying material. The samples were taken in triplicate for conducting physicochemical quality analyses.

3.6. Seed harvesting

The dried capsules were crushed using mortar and pestle and the seeds with the mucilage were separated from the capsules. The seeds were separated from the mucilage by traditional winnowing methods using tray. The dried seeds were then milled by small milling machine at the post-harvest management laboratory at Jimma University College of Agriculture and Veterinary Medicine.

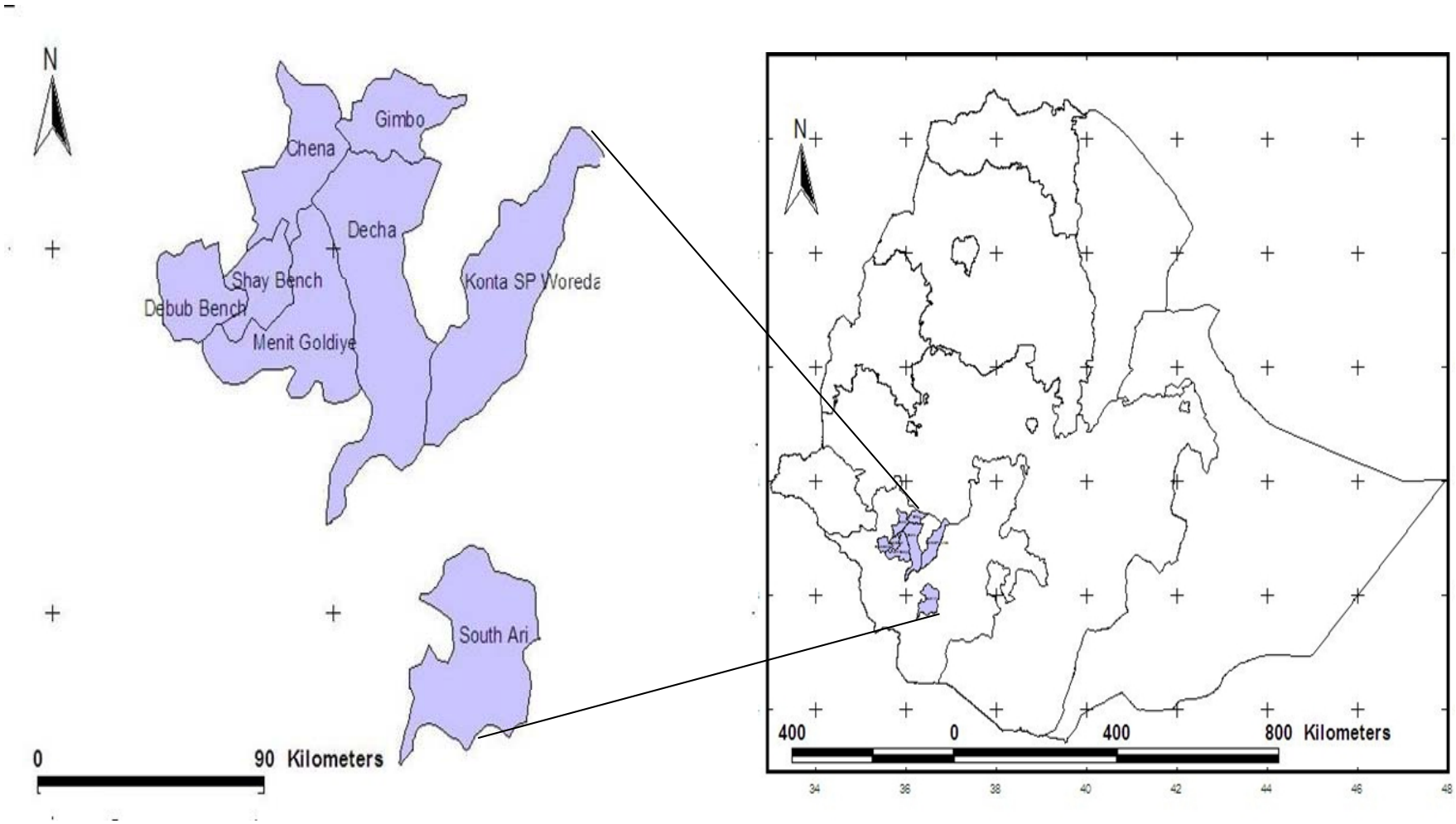


Figure 1**.** Geographical location of korarima (*Affframomum corrorima* (Braun). P.C.M. Jansen) sampling areas in Ethiopia

3.6. Physical parameters determination

3.6.1. Fresh Capsule Diameter (cm)

Five capsules from each sample were randomly selected and their diameter was measured using a vernier caliper. The average diameter of the five capsules from each sample was taken as capsule diameter.

3.6.2. Length of fresh capsules (cm)

The average length of five randomly selected capsules from each sample was taken using a vernier caliper and considered as capsule length.

3.6.3. Capsule shape index

Capsule shape index was expressed as the ratio of the length of the capsule to the diameter at its widest point using the following formula:

$$\text{Capsule shape index} = \frac{\text{Length of capsule (cm)}}{\text{Width of capsule (cm)}}$$

3.6.4. Fresh capsule circumference (cm)

The average circumference of five randomly selected capsules from each sample were taken using a measuring meter and considered as capsule circumference.

3.6.5. Fresh weight of single capsule (g)

This was measured using electronic sensitive balance (FA series) of 0.1mg accuracy level. Five capsules were weighed individually from each sample and their average weight was taken as fresh weight of single capsule.

3.6.6. Dry weight of seeds per capsule (g)

This was measured by separating seeds from a dried capsule. The seeds were weighed using electronic sensitive balance (FA series) of 0.1mg digit accuracy level and the average weight of seeds from five dried capsules was taken as dry weight of seeds per capsule

3.6.7. Seed to husk ratio

Seed to husk ratio was done by separating the seeds from the husk and measuring each part separately. The ratio was calculated as follows:

$$\text{Seed to husk ratio} = \frac{\text{Seeds weight in capsule (g)}}{\text{Husk weight (g)}}$$

3.6.8. Hundred seed weight (g)

Seeds were separated from five randomly selected capsules and mixed up. 100 seeds were randomly taken and weighed using an analytical balance. The measured weight in gram was considered as 100 seed weight.

3.6.9. Number of seeds per capsule

Five capsules were randomly selected from each sample. The seeds from each capsule were separated from the husk and counted. The average number of seeds from five capsules of each sample was considered as number of seeds per capsule.

3.6.10. Seed length (mm)

The average length of ten randomly selected seeds of each sample measured by a digital caliper was taken as seed length.

3.6.11. Seed diameter (mm)

The average diameter of ten randomly selected seeds of each sample measured by a digital caliper was taken as seed length.

3.6.12. Seed shape index

Seed shape index was calculated by dividing length of seed of each sample to the corresponding seed width using the following formula:

$$\text{Seed shape index} = \frac{\text{length of seed (cm)}}{\text{Width of seed (cm)}}$$

3.7. Phytochemical Analysis

3.7.1. Moisture content determination

Empty containers were weighed and five gram of ground seed sample was weighed and put directly into each empty container. Then the samples with their containers were weighed together (W1). After that, containers were kept in the oven which has already been heated to 105^{o}C until the samples weight during two consecutive measurements was identical. At the end of the drying period (24 hr), containers were closed with their covers. The containers were transferred into a desiccator, the disiccator was closed and the samples were allowed to cool. The dried samples were weighed again along with the containers (W2) and finally the moisture content of ground seeds were expressed in percentage by weight on wet basis using the following formula:

$$\%MC = \frac{W1 - W2}{5g} \times 100$$

Where,

MC = percentage moisture content

W1 = weight of container with ground sample before dried

W2 = weight of container with ground samples after dried

5g = weight of sample before dried

3.7.2. Hydro-distillation of essential oils

The essential oil extraction was carried out according to ASTA (1997). The extraction of volatile oil from each plant materials were performed by using hydro-distillation of modified Clevenger method. One hundred gram of ground sample was weighed out and transferred quantitatively into a 500 ml round bottom flak of the volatile oil apparatus. Each flask was filled with 200ml of distilled water. Then the trap was fixed on the flask and filled with water. The condenser was connected and the whole system was fixed onto a stand on heating mantle. The flask was heated to boiling and a reflux rate of 1-2 drops per second was maintained. Continuing the refluxing until two consecutive readings taken at one-hour interval showed no change of oil volume in the trap. It took about 3 hours to complete each cycle of distillation process. The extraction setup was allowed to cool. Then the extracted oils were carefully separated from its hydrolates. Each oil sample was allowed to dry by putting anhydrous sodium sulphate ($NaSO_4$) and then pure oils were harvested. The percentage volatile oil content was calculated using the following equation,

$$\text{Volatile oil, \%(v/w)} = \frac{\text{Volume of oil (ml) } 25^{o}\text{C}}{\text{Weight of sample (g)}} \times 100$$

3.7.3. Acetone extractable solutes (Oleoresin)

Oleoresin of korarima seeds was determined by acetone extract method using soxhlet apparatus. Thirty grams of ground sample was weighed and put into a paper extraction thimble, a cup made of whatman 1 filter paper. The thimble, containing sample was placed in

the container of the extractor. Condenser was fixed on to it. The apparatus was assembled and started the extracting with acetone as solvent. Extraction was extended to 4-6 hours. After the process the extract was transferred in to a beaker quantitatively. On a steam bath (Heidolph, rotary evaporator, Germany) the solvent will be evaporated completely. When the last traces of acetone were evaporated, the container was placed in a hot air oven at $110^{o}\pm2^{o}C$ until two consecutive weightings taken at $1^{1}/_{2}$-hour intervals didn't differ by more than 1mg. the dried residue was acetone extractable solute (oleoresin) (ASTA, 1997). Percentage of oleoresin was calculated using the following formula,

$$\text{Oleoresin, \% (w/w)} = \frac{\text{Weight of residue (g)}}{\text{Weight of sample (g)}} \times 100$$

3.7.4. Crude protein determination

The crude protein was determined according to AOAC (1990). A sample of 0.5g was weighed from each sample into the Kjeldahl flask. To this were added $CuSO_4$ and K_2SO_4 in 1:10 ratio as catalysts and 5 ml of conc. (99%) H_2SO_4. These were set in the appropriate hole of the digestion block heaters in a fume cupboard. The digestion was left on for 4 hours after which a clear colorless solution was left in the tube. The digest was carefully transferred into 100ml volumetric flask, thoroughly rinsing the digestion tube with distilled water and the volume of the flask made up to the mark with distilled water. 5ml portion of the digest was then pipetted to Kjeldahl apparatus and 25ml of 40% (w/v) NaOH added. The mixture was then steam distilled and the liberated ammonia collected into a 50ml conical flask containing 25ml of 4% boric acid plus mixed indicator solution. The green color solution was then titrated against 0.1N HCl solutions. At the end point, the green colour turns to wine colour, which indicates that, all the nitrogen trapped as ammonium borate have been removed as ammonium chloride (AOAC, 1990). The percentage nitrogen was calculated by using the formula:

Calculation:

$$\% N = \frac{1.401 \times (V_{HCL} - \text{blank sample}) \times N \text{ of HCL } (0.1)}{\text{Weight of sample} \times \text{Dry matter \%}} \times 100\%$$

Where, *V* is volume of HCL in *L* consumed on titration, N is normality of HCL used which was 0.1N.

Nitrogen (%) was converted to % of protein by using appropriate conversion factors:

%Crude protein = 6.25* x %N. (* conversion factor).

3.7.5. Determination of Ash content

Ash content was determined by heating the dried end product in furnace at 550^{o}C overnight till the difference between two successive weighing not more than 0.1%. The mass of a porcelain dishes was measured (A), 2g of each sample (B) from the oven-dried test samples from a moisture determination were placed in the dishes and then, the dishes were placed in a muffle furnace and the temperature in the furnace was brought gradually to 550°C and hold until the samples were completely ashed (no change of mass occurs after a further period of heating). The ashed samples were covered with the retained aluminum foil cover, cooled in a desiccator, and the masses were measured (C) (AOAC, 1990). The ash percentages were calculated as follows:

$$\%Ash = \frac{C - A}{B} \times 100\%$$

Where,

C = weight of ashed samples +dishes

A = weight of porcelain dishes

B = weight of samples (2g)

3.7.6. Crude fat content determination

Fat content was determined using Soxhlet apparatus on dried sample. For crude fat content, 2 g from each sample was measured and placed in known weight containers and boiled for 30 minutes in 12.5% sulfuric acid, filtered and washed with hot distilled water until no longer acidic before boiling in 12.5% sodium hydroxide and was washed till no longer alkaline. Containers with its content was dried for 2 hrs, transferred into the incinerator oven and heated at 105^{o}C overnight till the difference between two successive weighing was be no more than 0.1% (AOAC, 1990). The percent crude fat was determined using the following formula:

$$\%\text{crude fat} = \frac{(\text{wt of ether extract + container}) - \text{wt of empty container} \times 100\%}{\text{Weight of sample}}$$

3.7.7. Crude fiber determination

A sample of 1.5 g was weighed from each and transferred to labeled porous crucible. Then the crucible were placed into Dosi-fiber (Crude fiber Analyzer) unit and kept the valve in "OFF" position. After that added 150 ml of preheated H_2SO_4 (1.25% v/v) solution and some drops of foam-suppresser to each column. Then the cooling circuit was opened and turned on the heating elements (power at 90%). When it started boiling, the power was reduced to 30% and left it for 30 min. Valves were opened for drainage of acid and rinsed with distilled water thrice to completely ensure the removal of acid from sample. The same procedure was used for alkali digestion by using NaOH instead of H_2SO_4. The samples were dried were in an oven at 150^{o}C for 1 h. Then allowed the samples to cool in a desiccator and weighed (W_1). The samples were kept with crucibles in muffle furnace at 550^{o}C for 3-4 hrs. Cooled the samples in desiccator and weighed again (W_2) (AOAC, 1990). Calculations were done by using the following formula:

$$\%\text{crude fiber} = \frac{W_1 - W_2}{\text{Weight of sample}} \times 100\%$$

Determination of Nitrogen Free Extract

Nitrogen Free Extract (NFE) was calculated as following:

NFE (Carbohydrate) = 100 - (%moisture + %crude protein + %crude fat + %ash + %crude fiber)

3.8. Statistical analysis

Analysis of variance was done using the General Linear Model procedure of Statistical Analysis Systems (SAS, 2010) version 9.2 to determine the significance of variation among samples. Means of the samples were compared using Least Significant Difference (LSD) test at 5% probability level. The treatment means showing significant differences were separated by using the small letters a to z. Bartlett's test for homogeneity of variance was done using Minitab 15 (Minitab version 15, Minitab Inc., State College, PA, USA) statistical software to check the validity of the data and transformation of data was carried out for those who failed the test. The mean values of transformed data's were presented after retransformation was carried out.

The CRD linear Additive ANOVA Model

$y_{ij} = \mu + \tau_i + \varepsilon_{ij}$

Where, y_{ij} is the j^{th} observation of the i^{th} treatment,

μ is the overall population mean of the response

τ is the treatment effect of the i^{th} treatment, and

ε_{ij} is error term of the i^{th} treatment and j^{th} replication.

Multivariate statistical analysis

Prior to multivariate analysis, the data were pre-processed by the standard procedure. This procedure includes mean-centering (the mean value of each variable is calculated and subtracted from the data),

Principal component analysis

Principal component analysis (PCA) was performed to the patterns of morphological variation in order to examine the relationships among the quantitative characters that are correlated among each others by converting into uncorrelated characters called principal components. In Those PCs with eigenvalues >1.0 were selected, as proposed by Jeffers (1967). Data were processed using statistic program Minitab 15 (Minitab version 15, Minitab Inc., State College, PA, USA).

Correlation studies

Simple correlation analysis was done to understand some of the interrelationships between capsules and seeds physical and biochemical traits of korarima samples. Correlation coefficients (r) were calculated in Minitab Statistical software package version 15 and tests of significance were applied as per the procedure outlined by Little and Hils (1978).

Cluster analysis

To determine the relationship of the samples based on quantitative traits a dendogram was constructed using mean values of the traits. Average linkage clustering Euclidean distance method was used to calculate distance between clusters. Data were processed using statistic program Minitab 15 (Minitab version 15, Minitab Inc., State College, PA, USA). Distance between cluster centroids was done to identify the relatedness among the clusters.

4. RESULTS AND DISCUSSIONS

Results of the analysis of variance revealed a significant variation among korarima samples from various growing regions in all of the traits considered in the study (Table 3).

Table 3. Analysis of variance for the 18 characters of korarima samples collected from different growing regions

	Mean squares	
Characters	Accessions	Error
Capsule length	0.967**	0.100
Capsule diameter	0.072*	0.032
Capsule shape index	0.044**	0.017
Capsule circumference	0.872**	0.119
Single capsule weight	21.934**	5.465
No. of seeds per capsule	2.736**	0.027
Seed to husk ratio	0.219**	0.000
Seed length	0.024**	0.008
Seed diameter	0.012*	0.006
Seed shape index	0.005**	0.002
Hundred seed weight	3.243**	0.039
Essential oil	0.811**	0.013
Oleoresin	4.506**	0.113
Crude fat	0.700**	0.000
Crude fibre	489.244**	0.001
Ash content	72.167**	0.001
Crude protein	0.203**	0.000
Carbohydrate	113.378**	0.024

* and ** indicates significant differences at 5 and 1 % respectively.

4.1. Characterization of physical traits

Physical quality parameters such as length, diameter, and circumference of capsules, number of seeds per capsule, hundred seed weight, seed length, seed diameter, seed husk ratio, are presented in Table 4.

Capsule length, diameter and circumference

Table 4 shows the mean values of the different physical parameters of the twenty two korarima samples collected from various growing regions. The maximum average capsule length (CL) in centimeter was observed in Eremo and Wana Bola samples (6.73) which were statistically at par with Boba Gecha (6.60), Keja Araba (6.51), Dukara Weshi (6.49) and Kuta Shoray (6.22) but significantly superior over the rest of the samples. Samples collected from Maz showed the least (4.81) capsule length. Sample collected from Gisu was the maximum in terms of average capsule diameter (3.39) which was at par with Girsha (3.34) Adisu Zemikn (3.31), Gaus (3.25), Pelpa (3.22), Dukara Weshi (3.13), Kobut (3.12), Boba Gecha (3.11) and Metser (3.11) and followed by Eremo (3.09). Sample collected from Michiti scored the least (2.80) from the others. The observed capsule length and diameter was comparable to the earlier studies of Jansen, (1981) and Fissiha, (2012) who reported up to ca 6 cm, 6.18 cm long and 3.5 cm, 3.71 cm diameter for mature red korarima capsule, respectively. The maximum capsule circumference was observed in Boba Gecha (11.10) and it was statistically at par with Eremo (10.93), Dukara Weshi (10.83), Kuta Shoray (10.77), Adisu Zemikin (1073), Keja Araba (10.66) and Shapa (10.46) but significantly different from the rest of the samples. Sample from Maz was the least (9.22) in terms of capsule circumference. Thomas *et al.* (2006) made comparative quality characterization of Indian, Sri Lankan and Guatemalan cardamoms and found variation in length and circumference of capsules.

Capsule and seed shape indices

The ANOVA result in Table 3 show that a significant (p<0.01) variation was observed both in terms of capsule and seed shape indices of the korarima samples. With regard to capsule shape index, Baita sample significantly different from the others. Sample from Kobut was significantly different from the others except with that of Gachit and Eremo samples whereas Wana Bola was significantly different from Gachit and Kobut but not significantly different from the rest. According to results presented in Table 4 capsule shape index was varied from 2.56 to 1.90. The highest value for capsule shape index was obtained from Kobut which was at par with Gachit (2.36) and Eremo (2.35) but significantly different from the rest. The least index of capsule shape was found from Baita sample. In addition to this, the highest index of seed shape was obtained from Baita (1.43) followed by Michiti (1.35) and Zenba (1.34) whereas Kobut scored the least (1.23). In most of the samples the capsule shape index was greater than 2 (Table 4). Therefore, according to IPGRI (1994) most of the fruits were Ovoid shape than Globose. Shape analysis of agricultural products is growing in importance due to many factors including consumers' choices, industrial processing, cultivar description and selection (Costa *et al.,* 2011). However, a relatively low variability was obtained for capsule (CV% = 7.24) and seed (CV% = 4.23) shape indices among the samples (Table 6).

Fresh capsule weight

A highly significant (p<0.01) difference was observed for fresh capsule weight among the samples. Samples from Adisu Zemikn showed the highest fresh capsule weight, (27.44) statistically at par with Gachit (27.32g), Boba Gecha (25.00g), Eremo (24.92g), Girsha (24.39g), Gisu (24.21g), Dukara Weshi (23.95g) and Baita (23.88g); however, it was significantly superior over the rest of the samples. Samples collected from Kobut and Michiti had the least, 18.59 and 17.22 grams respectively, in respect of fresh capsule weight. In a previous study, Fissiha (2012) found medium (22.52g) result for fresh weight of red korarima capsule collected from Masha zone. In the present study a high heterogeneous groups was obtained in terms of fresh capsule weight. The relatively high coefficient of variation (14.74) (Table 6) reinforced the heterogeneity among the samples. This is important for further selection and breeding purposes.

Seed number per capsule

A highly significant (p<0.01) variation was observed among the samples in terms of seed number per capsule (Table 3). A significantly higher number of seeds per capsule were obtained in Boba Gecha (232.80) sample followed by Michiti (211.20), Golish (203.00) and Maz (201.20). Maz was at par with Gachit (193.80) in respect of seed numbe per capsule. On the other hand samples from Shapa, Baita and Metser had the smallest number of seeds per capsule which were counted as 147.60 137.00 and 122.60 respectively. An extremely high level of variability was obtained among the korarima samples of various localities in terms of number of seeds per capsule. Very high variance (627.23) recorded in this trait reinforced this idea (Table 6). So far no published result has been reported concerning variation in seed per capsule of korarima from different growing regions. However, the present result was much higher than previously reported for 45-60 seed per capsule of korarima (Jansen, 1981). The high variation in seed number per capsule among the korarima samples may give a high advantage so that selection and further improvement can be done through breeding.

Seed to Husk Ratio

The samples varied significantly (p<0.01) in terms of seed to husk ratio (SHR). The highest SHR was observed in Keja Araba (2.76) followed by Bita Chega (2.72), Adisu Zemikin (2.68) Maz (2.61). The lowest ratio of seed over husk was revealed in Eremo (2.07) and Michiti (1.72) samples. In this trait the samples were significantly different from each other except Baita and Girsha samples. Amma *et al.* (2010) studied physicochemical qualities of four major varieties of cardamom viz. Mysore, Malabar, Vazhukka and Guatemala from India and found seed to husk ratio of 62: 38, 76: 24, 70: 30 and 66: 34, respectively which was by fa lower than the present findings. Similar result was also reported by Akande *et al.* (2012) who documented variation in seed to husk ratio of castor (*Ricinus communis* L.) seeds from four major cities across the country of Nigeria. In comparable with the current finding, in a previous study Fissiha (2012) reported 2.42: 1 to 3.36: 1 ratio of seed over husk for korarima collected from Masha area.

Seed length and diameter

A significant (p<0.05) difference was observed among the samples on the seed length trait. The maximum seed length was measured in Gisu (3.89mm) which was statistically at par with Michiti (3.87mm), Zenba (3.85mm), Baita (3.85mm), Kobut (3.85mm), Shapa (3.80mm), Keja Araba (3.79mm), Seri Shewa (3.79mm), Wana Bola (3.79mm), Kuta Shoray (3.76mm) and Dukara Weshi (3.75mm) but significantly superior over the rest of the samples. Maz (3.56mm) and Gachit (3.60mm) had the minimum seed length. A significant (p<0.05) variation was obtained among the samples in terms of seed diameter. The maximum mean of seed diameter in millimeter was found in Gisu (2.97) which was at par with Kobut, Shapa, Eremo, Kuta Shoray, Seri Shewa, Gaus, Keja Araba, Zenba, Boba Gecha, Dukara Weshi and Michiti; however, it was significantly different from the rest of the samples. On the other hand, Girsha and Baita recorded the least with values 2.79 and 2.70mm, respectively. Ezeagu *et al.* (2003) studied the physicochemical characteristics of 12 accessions of Mucuna (velvet bean) seeds from Nigeria and found variability in seed length among the accessions. The present result is in agreement with Jansan (1981) and Fissiha (2012) who reported 2-5mm and 2.27-5.27mm diameter for korarima seeds respectively. The coefficient of variation for the seed length (3.06) and diameter (3.11) indicated that there existed high homogeneity among the samples for these traits (Table 4).

Hundred Seed weight

Data on hundred seed weight indicated that there was significant (p<0.01) difference among the samples (Table 3). The highest average hundred seed weight was recorded in Keja Araba (2.34g) sample which was at par with Kuta Shoray (2.34g) and Eremo (2.32g) but significantly superior over the rest of the samples. Genotypes and localities as influencing factors in variation of seed weight were reported by Hussain (2011) in *Elaeagnus umbellata* (Thunb) fruit from Rawalakot (Azad Kashmir) Pakistan. In the present study, the seed weight was found to be diverse among the samples collected from various locations (Table 4).

Table 4. Mean values of physical parameters for capsules and seeds of the korarima samples

Samples	CL (cm)	CD (cm)	CSI	CC (cm)	SCW(g)	SPC	SL(mm)	SD(mm)	SSI	HSW(g)	SHR
Michiti	5.76^{defgh}	2.80^{f}	2.13^{d}	9.75^{hijkl}	17.22^{g}	211.20^{b}	3.87^{ab}	2.87^{abcde}	1.35^{b}	1.39^{i}	1.72^{t}
keja Araba	6.51^{ab}	3.03^{cdef}	2.21^{bcd}	10.66^{abcde}	22.41^{bcdef}	188.60^{ef}	3.79^{abcdef}	2.90^{abcde}	1.31^{bc}	2.34^{a}	2.76^{a}
Bita Chega	6.11^{bcdef}	2.91^{ef}	2.14^{d}	10.22^{defghi}	20.22^{defg}	166.80^{i}	3.74^{bcdefgh}	2.83^{cdef}	1.32^{bc}	2.22^{cd}	2.72^{b}
Boba Gecha	6.60^{ab}	3.11^{abcde}	2.22^{bcd}	11.10^{a}	25.00^{ab}	232.80^{a}	3.71^{cdefgh}	2.87^{abcde}	1.29^{bcde}	2.30^{b}	2.38^{i}
Shapa	6.27^{abcd}	2.95^{def}	2.29^{bcd}	10.46^{abcdef}	20.77^{cdefg}	147.60^{k}	3.80^{abcdef}	2.95^{abc}	1.29^{bcde}	2.31^{b}	2.33^{l}
Eremo	6.73^{a}	3.09^{bcdef}	2.35^{abc}	10.93^{ab}	24.92^{ab}	167.00^{i}	3.68^{fghi}	2.94^{abc}	1.25^{cde}	2.32^{ab}	2.07^{r}
Dukara Weshi	6.49^{abc}	3.13^{abcde}	2.20^{bcd}	10.83^{abc}	23.95^{abcd}	157.40^{j}	3.75^{abcdefg}	2.87^{abcde}	1.31^{bc}	2.22^{cde}	2.20^{o}
Kuta Shoray	6.22^{abcde}	3.02^{cdef}	2.26^{bcd}	10.77^{abcd}	22.41^{bcdef}	176.80^{h}	3.76^{abcdefg}	2.92^{abcd}	1.29^{bcde}	2.34^{a}	2.55^{e}
Wana Bola	6.73^{a}	3.03^{cdef}	2.15^{cd}	10.39^{bcdefg}	22.56^{bcde}	177.00^{h}	3.79^{abcdef}	2.85^{abcde}	1.33^{b}	2.15^{fg}	2.37^{j}
Baita	5.13^{ijk}	3.04^{cdef}	1.90^{e}	9.83^{ghijk}	23.88^{abcd}	137.00^{l}	3.85^{abcd}	2.70^{f}	1.43^{a}	2.12^{g}	2.12^{p}
Golish	5.45^{hij}	3.07^{bcdef}	2.12^{d}	9.65^{jkl}	22.23^{bcdef}	203.00^{c}	3.70^{efghi}	2.80^{def}	1.32^{bc}	2.19^{def}	2.12^{q}
Maz	4.81^{k}	2.87^{ef}	2.17^{bcd}	9.26^{l}	18.74^{efg}	201.20^{cd}	3.60^{hi}	2.79^{def}	1.29^{bcde}	1.90^{h}	2.61^{d}
Gisu	5.74^{efgh}	3.39^{a}	2.28^{bcd}	10.37^{bcdefg}	24.21^{abc}	178.40^{gh}	3.89^{a}	2.97^{a}	1.31^{bc}	2.12^{g}	2.32^{l}
Gaus	5.63^{fghi}	3.25^{abcd}	2.26^{bcd}	10.32^{cdefgh}	27.32^{a}	157.00^{j}	3.73^{bcdefgh}	2.90^{abcde}	1.29^{bcde}	2.22^{cd}	2.49^{g}
Adisu Zemikin	5.63^{fghi}	3.31^{abc}	2.24^{bcd}	10.73^{abcd}	27.44^{a}	154.40^{j}	3.63^{ghi}	2.85^{bcde}	1.28^{bcde}	2.17^{ef}	2.68^{c}
Gachit	5.00^{jk}	2.86^{ef}	2.36^{ab}	9.22^{l}	19.65^{efg}	193.80^{de}	3.56^{i}	2.90^{abcde}	1.23^{de}	1.88^{h}	2.22^{n}
Girsha	5.98^{cdefg}	3.34^{ab}	2.15^{cd}	10.31^{cdefgh}	24.39^{abc}	177.40^{h}	3.63^{ghi}	2.79^{ef}	1.30^{bcd}	1.90^{h}	2.12^{p}
Kobut	5.47^{ghij}	3.12^{abcde}	2.56^{a}	9.467^{lk}	18.59^{fg}	157.40^{j}	3.84^{abcde}	2.97^{ab}	1.23^{e}	2.10^{g}	1.82^{s}
Metser	5.60^{fghi}	3.11^{abcde}	2.17^{bcd}	10.05^{fghij}	21.65^{bcdef}	122.60^{m}	3.71^{defgh}	2.83^{cde}	1.31^{bc}	2.23^{cd}	2.35^{k}
Zenba	5.27^{hijk}	3.06^{bcdef}	2.16^{bcd}	10.10^{efghij}	21.06^{cdefg}	165.20^{i}	3.85^{abc}	2.89^{abcde}	1.34^{b}	2.25^{c}	2.28^{m}
Pelpa	5.36^{hij}	3.22^{abcd}	2.18^{bcd}	10.43^{bcdef}	21.67^{bcdef}	177.60^{g}	3.71^{cdefgh}	2.84^{bcde}	1.31^{bc}	1.92^{h}	2.47^{h}
Seri Shewa	5.63^{fghi}	3.09^{bcdef}	2.23^{bcd}	9.68^{ijkl}	19.81^{efg}	184.80^{gh}	3.79^{abcdef}	2.91^{abcde}	1.30^{bcde}	2.20^{de}	2.52^{f}
CV (%)	10.59	6.89	7.24	5.90	14.74	14.37	3.06	3.11	4.23	10.18	11.44

Values followed by different letters within a column are significantly different $p<0.05$ (lsd's test)

*CL: Capsule length, CD: Capsule diameter, CSI: Capsule shape index, CC: Capsule circumference, SCW: Single capsule weight, SPC: Seeds per capsule, SL, Seed length, SD, Seed diameter, SSI: Seed shape index, HSW: Hundred seed weight, SHR: Seed to husk ratio.

4.2. Characterization of phytohemical traits

Data pertaining to biochemical characteristics of the different samples is presented in Table 5. Surely, regarding analytical assays of fruits and vegetables, some factors inherent to the scientific research can influence the results e.g. environmental characteristics, period of harvesting, cultivar variability, fruit maturity and extraction solvent procedures (Sultan *et al*., 2009; Finco, *et al.,* 2012).

Essential oil

A significant ($p<0.01$) variation was observed among the samples in terms of essential oil yield (Table 3). The highest average (v/w) percentage of essential oil yield was obtained from Eremo (3.19) statistically at par with Pelpa (3.17) but significantly different from the rest of the samples. Samples collected from South Bench woreda, Gaus (0.94) kebele recorded the minimum essential oil yield than the others. In general the essential oil yield was varying from 3.17 to 0.94 (v/w) among the locations. The observed variation among the samples may be attributed to genetic and climatic differences (Hussain, 2009). Variation in yield of essential oil as affected by stage of maturity at harvest and processing conditions was reported by Fissiha (2012). The result indicated that, the oil yield varied from 2.82 to 5.53% among the samples of various maturity stage and processing conditions. Based on this, the essential oil yield of korarima samples in the current study can vary further following different post-harvest operations. Hymete *et al.* (2006) reported the yield of korarima essential oil extracted from dried seeds as 3.77% (v/w). In our study, volatile yields from only two sites, namely Eremo (3.19%) and Pelpa (3.17%) were comparable to the earlier reports, however, the rest of the samples were lower as compared to previous reports. Eyob *et al.* (2007) reported the essential oil yield from dried seeds of highland korarima. According to the authors, oil yields for seed (4.30%) was higher when extracted from fresh samples compared to dried seeds (3.77%). However, the volatile oil content of the samples in all locations was found to be much lower than from Indian (10%), Guatemalan (5%) and Sri Lankan (14%) cardamom korarima (Thomas *et al.,* 2006) as well as from Indian korarima of different varieties (Amma *et al.,* 2010). Similar result was obtained by Kizhakkayil and Sasikumar (2009) on quality

traits of global germplasm collection of ginger. According to the authors the yield of ginger essential oil ranged from 0.9 to 4%.

Oleoresin (w/w %)

The highest weight by weight percentage of oleoresin content was recorded for sample collected from Pelpa (7.84) followed by Adisu Zemikn (6.87). However, oleoresin content of sample collected from Addisu Zemikin was found at par with Bita Chega (6.78) and Michiti (6.47) but statistically superior ($P<0.01$) over the rest of the samples. Among the samples collected from different locations oleoresin content ranged from 2.19 to 7.83 (w/w%), while the least value was recorded for samples obtained from Gaus. The result obtained is comparable with the previous reports for oleoresin content (4.87 to 9.16%) (Fissiha, 2012). The high coefficient of variation (33.71%) obtained in this trait revealed that there existed high heterogeneity among the samples in terms of oleoresin content. The finding of this study is in agreement with what was reported by Kizhakkayil and Sasikumar (2009), who got high variation in oleoresin content of global germplasm collection of ginger.

Crude fiber (%)

The data presented in Table 3 indicates that there was variation among the samples with regard to crude fiber percentage. Sample from Gachit recorded 48.44 % which was significantly superior over the rest of the samples followed by Gaus (31.84%) and Keja Araba (25.47)**.** On the other hand the least crude fiber percentage was also obtained from Wana Bola sample (7.44%) followed by Girsha (10.87%). All the samples were significantly different from each other in terms of crude fiber content except korarima samples from Michit and Pelpa. Crude fiber content of samples from Gachit (48.44%) and Gaus (31.84%) were somewhat far from the average and resulted in low oil content. Fissiha (2012) reported 22.85% for maximum crude fiber content of korarima seeds sample from Masha zone which was by far lower than the maximum obtained in the present study. On the other hand the crude fiber content of samples from Wana Bola and Girsha are comparable with crude fiber percentage of cardamom of different countries; Indian (16.3%), Guatemalan (12.2%) and Sri Lankan (12.5%) cardamoms (Thomas *et al.,* 2006). In another study, Kizhakkayil and Sasikumar (2009) found low range of crude fiber content (4-5%) in most of ginger accessions.

However, both small and high fiber content samples are important depending on the end use. Fiber helps in the maintenance of human health and has been known to reduce cholesterol level in the body (Bello *et al.,* 2008). Fiber diets promote the wave-like contraction that move food through the intestine, high fibre food expands the inside walls of the colon, easing the passage of waste, thus making it an effective anti-constipation.

Crude fat (%)

There was a significant ($P<0.01$) variation among the samples regarding the crude fat content (Table 5). Sample from Gachit recorded the higher crude fiber content (2.85%) which was at par with Pelpa (2.83) and followed by Shapa (2.65). The crude fat content ranged from 1.25 to 2.85 and the least amount was obtained from Seri Shewa. Crude fat percentage of cardamom from six growing regions of India was found ranged from 2.0-3.6 (Chempakam and Sindhu, 2008). Although those with low oil content are relegated as a source of oil commercially, they can be recommended as part of weight reducing diets (Bello *et al.,* 2008). In the present study the average crude fat content of the *Afframomum corrorima* korarima samples was lower than *Afframomum longiscapum* (7.13%) and *Afframomum melegueta* (6.14%) seeds; however, it was comparable with crude fat obtained from *Afframomum sceptrum* which were previously reported by Aliyu *et al*. (2012), Erukainure *et al*. (2011) and Ibekwe and Orok (2010), respectively.

Ash content (%)

According to the results on Table 5 ash content of the samples ranged from 3.08 to 15.36%. The highest ash content was recorded by Girsha (15.36%) followed by Golish (12.92). Sample from Golish was found at par with Baita (10.88) but significantly different from the rest of the samples. The least ash content was recorded by Pelpa of South Omo (3.08). Most of the korarima samples were found superior over the previously reported ash contents (5.45%) (Fissiha, 2012). Variation in ash content of cardamom of different locations was reported by Tomas *et al.* (2006). Amma *et al.* (2010) reported the variability in the ash content of four different cultivars of cardamom. The content ash of the sample gives an idea about the inorganic content of the samples from where the mineral content could be obtained (Bello *et al.,* 2008; Oko and Ugwu, 2011). Samples with high percentages of ash contents are expected

to have high concentrations of various mineral elements, which are expected to speed up metabolic processes and improve growth and development (Bello *et al.*, 2008).

Table 5. Mean values of phytochemical parameters for seeds of the korarima samples

Samples	Moisture content	EO* (v/w%)	OC (w/w%)	CFBR (%)	CF (%)	Ash (%)	CP (%)	CH (%)
Michiti	11.05^{i}	2.16^{c}	6.47^{bc}	18.30^{i}	2.25^{f}	7.73^{f}	7.95^{a}	52.72^{ij}
keja Araba	12.80^{ab}	1.36^{fg}	3.25^{j}	25.47^{c}	2.18^{g}	3.70^{o}	7.51^{f}	48.35^{n}
Bita Chega	12.32^{e}	1.63^{d}	6.78^{b}	11.74^{p}	2.50^{d}	6.96^{h}	7.47^{g}	59.02^{c}
Boba Gecha	12.18^{e}	1.46^{def}	4.08^{gh}	24.04^{e}	2.43^{e}	5.35^{k}	7.46^{g}	48.56^{n}
Shapa	12.61b^{cd}	1.56^{def}	3.96^{ghi}	12.20^{o}	2.65^{b}	7.74^{f}	6.89^{o}	57.91^{d}
Eremo	11.42^{gh}	3.19^{a}	4.85^{ef}	13.44^{n}	2.50^{d}	6.21^{i}	7.20^{k}	59.25^{c}
Dukara Weshi	11.84^{f}	2.41^{b}	5.38^{de}	22.17^{f}	1.93^{j}	5.55^{j}	7.63^{e}	50.90^{l}
Kuta Shoray	11.67^{fg}	1.46^{def}	3.84^{ghij}	24.30^{d}	2.38^{e}	3.90^{n}	7.41^{h}	50.34^{m}
Wana Bola	12.16^{e}	1.63^{d}	4.86^{ef}	7.435^{u}	2.15^{g}	9.75^{e}	7.46^{g}	61.06^{a}
Baita	12.66^{bc}	1.52^{def}	3.67^{hij}	11.40^{r}	2.28^{f}	10.88^{c}	7.50^{f}	55.29^{g}
Golish	12.83^{ab}	0.98^{i}	3.18^{jk}	13.90^{l}	2.43^{e}	12.92^{b}	7.31^{i}	50.62^{lm}
Maz	12.16^{e}	1.58^{def}	3.84^{ghij}	11.07^{s}	2.00^{i}	7.72^{f}	7.26^{j}	59.80^{b}
Gisu	13.01^{a}	1.21^{gh}	3.50^{hij}	11.57^{q}	2.00^{i}	4.49^{m}	7.73^{d}	61.21^{a}
Gaus	12.37^{de}	0.94^{i}	2.19^{l}	31.84^{b}	2.38^{e}	3.52^{p}	6.87^{o}	43.03^{o}
Adisu Zemikin	11.79^{f}	1.38^{efg}	6.87^{b}	13.77^{m}	2.58^{c}	10.24^{d}	7.03^{m}	54.60^{h}
Gachit	11.58^{fg}	1.08^{hi}	3.37^{ij}	48.44^{a}	2.85^{a}	3.21^{q}	7.80^{b}	26.13^{p}
Girsha	12.39^{cde}	1.51^{def}	2.53^{kl}	10.87^{t}	2.15^{g}	15.36^{a}	7.08^{l}	52.16^{k}
Kobut	12.66^{bc}	1.11^{hi}	3.59^{hij}	15.30^{k}	2.08^{h}	7.38^{g}	6.90^{o}	55.69^{f}
Metser	11.44^{gh}	2.53^{b}	3.70^{ghij}	21.57^{g}	2.43^{e}	4.65^{l}	7.00^{n}	52.92^{i}
Zenba	12.23^{e}	1.60^{de}	5.98^{dc}	18.80^{h}	2.30^{f}	6.96^{h}	7.26^{j}	52.45^{jk}
Pelpa	12.18^{e}	3.17^{a}	7.84^{a}	18.44^{i}	2.83^{a}	3.08^{r}	7.06^{l}	56.43^{e}
Seri Shewa	11.28^{hi}	2.15^{c}	4.38^{fg}	16.44^{j}	1.25^{j}	12.91^{b}	7.78^{c}	50.35^{m}
CV (%)	4.53	37.16	4.53	14.98	14.62	25.04	4.29	14.13

Values followed by different letters within a column are significantly different $p<0.05$ (lsd's test)

* EO: Essential oil, OC: Oleoresin content, CP: crude protein, CF: Crude fat, CFBR: Crude fiber, CH: Carbohydrate.

Crude protein

The analysis of variance revealed that there existed a significant (p<0.01) variation among the different samples in terms of crude protein content. Sample from Michiti registered the highest in protein content (7.95) followed by Gachit (7.802) whereas, Gaus (6.873) had the least with no significant variation with Shapa (6.89) and Kobut (6.90). The protein contents of *Affframomum melegueta* (Alligator pepper), *Affframomum longiscapum* and *Affframomum sceptrum* seeds were reported by Ibekwe and Orok (2010), Aliyu *et al*. (2012) and Erukainure *et al*. (2011) respectively. The average protein content of korarima samples was higher than Affframomum *melegueta* (4.81); however, it was lower than that of *Affframomum longiscapum* (10.38) and *Affframomum Sceptrum.* The variations in crude protein contents of the korarima samples may be accounted to the differences in climatic conditions, edaphic factors and ages of the plants (Edim *et al.,* 2011; Melesse; 2011 and Oko and Ugwu, 2011; Ardabili *et al*., 2011).

Carbohydrate content

A significant (p<0.01) variation was observed among the samples from different locations for carbohydrate content (Table 5). Korarima samples collected from Gisu scored the highest carbohydrate content (61.21) followed by Wana Bola (61.06) and Airemo (59.25). In a wider gap from other samples Gachit was found to be inferior for carbohydrate content (26.13). In general, the carbohydrate content (percentage) was higher in all korarima samples as compared to other proximate compositions regardless of variation among the samples. This finding was supported by Ibekwe and Orok (2010) who found high nitrogen free extract in *Affframomum melegueta* seeds. Similar results also reported by Aliyu *et al*. (2012) on *Aframomum longiscapum* seeds from Nigeria. In this study a significant variation was obtained among the different locations in terms carbohydrate content since the locations might vary in their ecological natures. High heterogeneity was obtained among the samples in terms of carbohydrate content. The comparatively high variance (55.38) recorded in this trait reinforced this idea (Table 6).

Table 6. Variation in quantitative traits of the indigenous korarima samples from different localities of southwestern Ethiopia

Traits	Max.	Mean±SD	Min.	Range	CV (%)	Variance
Capsule length	6.73	5.82±0.62	4.81	1.92	10.59	0.38
Capsule diameter	3.39	3.08±0.21	2.80	0.59	6.89	0.05
Capsule shape index	2.56	2.22±0.16	1.90	0.66	7.24	0.03
Capsule circumference	11.10	10.21±0.60	9.22	1.88	5.90	0.36
Single capsule weight	27.44	22.28±3.28	17.22	10.22	14.74	10.79
No. of seeds per capsule	232.80	174.32±25.05	122.60	110.20	14.37	627.23
Seed to husk ratio	2.76	2.33±0.27	1.72	1.04	11.44	0.08
Seed length	3.89	3.74±0.12	3.56	0.33	3.06	0.01
Seed diameter	2.97	2.87±0.09	2.70	0.27	3.11	0.01
Seed shape index	1.43	1.30±0.06	1.23	0.20	4.23	0.00
Hundred seed weight	2.38	2.13±0.22	1.38	1.00	10.18	0.05
Oleoresin	7.94	4.46±1.50	1.98	5.96	33.71	2.26
Essential oil	3.30	1.71±0.63	0.88	2.42	37.16	0.40
Moisture content	12.12	13.26±0.55	10.96	2.30	4.53	0.30
Crude fat	2.85	2.29±0.34	1.25	1.60	14.62	0.11
Crude fiber	48.47	18.29±0.18	7.40	41.07	14.98	0.03
Ash content	15.38	7.28±0.20	3.08	12.30	25.04	0.04
Crude protein	7.96	7.34±0.32	6.87	1.09	4.29	0.10
Carbohydrate	61.45	52.67±7.44	26.06	35.39	14.129	55.382

4.3. Correlation studies

The Pearson correlation matrix for the data set is shown in Table 7. In this study, the association of different physicochemical traits with essential oil yield and relationship with each other was discussed.

Essential oil yield was positively but not significantly correlated with capsule length and capsule circumference, however it was negatively correlated with crude fiber and ash contents. Highly significant (p<0.01) and positive association (r = 0.55) was observed between essential oil yield and oleoresin content. A positive and highly significant (p<0.01) association (r = 0.84) was observed between capsule shape index (CSI) and seed diameter and a negative and highly significant correlation (r = -0.91) was found between CSI and seed shape index (SSI). Seed shape index was correlated (r = 0.49) positively and significantly (p<0.05) with seed length and negatively (-0.65) with seed diameter. Capsule circumference was positively and significantly (p<0.05) correlated with capsule length (r = 0.79) and capsule diameter (r = 0.43). Fresh capsule weight was positively but not significantly correlated with capsule length and positively and highly significantly correlated (P<0.01) with capsule diameter (r = 0.73) and capsule circumference (r = 0.68). Seed length was positively correlated with Capsule length, and negatively correlated with fresh capsule weight. Seed diameter (SD) was positively correlated with capsule length, capsule diameter, capsule circumference and seed length. Hundred seed weight (HSW) was positively and significantly (P<0.05) correlated with capsule length (r = 0.43), capsule circumference (r = 0.52) and fresh capsule weight (r = 0.48). Oleoresin content was positively correlated with capsule length and capsule circumference and negatively correlated with capsule diameter, fresh

Table 7. Correlation coefficients among 16 phytochemical quantitative traits in korarima samples of various regions

	CL	CD	CSI	CC	SCW	SPC	SL	SD	SSI	HSW	EO	OC	CP	CF	Ash	CFBR
CD	0.09															
CSI	0.12	0.11														
CC	**0.79****	**0.43***	0.00													
SCW	0.33	**0.73****	-0.11	**0.68****												
SPC	0.08	-0.26	0.03	-0.07	-0.23											
SL	0.15	0.00	-0.10	0.06	-0.19	-0.156										
SD	0.33	0.11	**0.84****	0.22	-0.07	0.05	0.27									
SSI	-0.08	-0.10	**-0.91****	-0.01	0.02	-0.12	**0.49***	**-0.65****								
HSW	**0.43***	0.27	0.15	**0.52***	**0.48***	-0.34	0.06	0.24	-0.13							
EO	0.22	-0.01	-0.10	0.28	-0.08	-0.17	-0.04	-0.01	-0.06	-0.09						
OC	0.04	-0.12	-0.16	0.20	-0.16	-0.00	0.09	-0.07	0.17	-0.22	**0.55****					
CP	0.05	-0.38	-0.24	-0.16	-0.31	**0.50***	0.23	0.00	-0.24	-0.34	0.00	0.12				
CF	-0.04	-0.11	0.04	0.18	0.16	-0.09	-0.37	-0.08	-0.17	-0.02	0.03	0.22	-0.35			
Ash	-0.09	0.11	-0.35	-0.25	-0.00	0.02	-0.03	**-0.46***	-0.35	-0.14	-0.15	-0.09	-0.02	-0.40		
CFBR	-0.16	-0.19	0.31	-0.11	-0.01	0.17	0.24	-0.04	-0.40	-0.18	-0.23	0.32	0.20	0.32	**-0.59****	
CH	0.24	0.18	-0.19	0.24	0.00	-0.22	0.39	-0.07	0.32	0.11	0.32	0.33	-0.24	-0.23	0.26	**-0.93****

CL: Capsule length, CD: Capsule diameter, CSI: Capsule shape index, CC: Capsule circumference, SCW: Single capsule weight, SPC: Seeds per capsule, SL, Seed length, SD, Seed diameter, SSI: Sees shape index, HSW: Hundred seed weight, EO: Essential oil, OC: Oleoresin content, CP: crude protein, CF: Crude fat, CFBR: Crude fiber, CH: Carbohydrate.

capsule weight and hundred seed weight. A positive and significant (p<0.05) association (r = 0.50) was observed between crude protein and number of seeds per capsule and a positive but not significant correlation between crude protein and seed length. Crude fat (CF) content was negatively correlated with SL and positively correlated with OC. Ash content was negatively but significantly (p<0.05) correlated (r = -0.46) with seed diameter and crude fat (CF). Crude fiber (CFBR) content was negatively but not significantly correlated with Essential oil content and oleoresin content. A highly significant (p<0.01) and negative association (r = -0.59) was also obtained from CFBR and ash contents. A highly significant (p<0.01) but negative correlation (r = -0.93) was observed between carbohydrate and crude fiber contents.

Fresh capsule weight was positively (r = **0.73)** correlated with capsule diameter (Table 7). It was expected that seed shape index was positively (r = **0.49)** correlated with seed length and negatively (**-0.65)** correlated with seed diameter since the value SSI was the ratio of the two. This finding was also in-line with the results of Imran *et al.* (2010) who found a negative and highly significant correlation between Crude fiber and nitrogen free extract, a negative correlation between crude protein and crude fat and a negative correlation between crude fiber and ash contents.

The association between essential oil yield and other physical and biochemical traits was not significant except for oleoresin content (Table 7). This may be due to the fact that essential oil yield is mainly influenced by other factors vis. varietal differences, stage of maturity at harvest, geographical locations, and processing conditions (Puseglove *et al.,* 1981; Fissiha, 2012). Together with this, the difference in yield of essential oil of korarima samples was significant among the different locations. Different authors reported the association of essential oil yield with other factors. Study on the essential oil composition and genetic variability of thirteen commercial thyme accessions have shown that there was 20% variation between thyme and is due to one province dispersal of thyme (Alamdary *et al.,* 2011). Hassiotis *et al.* (2010) reported the variation in essential oil yield and compositions of lavender (*Lavandula angustifolia* Mill.) collected from two different locations of Greece. Leela *et al.* (2008) and Girma et al. (2006 and 2009) reported the essential oil yield variation resulted by different stages of maturity. Abeysekera and Illeperuma (2005) found significant

variation in essential oil and oleoresin contents among different ginger varieties dried at different temperatures.

4.4. Principal component analysis

4.4.1. Principal component analysis of capsule and seeds physical parameters

The results from principal component analysis of the physical traits are given in Table 8. Based on the eleven capsule and seed physical characters used the first five principal components which had eigenvalues more than one explained 89.0% of the total variation (Table 9). The first PC accounted for 29.9%, the second PC accounted for 23.6%, the third for 14.4%, the fourth for 11.6% and the fifth PC accounted for 9.4%. Taking into account that as larger the coefficient, the greater is the contribution of the respective variable to the discrimination between groups (Gallegos–Vásquez *et al.*, 2011), characters such as hundred seed weight, capsule circumference, fresh capsule weight, capsule length and diameter contributed more for the first PC, capsule and seed shape indices and seed diameter explained the second PC, seed length, seed to husk ratio and capsule length contributed more for the third PC, seed per capsule, capsule length and diameter contributed for the fourth PC and seed to husk ratio, hundred seed weight, capsule diameter, seeds per capsule and fresh capsule weight contributed more for the fifth PC.

Table 8. Eigenvector values for principal components using nine capsule and seed physical traits of korarima samples

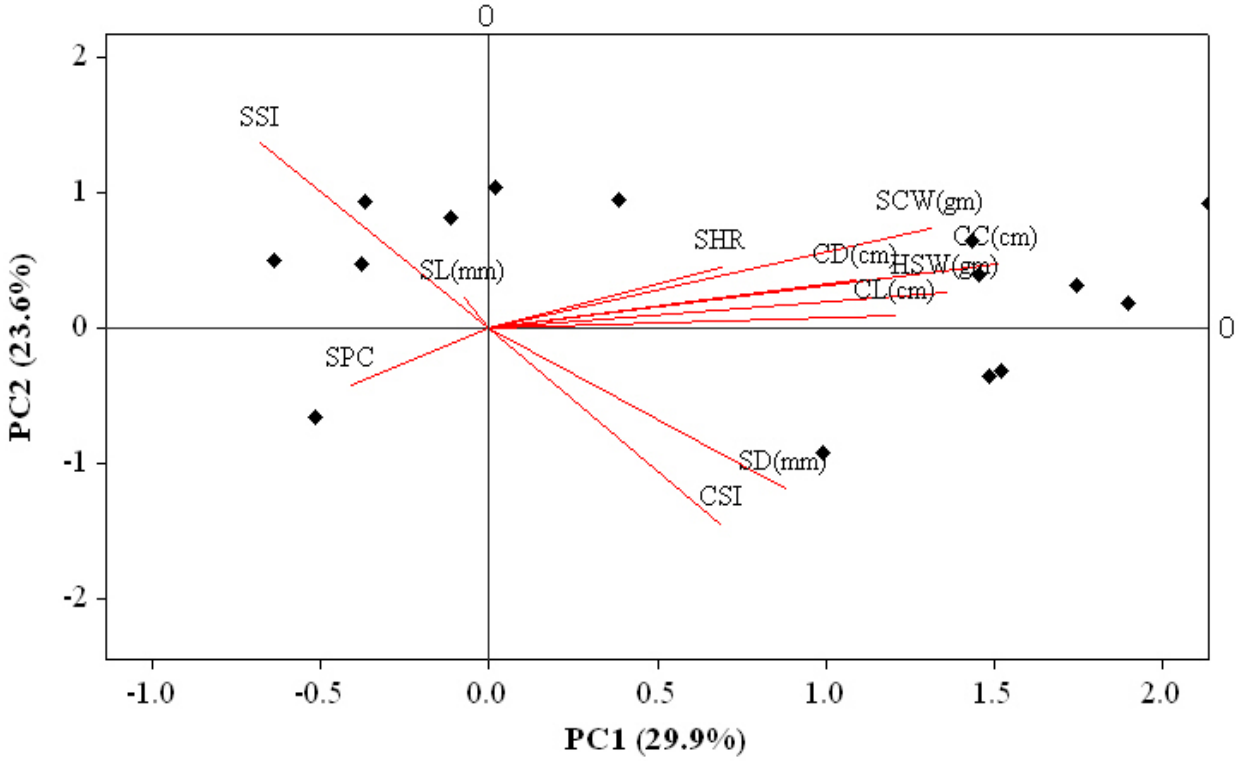
Eigenvalue	3.29	2.60	1.59	1.27	1.04
Proportion	0.299	0.236	0.144	0.116	0.094
Cumulative	0.299	0.536	0.680	0.795	0.890
Variable	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
CL(cm)	0.37*	0.03	0.31	-0.45	0.10
CD(cm)	0.33	0.13	-0.11	0.45	0.42
CSI	0.21	-0.56	-0.00	0.15	-0.02
CC(cm)	0.46	0.18	0.13	-0.26	0.17
SCW(gm)	0.40	0.28	-0.19	0.14	0.32
SPC	-0.12	-0.16	-0.07	-0.64	0.38
SL(mm)	-0.02	0.09	0.73	0.15	-0.11
SD(mm)	0.27	-0.46	0.29	0.03	-0.08
SSI	-0.21	0.52	0.29	-0.03	-0.02
HSW(gm)	0.41	0.10	0.01	0.02	-0.49
SHR	0.21	0.17	-0.37	-0.25	-0.53

*Traits that are corresponding to underlined numbers are the most significant traits that contribute much of the variation in each PC

CL: Capsule length, CD: Capsule diameter, CSI: Capsule shape index, CC: Capsule circumference, SCW: Single capsule weight, SPC: Seeds per capsule, SHR: Seed to husk ratio, SL, Seed length, SD, Seed diameter, SSI: Seed shape index HSW: Hundred seed weight, SHR: Seed to husk ratio

Figure 2 displays the two way loadings and score plots of capsule and seed physical parameters. Biplots similarly provide plots of the *n* observations, but *simultaneously* they give plots of the relative positions of the *p variables* in two dimensions. Furthermore, superimposing the two types of plots provides additional information about relationships between variables and observations not available in either individual plot (Jolliffe, 2002). Distance of each variable with respect to PC1 and PC2 showed the contribution of this trait in the variation of the samples (Maqbool *et al*., 2010). It can be seen that, expression of seed to husk ratio, capsule length, diameter and circumference, fresh capsule weight and hundred seed weight are close together, reflecting their relatively positive association. On the other

hand, capsule and seed shape indices are plotted in the opposite direction, showing their fairly large negative correlation. This further supported by the correlation studies presented in Table 7.



CL: Capsule length, CD: Capsule diameter, CSI: Capsule shape index, CC: Capsule circumference, SCW: Single capsule weight, SPC: Seeds per capsule, SHR: Seed to husk ratio, SL, Seed length, SD, Seed diameter, SSI: Seed shape index HSW: Hundred seed weight, SHR: Seed to husk ratio

Figure 2**.** Biplot of the results of the principal component analysis of 22 korarima samples based on scores of 11 capsule and seed physical traits

4.4.2. Principal component analysis of phytochemical traits of seeds

The principal components with corresponding eigenvalues and proportions are displayed in Table 9**.** According to biochemical traits of seeds the first three principal components which accounted 81.1%, explained much proportion of the variation. The first PC contributed 36.3 % of the total variation, the second PC accounted of 25.3% while the third contributed 18.5%. Traits such as crude fiber, carbohydrate and ash contents contributed more for the first PC,

Oleoresin, volatile oil, crude fat and ash contents for the second PC whereas crude protein and crude fat contents explained more for the third PC.

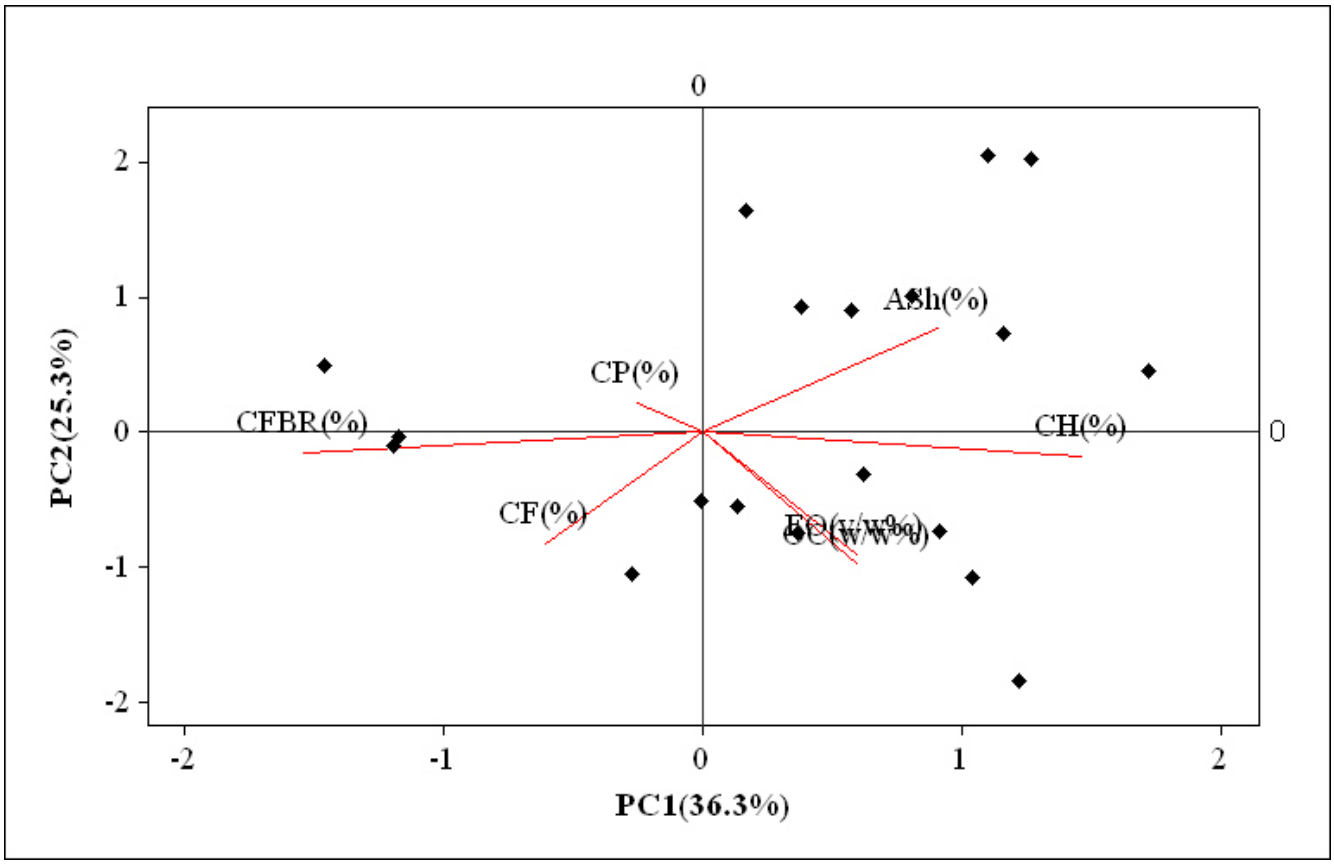
Table 9. Eigenvector values for principal components using seven seed biochemical traits of korarima samples

Eigenvalue	2.54	1.77	1.30
Proportion	0.363	0.253	0.185
Cumulative	0.363	0.616	0.801
Variable	**PC1**	**PC2**	**PC3**
EO (v/w%)	0.23	-0.51	0.28
OC (w/w%)	0.23	-0.55	0.27
CP (%)	-0.10	0.12	0.80
CF (%)	-0.24	-0.47	-0.44
CFBR (%)	-0.61*	-0.09	0.12
Ash (%)	0.36	0.43	-0.03
CH (%)	0.57	-0.10	-0.12

*Traits that are corresponding to underlined numbers are the most significant traits that contribute much of the variation in each PC

EO: Essential oil, OC: Oleoresin content, CP: crude protein, CF: Crude fat, CFBR: Crude fiber, CH: carbohydrate

The two way loadings of PC1 against PC2 based on seed biochemical traits is showed in Figure 3. This figure showed how the samples were differently structured according to their seed biochemical composition. Essential oil (EO) and oleoresin (OC) contents are expressed closely in the biplot quadrant, showing there was a strong positive association between them. Association was also observed between carbohydrate and ash contents. Crude fiber was in the oposite direction to ash and carbohydrate contents, reflecting their strong negative correlation. The coefficient of correlation values in Table 7 reinforced this idea. Biochemical variation of plant samples from different locations using principal component analysis was reported by many authors (Abel Teshome, 2007; Blessing *et al.,* 2011).



EO: Essential oil, OC: Oleoresin content, CP: crude protein, CF: Crude fat, CFBR: Crude fiber, CH: carbohydrate

Figure 3**.** Biplot of the results of the principal component analysis of 22 korarima samples based on scores of 7 seed phytochemical traits

4.5. Cluster analysis

Dendogram based on Euclidian distance coefficients using 14 quantitative traits placed 22 samples into four main clusters (Figure 4). Cluster analysis for estimation of variability among the accessions based on the parameters studied exhibits diversity/relatedness. Cluster I consisted of samples from four kebeles vis. Boba Gecha, Maz, Golish and Michiti. From these two were belonging to keffa area (Boba Gecha and Michiti) and the rest two were from Bench Maji Zone (Maz and Golish). The korarima samples grouped under cluster one were characterized by having high number of seeds per capsule, low seed weight, low seed to husk ratio, high ash content and red capsule color (Table 10). Cluster II consisted of a total of fifteen samples. Cluster II was further divided into two sub-clusters (i and ii). Sub cluster i consisted of samples from six kebeles vis. Gaus, Kobut, Zenba, Dukura Weshi, Addisu Zemikin, and Shapa. From sub-cluster (i) three of them located in Keffa area, two of them from Bemch Maji area and the rest one was belong to South Omo area. Sub-cluster (ii) consisted of samples from nine kebeles vis. Seri Shewa, Girsha, Gisu, Wana Bola, Pelpa, Kuta Shoray and Keja Araba. Cluster II was characterized by high capsule length, diameter and circumference, high capsule fresh weight, high seed weight, high seed to husk ratio, high oleoresin content, low crude fat content and high carbohydrate conetent (Table 10). Cluster III consisted of samples from two kebeles vis. Metser and Baita. Metser was found in South Omo zone whereas Baita was from Bench Maji area. Samples grouped in this cluster were mainly characterized by having low number of seeds per capsule, high seed length, high volatile oil content, high ash content and high carbohydrate content. The fourth cluster (IV) was represented by only sample from Gachit Kebele. This cluster consisted of sample with low capsule length, diameter and circumference, low fresh capsule weight, low seed length, high seed diameter, low seed weight, low essential oil and oleoresin contents, high crude protein, high crude fat, high crude fiber contents and low ash and carbohydrate contents (Table 10). Samples from different geographical locations groped under the same clusters. This may be an indication of similarity between samples and/or germplasm exchange between the different geographical regions.

Table 10. Cluster means of the sixteen traits of korarima samples used for the study

Variable	Cluster I	Cluster II	Cluster III	Cluster IV	Grand means
CL (cm)	5.66	5.98	5.36	5.00	5.82
CD (cm)	2.96	3.13	3.07	2.86	3.08
CSI	2.16	2.24	2.03	2.36	2.22
CC (cm)	9.94	10.38	9.94	9.22	10.21
SCW (gm)	20.80	22.78	22.77	19.65	22.28
SPC	212.05	168.89	129.80	193.80	174.32
SL (mm)	3.72	3.76	3.78	3.56	3.74
SD (mm)	2.83	2.89	2.77	2.90	2.87
SSI	1.31	1.30	1.37	1.23	1.30
HSW(gm)	1.95	2.19	2.17	1.88	2.13
SHR	2.21	2.38	2.24	2.22	2.33
EO (v/w%)	1.54	1.75	2.03	1.08	1.71
OC (w/w%)	4.39	4.65	3.69	3.37	4.46
CP (%)	7.49	7.28	7.25	7.80	7.34
CF (%)	2.28	2.26	2.35	2.85	2.29
CFBR (%)	16.83	16.92	16.48	48.43	18.29
Ash (%)	8.43	7.18	7.77	3.21	7.28
CH (%)	52.92	54.18	54.10	26.13	52.67

CL: Capsule length, CD: Capsule diameter, CSI: Capsule shape index, CC: Capsule circumference, SCW: Single capsule weight, SPC: Seeds per capsule, SHR: Seed to husk ratio, SL, Seed length, SD, Seed diameter, SSI: seed shape index, HSW: Hundred seed weight, EO: Essential oil, OC: Oleoresin content, CP: crude protein, CF: Crude fat, CFBR: Crude fiber, CH: Carbohydrate.

Similar results were obtained by Akbar *et al.* (2011) and Chtourou-Ghorbel *et al*. (2012) who found clustering of sesame landraces and Tunisian tall fescue respectively, due to their morphological differences instead of geographical distribution. Clustering of genotypes belonging to different geographic region suggests that they might have evolved from the existing korarima gene pool from which they were selected by local people to domesticate them in different areas for cultivation (Akbar *et al*., 2011; Kholghi *et al*., 2011; Vasugi *et al.,*

2012). Therefore, selection of parental material for hybridization simply based on geographic diversity may not be beneficial (Kholghi *et al*., 2011).

Goodarzi *et al.* (2012**)** reported that one possible reason for the similarity among germplasm from different regions is that the materials might have originally been introduced from the same region, in our case from one region to different regions within the country. The result from cluster analysis showed that fifteen samples (68%) grouped together indicating there was little variation among the samples of various locations though a significant difference was observed in all of the traits. The reason for this may be due to low farm based biodiversity of korarima (Eyob *et al.,* 2009). In addition, as korarima is almost entirely propagated by cutting in farmers' field, there is no chance for segregation and recombination; thus, there is no chance of creating and accumulation of variation in successive generations.

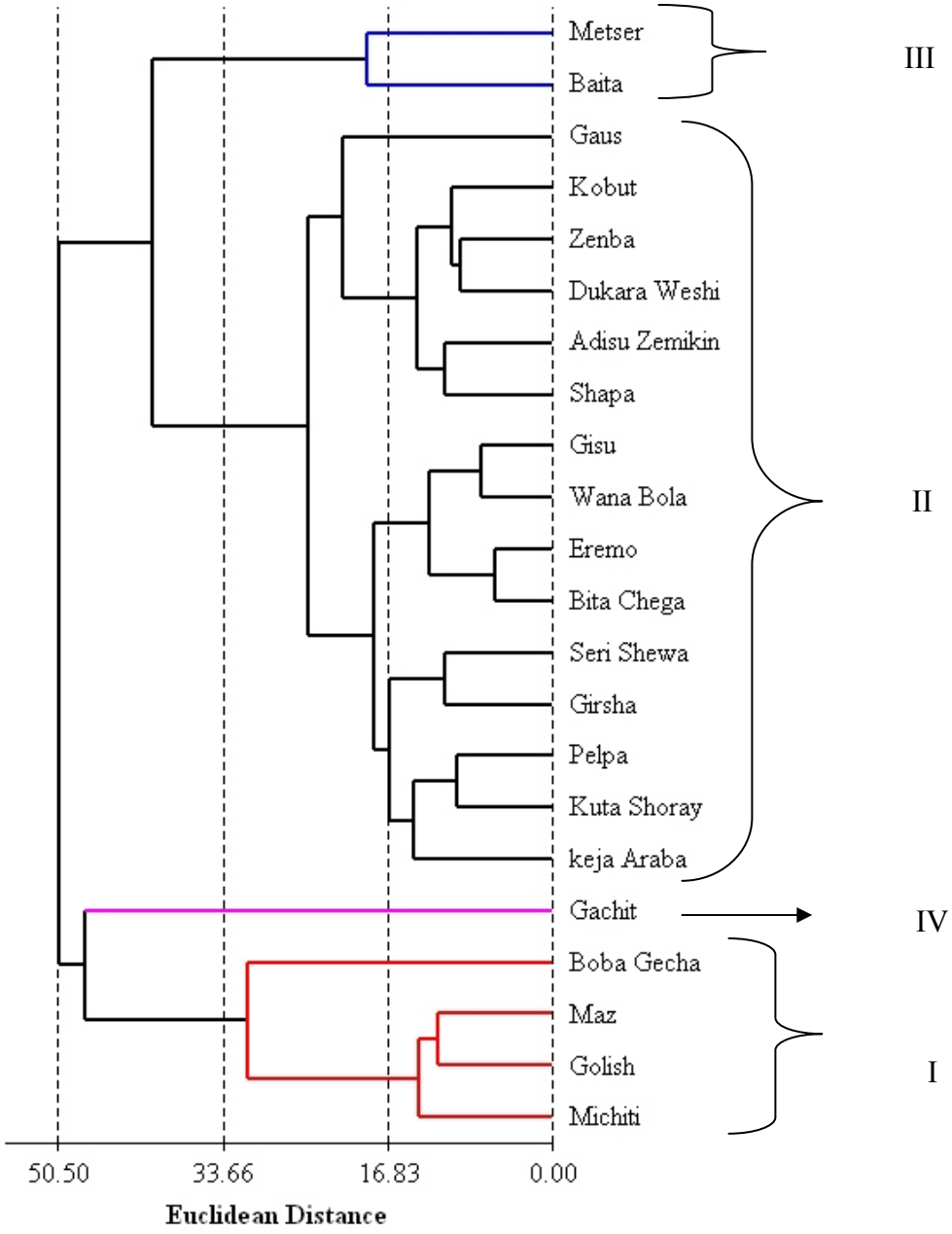


Figure 4. Cluster analysis showing the relationship between *korarima samples* based on capsule and seed phytochemical traits.

Table 11. Distances between Cluster Centroids

Cluster	1	2	3	4
1	0.00	43.25	82.29	45.62
2		0.00	39.12	49.31
3			0.00	77.02
4				0.00

The average distance between cluster centroids ranged from 39.12 to 82.29. The largest inter-cluster distance (82.29) was observed between cluster 1 and 3 and the lowest one (39.12) was observed between cluster 2 and 3 (Table 12). Whenever further improvements needed focusing on individuals from clusters with maximum inter-cluster distance may give high advantage (Kholghi *et al*., 2011). The minimum inter cluster distance observed between cluster 2 and 3 indicated the close similarity of samples in these clusters.

.

The relative distribution of the 22 samples based on two axes of principal components was presented in Figure 5. The distribution displayed in figure 5 was comparable to the clustering observed in the dendrogram (Figure 4). With the exception of sample from 'Kobut' which was grouped in cluster II of the dendogram and grouped in the fourth cluster of in PC scatter diagram. In another exception 'Boba Gecha' sample transferred to second cluster in PC from cluster IV of what it was in the dendogram. Similar result was reported by Taamalli *et al.* (2006) who found exceptions on the similarity of distribution of Tunisian Olive germplasm collections between clustering dendogram and principal component scatter diagram. Jan *et al.* (2012) also found no clear separation of the turmeric genotypes in the PCs into different groups. With some exceptions what was grouped in the dendogram they found various genotypes of three populations were interspersed and had a wider spread across two principal components.

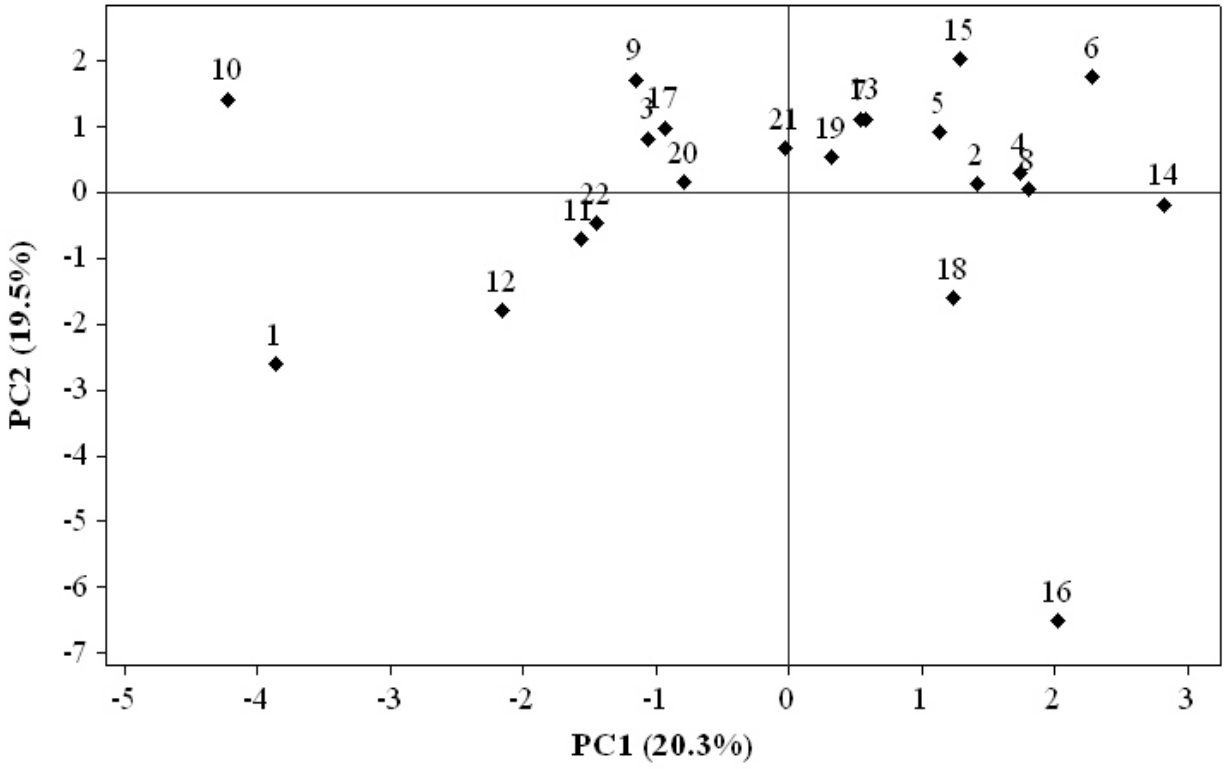


Figure 5. Scatter diagram of the first and the second axis studied in the principal components and positions of the 22 korarima samples based on mean values of quantitative traits (Number of samples corresponds to those in Table 2).

4.6. Variation in *Afframomum corrorima* samples in each Administrative Zones based on phytochemical parameters

The variation in physicochemical traits of korarima samples in each administrative zone was presented in Table 12. The result showed that there was a significant variation among the administrative zones in all physicochemical characteristics of korarima samples except SSI.

Table 12. Mean values of the four Administrative zones based on the 18 phytochemical traits

		Administrative zones			
Variable	CV (%)	Keffa	BM	SO	Konta SW
CL(cm)	7.37	6.38a*	5.43c	5.41c	5.63b
CD(cm)	1.62	3.01b	3.14a	3.13a	3.09ab
CSI	2.04	2.22ab	2.23a	2.17b	2.23a
CC(cm)	3.36	10.57a	9.91c	10.20b	9.68d
SCW(g)	5.58	22.16b	22.94a	21.46c	19.81d
SPC	3.48	180.58b	173.29c	155.13d	184.80a
SL(mm)	1.10	3.77a	3.71b	3.76a	3.79a
SD(mm)	1.32	2.89ab	2.85b	2.85b	2.91a
SSI	2.42	1.30a	1.30a	1.32a	1.30a
HSW(g)	3.03	2.18b	2.07c	2.13b	2.20a
SHR	4.73	2.34b	2.28c	2.37b	2.52a
EO (v/w%)	23.92	1.87c	1.25d	2.43a	2.15b
OC (w/w%)	17.81	4.83b	3.64d	5.84a	4.38c
CP (%)	3.48	7.44b	7.27c	7.11d	7.78a
CF (%)	25.46	2.33b	2.30b	2.52a	1.25c
CFBR (%)	6.85	17.67c	18.68b	19.60a	16.43d
Ash (%)	38.97	6.32c	8.41b	4.90d	12.91a
CH (%)	3.46	54.23a	50.94c	53.93b	50.35d

*means connected by different letter within a row are significantly different ($p<0.05$)
CL: Capsule length, CD: Capsule diameter, CSI: Capsule shape index, CC: Capsule circumference, SCW: Single capsule weight, SPC: Seeds per capsule, SHR: Seed to husk ratio, SL, Seed length, SD, Seed diameter, SSI: Seed shape index. HSW: Hundred seed weight, EO: Essential oil, OC: Oleoresin content, CP: crude protein, CF: Crude fat, CFBR: Crude fiber, CH: Carbohydrate.

Physical characteristics

Perusal of data mentioned in table 13 showed that length, diameter and circumference of capsule varied from 5.41 to 6.38cm, 3.01 to 3.14cm and 9.91 to 10.57cm, respectively, at the four administrative zones. Maximum capsule length was recorded at Keffa and minimum at South Omo. However a significant close variation was obtained in both length and diameter of capsule. Maximum capsule shape index was obtained from Konta closely followed by Keffa. Fresh capsule weight was varied from 19.81 to 22.94g and maximum was obtained from Bench Maji and minimum from Konta. Seed per capsule was higher in konta and the lowest was obtained from South Omo. Maximum length and diameter of seed was found from Konta and minimum was obtained from Bench Maji. Maximum seed shape index was found in South Omo; however, it was statistically at par with the other three. Hundred seed weight was varied from 2.07 to 2.20g and maximum was obtained from Konta. Seed to husk ratio was maximum in Konta and closely followed by South Omo. Nothing was reported concerning capsule and seed physical quality variation of korarima from different administrative zones however, the variation could be linked to environmental and soil conditions as well as crop management and cultural practices (Thomas et al., 2006; Okello, 2010; Thakur *et al*., 2011)

Phytochemical characteristics

Maximum volatile oil content (2.43%) was obtained from South Omo and the minimum was from Bench Maji. Oleoresin content was higher in South Omo followed by Keffa. Crude protein was varied from 7.1 to 7.77 % and the maximum value was scored by Konta whereas the minimum was obtained from South Omo. Crude fat content was higher in South Omo and the least was obtained from Konta. Further, Ash content was ranged from 4.90 to 12.91% which was higher in Konta at far followed by Bench Maji and the least was obtained from South Omo. The data revealed that carbohydrate content was ranged from 50.35 to 54.23 % and the maximum was obtained from Keffa closely followed by South Omo and the least was found from Konta. The variation in different biochemical characteristics of korarima at the different administrative zones may be due to varietal, environmental, age of the plant and soil factors (Okello, 2010; Thakur *et al*., 2011; Melese, 2011).

Cluster analysis

Cluster analysis based on eighteen physicochemical characteristics grouped the administrative zones into two groups (Figure 6). Cluster I is further divided into two sub clusters i and ii, sub-cluster i contains two administrative zones vis. Keffa and Bench Maji and sub-cluster ii contains only one Administrative zone Konta. Cluster II was formed by only one Administrative zone South Omo (Figure 6). As clearly seen from the figure Keffa and Bench Maji zones were found to be 73% similar while Konta was 63 % similar. However, South Omo showed only 19% similarity. Cluster I is mainly represented by higher values for capsule length, seed per capsule, crude protein and ash contents (Table 13). Cluster II had higher values of volatile oil, oleoresin, crude fat, crude fiber and carbohydrate contents.

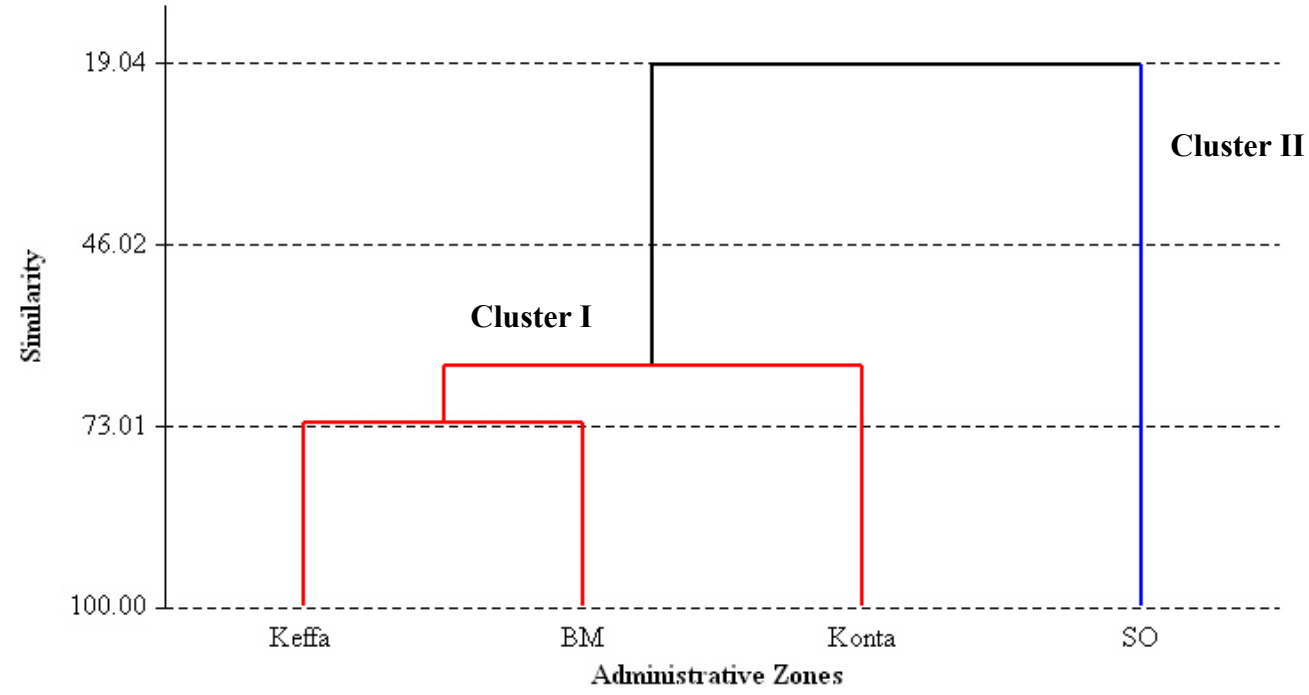


Figure 6. Cluster analysis showing the similarity among korarima samples in each Administrative Zones based on capsule and seed phytochemical traits.

Table 13. Cluster means of the eighteen traits of korarima samples based on Administrative zones

Variable	Cluster I	Cluster II	Grand centroid
CL	5.81	5.41	5.71
CD	3.08	3.13	3.09
CSI	2.23	2.17	2.21
CC	10.05	10.20	10.09
SCW	21.64	21.46	21.59
SPC	179.56	155.13	173.45
SL	3.76	3.76	3.76
SD	2.88	2.85	2.88
SSI	1.30	1.32	1.31
HSW	2.15	2.13	2.14
SHR	2.38	2.37	2.38
EO	1.76	2.43	1.93
OC	4.28	5.84	4.67
CP	7.50	7.11	7.40
CF	1.96	2.52	2.10
CFBR	17.60	19.60	18.10
Ash	9.22	4.90	8.14
CH	51.84	53.93	52.36

CL: Capsule length, CD: Capsule diameter, CSI: Capsule shape index, CC: Capsule circumference, SCW: Single capsule weight, SPC: Seeds per capsule, SHR: Seed to husk ratio, SL, Seed length, SD, Seed diameter, SSI: Seed shape index. HSW: Hundred seed weight, EO: Essential oil, OC: Oleoresin content, CP: crude protein, CF: Crude fat, CFBR: Crude fiber, CH: Carbohydrate.

Eyob *et al.* (2009) reported low farm based biodiversity of *Affframomum corrorima* species when compared with other native plants of Ethiopia such as enset, tef and sorghum in three administrative zones of southern Ethiopia. However, no previous study was reported concerning the phytochemical variation of korarima in different growing regions of southwestern Ethiopia.

5. SUMMARY AND CONCLUSIONS

The present study was carried out by collecting fully matured red korarima capsules from different growing regions southwestern Ethiopia at the peak harvesting time. Four administrative zones were addressed for sampling viz. Keffa, Bench Maji, South Omo and Konta. Over all 22 samples of red capsules were collected in order to assess the physical and biochemical characteristics of the capsules and seeds of the collected korarima samples. Though korarima is growing in many places across the country, this study tried to focus only on four administrative zones of south and southwestern Ethiopia due to limited time and merely financial resources.

The ANOVA indicated that there was a significant variation among the different *Affamomum korarima* accessions grown under different locations regarding the physicochemical traits of capsules and seeds. Highly significant ($p<0.01$) variation was obtained among the samples in terms of capsule length, capsule shape index, capsule circumference, fresh capsule weight, seed number per capsule, seed shape index, seed to husk ratio, hundred seed weight, Essential oil, oleoresin, crude fiber, crude fat and ash contents. There was also a significant ($p<0.05$) variation in characters such as capsule diameter, seed length and diameter. The variation might be related to varietal, environmental, soil conditions and management practices.

Cluster analysis based on physicochemical traits of capsule and seeds arranged the samples in four groups. Group I contained four samples, group II made by 15 samples, group III was represented by two samples and the fourth cluster contained only one sample. The cluster groping of the samples indicated that the samples were grouped based on their respective physicochemical traits rather than geographical locations. Samples from different agro ecological locations were grouped in the same cluster and this may be an indication of the domestications of the accessions from one area to the other. Focusing on comparative higher mean values for the traits of each cluster has paramount importance for commercialization as well as quality improvement works in the future.

The first five Principal components which had eigenvalues more than one explained most of the variation among the samples based on capsule and seed physical quantitative traits. The first PC explained 29.9% of the variation and the most important characters were 100 seed weight, capsule circumference, fresh capsule weight, capsule length and capsule diameter. For the second PC which explained 23.6% of the variation, traits such as capsule and seed shape indices and seed diameter contributed more. The principal component analysis based on seed biochemical traits revealed that the first three principal components described more (81.0%) of the variation. The first PC explained 36.3% and crude fiber, carbohydrate and ash contents were important characters. The second PC accounted for 25. 3% and oleoresin, volatile oil, crude fat and ash contents contributed more for this PC. Principal component showed the most important traits responsible for the variation among the samples which is important for further breeding and quality improvement purposes.

As far as the administrative zones were concerned the variation of koraima samples was grouped into two clusters. Close similarity was observed among Keffa, Bench Maji and Konta samples whereas South Omo samples were less similar. Though the variation could be linked to genotype and other agro-ecological factors focusing on less similar samples will give a better improvement in quality of korarima.

Despite the variation obtained in respect of capsule and seeds' physicochemical traits of *Afframomum corrorima* more research will be needed as far as its home of origin and wider adaptation is concerned. Furthermore, the locations selected for the study were very limited and there are a number of places to be included to make the study more conclusive. Though the findings from this study will be crucial in improving quality, it is very important to leave the following recommendation:

This thesis research was carried out on the indigenous and untouched-*Afframomum corrarima* (Ethiopian cardamom) species aimed at characterizing accessions from different locations based on capsules and seeds physical and biochemical characteristics.
Beside the above conclusions it is very important to leave the following recommendations for further research and quality improvement:

The characterization was done using only capsules and seeds phytocochemical traits only therefore, it is crucial to study using other morphological traits and molecular markers and more traits in order to have a deeper insight on the variation

Again due to financial and time limitation it was not possible to analyse the chemical compostions of essential oils korarima samples of various locations. Therefore, further research based on variability of essential oil compostions of korarima accesions from different location will be important in considering quality improvemrnt issues

Since physicochemical qualities can affected by processing conditions variability in physicochemical characteristics as a result of post harvest handling practices should be studied

6. REFERNCES

Abel T., 2007. Diversity study on seed quality traits of Ethiopian mustard Brassica carinata A. Braun) among seed samples selected from Oromiya regional state, Ethiopia assessed by proximate analysis. An MSc Thesis presented to the School of Graduate Studies of Addis Ababa University. 67p.

Abeysekera, W.K. and C.K. Illeperuma, 2005. Comparison of ginger varieties dried at different temperatures for oil and oleoresin contents. *Sri Lankan J. Agric. Sci.* **42**: 34–42

Adegoke, G.O. and B.J. Skura, 1994. Nutritional profile and antimicrobial spectrum of the spice *Aframomum danielli* K. Schum. *Plant Food Hum. Nutr.* **45**: 175-182

Agize, M., and L. van der Zouwen, 2008. The Marketing of Spices from South-West Ethiopia. Non Timber Forest Products and Participatory Forest Management R & D Project in S-W Ethiopia. Wageningen, The Netherlands.

Ahmed, M., M.A. Anjum, Z.K. Shinwari, M.S. Awan, and M.A. Rabbani, 2011. Assesment of variability in fruit quality parameters of *Pyrus* germplasm collected from Azad Jammu and Kashmir (Pakistan). *Pak. J. Bot*. **43**: 971-981

Akande, T.O., A.A Odunsi, O.S. Olabode and T.K. Ojediran, 2012. Physical and Nutrient Characterization of Raw and Processed Castor (*Ricinus communis* L.) Seeds in Nigeria. *World J. Agric. Sci*. **8**: 89-95

Akbar, F., M.A. Rabbani, Z.K. Shinwari and S.J. Khan, 2011. Genetic divergence in sesame (*Sesamum indicum* L.) landraces based on qualitative and quantitative traits. *Pak. J. Bot*. **43(6)**:
2737-2744

Alamdary, S.B.L., A. Safarnejad and M. Rezaee, 2011. Evaluation of Genetic Variation between *Thymus* Accessions Using Molecular Markers. *J. Basic. Appl. Sci. Res.*, **1**: 2552-2556

Aliyu, M. O. Abbas, N.U. Samuel and A.Z Ohunene, 2012. Nutrients and Anti-Nutrients Analyses of *Aframomum longiscapum* Seeds. International Journal of Food Nutrition and Safety, **1**: 120-126

Amma, K.P.P., M.P. Rani, I. Sasidharan and V.N.P. Nisha, 2010. Chemical composition, flavonoid - phenolic contents and radical scavenging activity of four major varieties of cardamom. *Int. J. Biol. Med. Res.* **1**: 20-24

Anonymous, (2008). Ethiopia: Second Country Report on the State of PGRFA to FAO. Institute of Biodiversity Conservation, Addis Ababa, Ethiopia.

AOAC, 1990. Official Methods of Analysis, 15th ed. Association of Official Analytical Chemists, Arlington, VA.

Ardabili, A.G., R. Farhoosh and M.H.H. Khodaparast, 2011. Chemical Composition and Physicochemical Properties of Pumpkin Seeds (*Cucurbita pepo* Subsp. pepo Var. Styriaka) Grown in Iran. *J. Agr. Sci. Tech.* **13**: 1053-1063

Ashafa, A.O., D.S. Grierson and A.J. Afolayan, 2008. Effect of Drying Methods on Chemical Compositions of Essential Oil from *Felicia muricata* leaves. *Asian J. Plant Sci.* **7**: 603-606

ASTA, 1997. *Official method of analysis.* Americal Spice Trade Association. Englewood cliffs, NJ, USA.

Bakkali, F., S. Averbeck, D. Averbeck and M. Idaomar, 2008. Biological effects of essential oils – A review. *Food Chem. Toxicol.* **46**: 446-475

Bekalo, T.H., S.D. Woodmatas and Z.A. Woldemariam, 2009. An ethnobotanical study of medicinal plants used by local people in the lowlands of Konta Special Woreda, southern nations, nationalities and peoples regional state, Ethiopia. *J. Ethnobiol. Ethnomed.* 2009, **5**: 1-15

Bello, M.B., O.S. Falade, S.R.A. Adewusi and N.O. Olawore, 2008. Studies on the chemical compositions and anti nutrients of some lesser known Nigeria fruits. *Afr. J. Biotechnol.* **7**: 3972-3979

Bizoux, J. and G. Mahy, 2007. Within–Population Genetic Structure and Clonal Diversity of a Threatened Endemic Metallophyte, Viola calaminaria (Violaceae). *Am. J. Bot.* **94**: 887-895

Blessing, A.C. U.M. Ifeanyi and O.B. Chijioke, 2011. Nutritional Evaluation of Some Nigerian Pumpkins (*Cucurbita*spp.). *Fruit, Veg. Cereal Sci. Biotech.* **5**: 64-71

Bozokalfa, M.K., D. Eşiyok and K. Turhan, 2009. Patterns of phenotypic variation in a germplasm collection of pepper (*Capsicum annuum* L.) from Turkey. *Span. J. Agric. Res.* **7**: 83-95

Cavalcante, Í.H.L., L.F. Cavalcante, J.M.de S. Miranda and A.B.G. Martins, 2012. Physical and Chemical Characteristics of Tropical and Non-Conventional Fruits. pp. 4-16. In: B. Valdez (ed). Food Industrial Processes - Methods and Equipment, InTech publisher, Rijeka, Croatia.

Chempakam, B. and S. Sindhu, 2008. Cardamom. pp. 59-69. In: V.A. Parthasarathy, B. Chempakam and T.J. Zachariah (eds). Chemistry of spices, vol.1. CAB International, London, UK.

Chtourou-Ghorbel, N., H. Elazreg, S. Ghariani, M. Chakroun and N. Trifi-Farah, 2012. Genetic diversity among wild accessions and cultivars of Tunisian tall fescue based on morpho-agronomical traits and ISSR markers. *J. Food, Agric. Environ.* **10**: 263-268

Costa, C., F. Antonucci, F. Pallottino, J. Aguzzi, DW. Sun, and P. Menesatti, 2011. Shape Analysis of Agricultural Products: A Review of Recent Research Advances and Potential Application to Computer Vision. *Food Bioprocess Technol.* **4**: 673–692

Curado, M.A., C.B.A. Oliveira, J.G. Jesus, S.C. Santos, J.C. Seraphin and P.H. Ferri, 2006. Environmental factors influence on chemical polymorphism of the essential oils of *Lychnophora ericoides*. *Phytochemistry,* **67**: 2363–2369

Dhetchuvi, J-B. and E. Fischer, 2006. Notes on tropical African plants: A new species of *Aframomum* (Zingiberaceae) from Nyungwe National Park/Rwanda. *Syst. Geogr. Pl*. **76**: 241-254

Díaz-Maroto, M.C., M.S. Pérez-Coello, M.A.G. Viñas and D.M. Cabezudo, 2003. *J. Agric. Food Chem*. **51**: 1265–1269

Edim, E.H., I. Blessing, and U. Sammuel, 2011. Comparative studies on consumption preference, mineral contents and proximate composition of five ecotypes of *Gnetum aficanum* Welw. from Northwest Cameroun and Southeast Nigeria. *Afr. J. Plant Sci.* **5**: 753-758

EIA, 2010. Investment Opportunity Profile for Spice processing In Ethiopia. Ethiopian Investment Agency, Addis Ababa, Ethiopia. http://www.ethioinvest.org (Accessed on, 4/11/2011)

EIAR, 1999. Crop technologies Manual. http://www.eiar.gov.et. (Accessed on, 22/10/2011).

Emara, K.S., and A.E. Shalaby, 2011. Seasonal variation of fixed and volatile oil percentage of four *Eucalyptus* spp. related to lamina anatomy. *Afr. J. Plant Sci.* **5**: 353-359

Engels, J.M.M. and L. Visser, 2003. A guide to effective management of germplasm collections. IPGRI Handbooks for Genebanks, No. 6. IPGRI, Rome, Italy.

Erukainure, O.L., O.V. Oke, F.O. Owolabi and O.S. Adenekan, 2011. Chemical composition and Antioxidant Activities of *Aframomum sceptrum*. *Trends Appl. Sci. Res.* **6**: 190-197

Eyob, S. 2009. Promotion of seed germination, subsequent seedling growth and *in vitro* propagation of korarima *Aframomum corrorima* (Braun) P. C. M. Jansen). *J. Med. Plant. Res*. **3**: 652-659

Eyob, S., A. Tsegaye, A. Appelgren, 2009. Analysis of korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen) indigenous production practices and farm based biodiversity in southern Ethiopia. *Genet. Resour. Crop Evol.* **56**: 573-585

Eyob, S., B.K. Martinsen, A. Tsegaye, M. Appelgren and G. Skrede, 2008. Antioxidant and antimicrobial activities of extract and essential oil of korarima (*Aframomum corrorima* (Braun) P.C.M. Jansen). *Afr. J. Biotechnol.* **7**: 2585-2592

Eyob, S., M. Appelgren, J. Rohloff, A. Tsegaye, Messele, G. 2007. Chemical composition and physical properties of essential oils from fresh plant parts of korarima (Aframomum corrorima) cultivated in the highland of southern Ethiopia. *J. Essent. Oil Res.* **19**:372–375

Ezeagu, I.E., B. Maziya-Dixon and G. Tarawali, 2003. Seed Characteristics and Nutrient and Antinutrient Composition of 12 Mucuna Accessions. *Trop. subtrop. agroecosyst.* **1**: 129 - 139

FAO, 2007. Ethiopia: Country report on the state of plant genetic resources for food and agriculture. Institute of Biodiversity conservation, Addis Ababa, Ethiopia.

Figueiredo, A.C., J.G. Barroso, L.G. Pedro and J.J.C. Scheffer, 2008. Factors affecting secondary metabolite production in plants: volatile components and essential oils. *Flavour Fragr. J.* **23**: 213–226

Finco, B.A., I.G. Silva and R.B. Oliveira, 2012. Physicochemical characteristics and antioxidant activity of three native fruits from Brazilian savannah (Cerrado). *Alim. Nutr. Araraquara*, **23**: 1-6

Fissiha Gebreyesus, 2012. Influence of havesting stages, drying structures and drying duations on quality of korarima (*Aframomum corrorima*) in Sheka zone , Southwesten Ethiopia. An MSc Thesis presented to the School of Graduate Studies of Jimma University. 108p.

Fullas, F. 2009. A Brief History of Spices in Ethiopia. *Ee-JRIF*, **1**: 114-127

Gallegos–Vásquez, C., A.F. Barrientos–Priego, J.A. Reyes–Agüero, C.A. Núñez–Colín and C. Mondragón–Jacobo, 2011. Clusters of commercial varieties of cactus pear and xoconostle using UPOV morphological traits. *J. PACD,* **13**: 10–22

Girma, H-M. and T. Digafie, 2006. The Effects of Stage of Maturity at Harvest on the Quality of Five Pepper (*Piper nigrum* L.) Cultivars.pp. 211-214. In: Proc. of the inaugural and First Ethiopian Horticultural Science Society conference. 27-30 March 2006, Inst. Agric. Res., Addis Ababa, Ethiopia.

Girma, H-M. T. Digafie, M. Ali and N. Amsalu, 2009.pp. 96-99. Effect of Stage of Maturity at Harvest on the Quality of Different Ginger Cultivars in Southernwestern Ethiopia. In: Proc. of the second Biennial conference of Ethiopian Horticultural Science Society. 22-23 January 2009, Inst. Agric. Res., Addis Ababa, Ethiopia.

Girma, H-M., T. Digafie, E. Edossa, Y-B. Belay and G. Weyesa, 2008. Spices Research Achievements, (Rev. ed.). Ethiopian Institute of Agricultural Research. Addis Ababa, Ethiopia.

Goettsch, E., 1991. Spice germplasm in Ethiopia. pp. 123-130. In: J.M.M. Engles, J.G. Hawkes and M. Worede (eds). Plant Genetic Resources of Ethiopia. Cambridge University press, New York, USA.

Goodarzi, F. R. Darvishzadeh, A. Hassani and A. Hassanzaeh, 2012. Study on genetic variation in Iranian castor bean (*Ricinus communis* L.) accessions using multivariate statistical techniques. *J. Med. Plant Res.* **6**: 1160-1167

Hassiotis, C.N., D.M. Lazari and K.E. Vlachonasios, 2010. The Effects of Habitat type and diurnal Hravest on Essential oil Yiled and Composition of *Lavandula angustifolia* Mill. *Fresenius Environ. Bull.* **19**: 1491-1498

Hawtin, G., M. Iwanaga and T. Hodgkin, 1997. Genetic resources in breeding for adaptation**.** pp. 277-288P. In: M.A. Tigerstedt (ed). Adaptation in plant breeding, vol.4. Kluwer Academic Publisher, Dordrecht, the Netherlands.

http://botany.si.edu/zingiberales/genera/genuspage.cfm?mygenus=Aframomum&myfamily=Zingiberaceae. (Accessed on 14/10/2012)

http://www.pgrfa.org/gpa/eth/documents/Second_Report_ethiopia.pdf. (Accessed on, 22/10/2011)

http://www.snnprs.gov.et/Investment.pdf. (Accessed on, 25/10/2011)

Hussain, A.I., 2009. Characterization and Biological Activities of Essentials of Some Species of Lamiaceae. A PhD Thesis presented to university of Agriculture, Faisalabad, Pakistan. 218p.

Hussain, I. 2011. Physiochemical and sensory Characteristics of Elaeagnus umbellata (Thunb) fruit from Rawalakot (Azad Kashmir) Pakistan. *Afr. J. Food Sci. Technol.*, **2**: 151-156

Hymete, A., J. Rohloff, T-H. Iversen, 2006. Essential oil from seeds and husks of Aframomum corrorima from Ethiopia. *Flavour Frag.* **21**: 642–644

Ibekwe, H.A. and E.E. Orok, 2010. Proximate Composition of Aframomum melegueta Seeds, Garcinia kola Seeds and Growth Performance of Broiler Chicks Treated with Powders from These Seeds. *Int. J. Poult. Sci.* **9**: 1152-1155

Imran, M., A. Hussain, R. Khalid, S. Khan, M.S. Zahid, Z.A. Gurmani, A. Bakhsh and Baig, D. 2010. Study of correlation among yield contributing and quality parameters in different millet parameters grown under and hwar conditions. *Sarhad J. Agric*. **26**: 365-368

IPGRI, 1994. Descriptors for cardamom (*Elletaria cardamomum* Maton). International Plant Genetic Resorces Institute, Rome, Italy.

Jan, H.U., M.A. Rabbani and Z.K. Shinwari, 2012. Estimation of genetic variability in turmeric (*Curcuma longa* L.) germplasm using agro-morphological traits. *Pak. J. Bot*. **44**: 231-238

Jansen, P.C.M., 1981. Spices, Condiments and Medicinal Plants in Ethiopia. Their Taxonomy and Agricultural Significance. PhD Thesis. Agricultural Research Reports 906, Centre for Agricultural Publishing and Documentation (Pudoc), Wageningen, The Netherlands. 327p.
Jansen P.C.M., 2002. *Aframomum corrorima* (Braun) P.C.M. Jansen. Record from protabase. In: Oyen LPA, Lemmens RHMJ (eds) PROTA (Plant Resources of Tropical Africa/ Ressources ve´ge´tales de l'Afrique tropicale). Wageningen, The Netherlands

Jeffers JNR. 1967. Two case studies in the application of principal component analysis. *Appl. Stat.* **16:** 225-236

Jerkovic, I., J. Mastelic and M. Milos, 2001. The impact of both thwe season of collection and drying on the volatile constituents of Origanum vulgare L. ssp. hirtum grown wild in Croatia. *Int. J. Food Sci. Technol.* **36**: 649-654

Jolliffe, I.T., 2002. Principal Component Analysis (2nd ed). Springer-verlag, New York.

Kholghi, M., I. Bernousi, R. Darvishzadeh, A. Pirzad and H.H. Maleki, 2011. Collection, evaluation and classification of Iranian confectionary sunflower (Helianthus annuus L.) populations using multivaraite statistical techniques. *Afr. J.Biotechnol.* **10**: 5444-5451

Kizhakkayil, J. and B. Sasikumar, 2009. Variabilty for quality traits in a global germplasm collection of ginger (Zingiber officinale R.). *Curr. Trends Biotechnol. Pharm.* **3**: 254 - 259

Leela, N.K., D. Prasath, and M.N. Venugopal, 2008. Essential oil composition of selected cardamom genotypes at different maturity levels. *Indian J. Hort.* **65**: 366-369

Little, T.M. and Hills, F. J. (1978). pp. 368. Agricltural experimentation: Design and Analysis. John Wiley and Sons, New York, USA.

Lock, J.M. 1978. Notes on the genus *Aframomum* (*Zingiberaceae*): The Ethiopian species. *Bull. Jard. Bot. Nat. Belg*. **48**: 387-391

Manju, P.R., and I. Sreelathakumary, 2002. Quality Parameters in Hot chilli (Capsicum chinense Jacq.*). J. Trop.Agric*. **40**: 7-10

Maqbool, R., M. Sajjad, I. Khaliq, A-u. Rehman, A.S. Khan and S.H. Khan, 2010. Morphological Diversity and Traits Association in Bread Wheat (*Triticum aestivum* L.). *Am-Euras. J. Agic. and Environ. Sci.* **8**: 216-224

Mazumdar, B.C. and K. Majumder, 2003. Methods on Physico Chemical Analysis of Fruits. Daya Publishing House, New Delhi, India. 187p.

Melesse, A. 2011. Comparative assessment on chemical compositions and feeding values of leaves of *Moringa stenopetala* and *Moringa oleifera* using invitro gas production method. *Ethiop. J. appl. Sci. Technol.* **2**: 31-41

Okello, J. 2010. Morphological and Nutritional Characteristics of *Tamarindus indica* (Linn) Fruits in Uganda. An MSc Thesis Presented to the School of Graduate Studies of Makerere University.

Oko, A.O. and S.I. Ugwu, 2011. The proximate and mineral compositions of five major rice varieties in Abakaliki, South-Eastern Nigeria. *Int. J. Plant Physiol. Biochem.* **3**: 25-27

Otunola, G.A., O.B. Oloyede, A.T. Oladiji and A.J. Afolayan, 2010. Comparative analysis of the chemical composition of three spices – *Allium sativum* L. *Zingiber officinale* Rosc. and *Capsicum frutescens* L. commonly consumed in Nigeria. *Afr. J. Biotechnol.* **9**: 6927-6931

Oyebade, B.A., B.A. Ekeke and F.C. Adeyemo, 2011. Fruits categorization and diagnostic analysis of *Chrysophylum albidum* (G. Don) in Nigeria. *Adv. Appl. Sci. Res.* **2**: 7-15

Pandey M., A.B. Abidi, S. Singh, R.P. Singh, 2006. Nutritional Evaluation of Leafy Vegetable Paratha. *J. Hum. Ecol*. **19**: 155-156

Purseglove, J.W., E.J. Brown, C.L. Green and S.R.J. Robbins, 1981. Spices, Vol 2. Longman Group Ltd. Longman House, Burnt Mill. Harlow, Essex, pp 581–643

Ravindran, P.N., M. Shylaja and N.K. Babu, 2002. pp. 330-340. False cardamoms. In: Ravindran, P.N. and K.J. Madhusoodanan, (eds). Cardamom: *The Genus Ellettaria.* CRC Press, Kerala, India.

SAS, 2010. Statistical Analysis System (version 9.2). SAS Institute, Carry, North Carolina, USA.

Seferoglu, S., H.G. Seferoglu, F.E. Tekintas and F. Balta, 2006. Biochemical composition influenced by different locations in Uzun pistachio cv. (*Pistacia vera L.*) grown in Turkey. *J. Food Comp. Anal.* **19**: 461–465

Sultan, M.T., M.S. Butt, F.M. Anjum, A. Jamil, S. Akhtar and M. Nasir, 2009. Nutritional profile of indigenous cultivar of black cumin seeds and antioxidant potential of its fixed and essential oil. *Pak. J. Bot*. **41**: 1321-1330

Taamalli, W., F. Geuna, R. Banfi, D. Bassi, D. Daoud and M. Zarrouk, 2006. Agronomic and molecular analyses for the characterisation of accessions in Tunisian olive germplasm collections. *Electron. J. Biotechn.* **9**:467-481

Takruri, H.R.H. and A.F.M. Dameh, 1998. Study of the Nutritional Value of Black Cumin Seeds (*Nigella sativa* L). *J. Sci. Food Agric.* **76**: 404-410

Tefera, W. and S. Wannakrairoj, 2004. Micropropagation of korarima (*Aframomium corrorima* (Braun) Jansen). *Sci. Asia*, **30**: 1-7

Tefera, W. and S. Wannakrairoj, 2006. Synergistic effects of some plant growth regulators on *in vitro* shoot proliferation of korarima (*Aframomum corrorima* (Braun) Jansen). *Afr. J. Biotechnol.* **5**: 1894- 1901

Thakur, N.S., G.S. Dhaygude and A. Gupta, 2011. Physico-chemical characteristics of wild pomegranate fruits in different locations of Himachal Pradesh. *Int. J. Farm Sci.* **1**: 37-44

Thomas, E., J. Kizhakkayil, T.J. Zachariah, S. Syamkumar and B. Sasikumar, 2006. Comparative quality characterization and molecular profiling of Indian, Sri Lankanand Guatemalan cardamoms. *J. Food Agric. Environ.* **4**: 129-133

UNIDO and FAO, 2005. Herbs, spices and essential oils: Post-harvest operations in developing countries. Vienna, Austria.

Upadhyaya, H.D., C.L.L. Gowda and D.V.S.S.R. Sastry, 2006. Plant genetic resources management: collection, characterization, conservation and utilization. *ICRISAT e-Jurnal*, **6**: 1-16

Vasugi, C.M., R. Dinesh, K. Sekar, K.S. Shivashankara, B. Padmakar and K.V. Ravishankar, 2012. Genetic diversity in unique indigenous mango accessions (Appemidi) of the Western Ghats for certain fruit characteristics. *Current science*, **103**: 199-2007

Viljoen, A.M., S. Petkar, S.F. van Vuuren, A.C. Figueiredo, L.G. Pedro and J.G. Barroso, 2006. The Chemo-Geographical Variation in Essential Oil Composition and the Antimicrobial Properties of "Wild Mint" – *Mentha longifolia* subsp. *Polyadena* (Lamiaceae) in Southern Africa. *J. Essent. Oil Res.* **18**:60-65

Viuda-Martos, M., Y. Ruíz-Navajas, J. Fernández-López, and J.A. Pérez-Álvarez, 2007. Chemical Composition of the Essential Oils Obtained From Some Spices Widely Used in Mediterranean Region. *Acta Chim. Slov.* **54**: 921–926

7. APPENDICES

Appendix Table 1. ANOVA of dependent variable: Capsule Length

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	20.31662311	0.96745824	9.67	<.0001
Error	44	4.40208333	0.10004735		
Corrected Total	65	24.71870644			

Appendix Table 2. ANOVA of Dependent Variable: Capsule Diameter

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	1.50484848	0.07165945	2.21	0.0135
Error	44	1.42853333	0.03246667		
Corrected Total	65	2.93338182			

Appendix Table 3. ANOVA of Dependent Variable: Capsule Circumference

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	18.31532727	0.87215844	7.33	<.0001
Error	44	5.23466667	0.11896970		
Corrected Total	65	23.54999394			

Appendix Table 4. ANOVA of Dependent Variable: Fresh Capsule Weight

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	460.6190213	21.9342391	4.01	<.0001
Error	44	240.4679573	5.4651808		
Corrected Total	65	701.0869787			

Appendix Table 5. ANOVA of Dependent Variable: Seeds per Capsule

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	39938.79818	1901.84753	100.69	<.0001
Error	44	831.08000	18.88818		
Corrected Total	65	40769.87818			

Appendix Table 6. ANOVA of Dependent Variable: Seed Length

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	0.50465976	0.02403142	3.03	0.0010
Error	44	0.34881133	0.00792753		
Corrected Total	65	0.85347109			

Appendix Table 7. ANOVA of Dependent Variable: Seed Diameter

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	0.26237103	0.01249386	2.15	0.0161
Error	44	0.25553733	0.00580767		
Corrected Total	65	0.51790836			

Appendix Table 8. ANOVA of Dependent Variable: Hundred Seed Weight

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	68.11136715	3.24339844	83.42	<.0001
Error	44	1.71064113	0.03887821		
Corrected Total	65	69.82200828			

Appendix Table 9. ANOVA of Dependent Variable: Oleoresin Content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	94.63272330	4.50632016	39.72	<.0001
Error	22	2.49582350	0.11344652		
Corrected Total	43	97.12854680			

Appendix Table 10. ANOVA of Dependent Variable: Essential Oil content

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	17.02326591	0.81063171	64.05	<.0001
Error	22	0.27845000	0.01265682		
Corrected Total	43	17.30171591			

Appendix Table 11. ANOVA of Dependent Variable: Crude Fiber

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	1.44028716	0.06858510	28955.1	<.0001
Error	22	0.00005211	0.00000237		
Corrected Total	43	1.44033927			

Appendix Table 12. ANOVA of Dependent Variable: Ash

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	1.79476443	0.08546497	6659.43	<.0001
Error	22	0.00028234	0.00001283		
Corrected Total	43	1.79504677			

Appendix Table 13. ANOVA of Dependent Variable: Crude Fat

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	4.90232955	0.23344426	373.51	<.0001
Error	22	0.01375000	0.00062500		
Corrected Total	43	4.91607955			

Appendix Table 14. ANOVA of Dependent Variable: CP

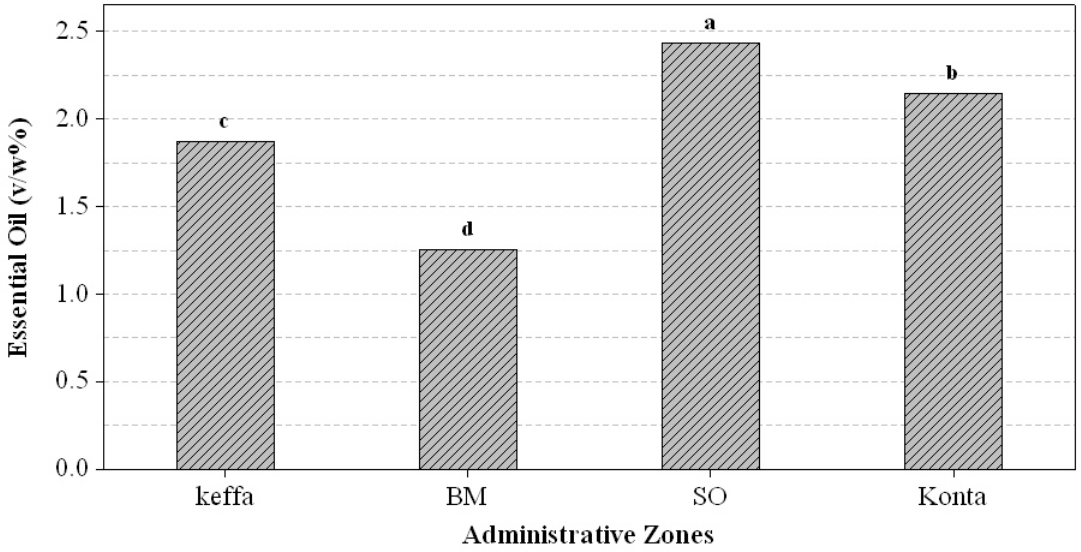
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	4.25931591	0.20282457	1531.28	<.0001
Error	22	0.00291400	0.00013245		
Corrected Total	43	4.26222991			

Appendix Table 15. ANOVA of Dependent Variable: Carbohydrate

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	21	2380.939464	113.378070	4735.75	<.0001
Error	22	0.526700	0.023941		
Corrected Total					

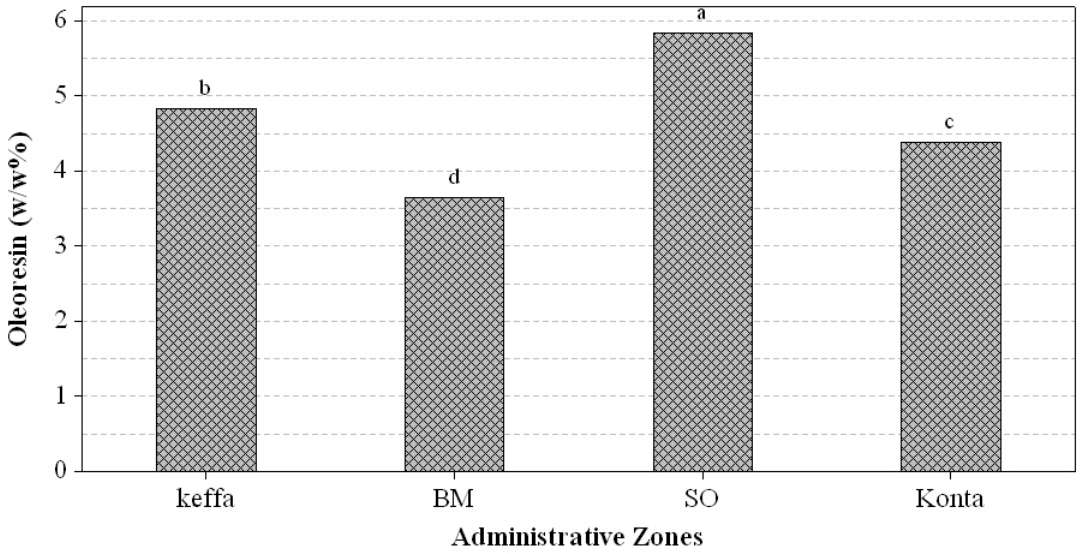
Appendix Table 16. Clusters, within cluster sums of squares and average and maximum distances from centroids

Clusters	No.	Within cluster sum of squares	Average distance from centroid	Maximum distance from centroid
1	4	877.78	13.2446	23.0498
2	15	3414.34	14.1267	23.0115
3	2	180.92	9.5110	9.5110
4	1	0.00	0.0000	0.000



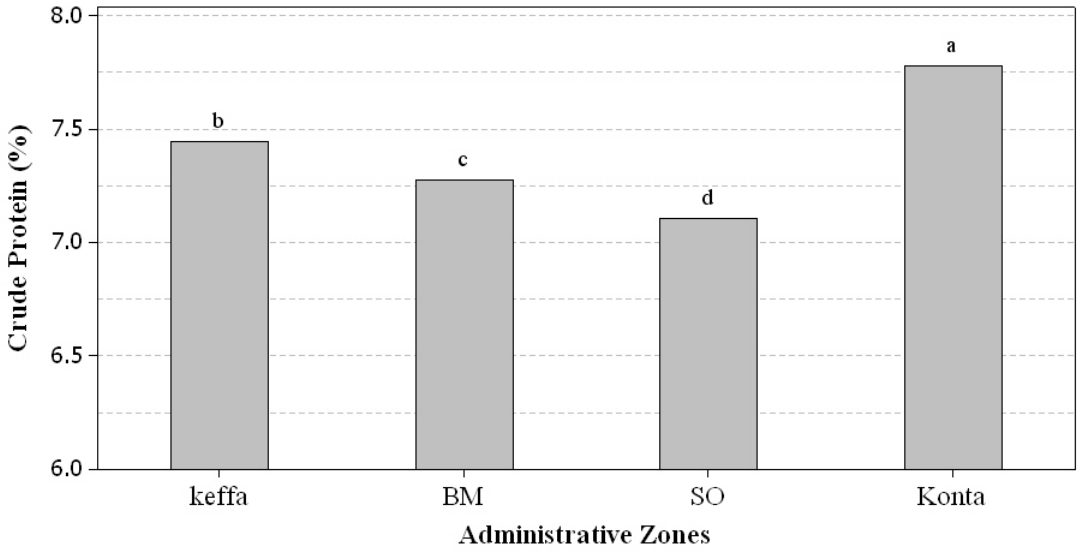
CV (%) = 23.92
LSD ($p<0.0001$)

Appendix Figure 1. Variation in volatile oil content of korarima from four Administrative zones



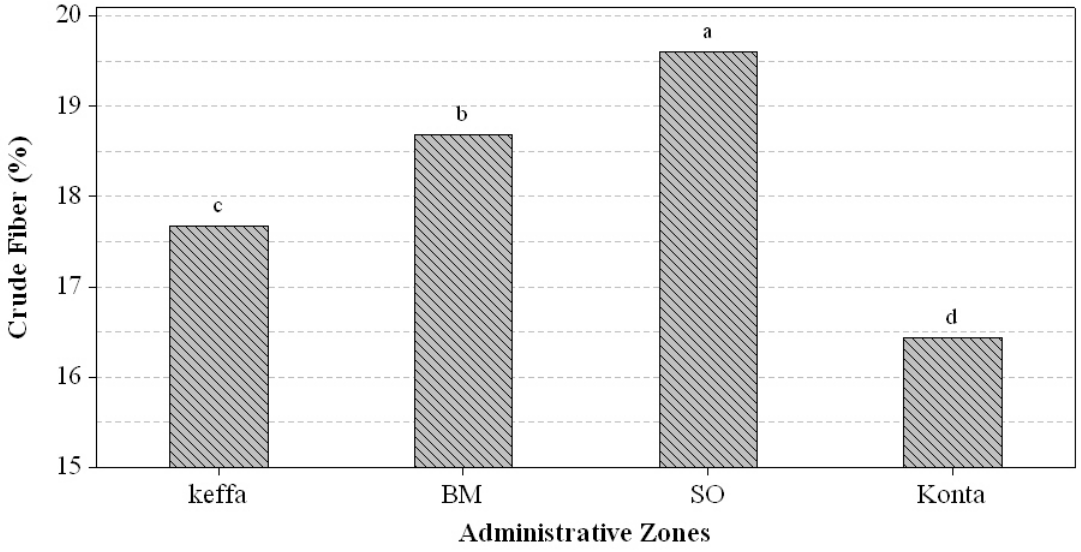
CV (%) = 17.81
LSD ($p<0.0001$)

Appendix Figure 2. Variation in crude protein, crude fiber and ash contents of korarima samples from four Administrative zones



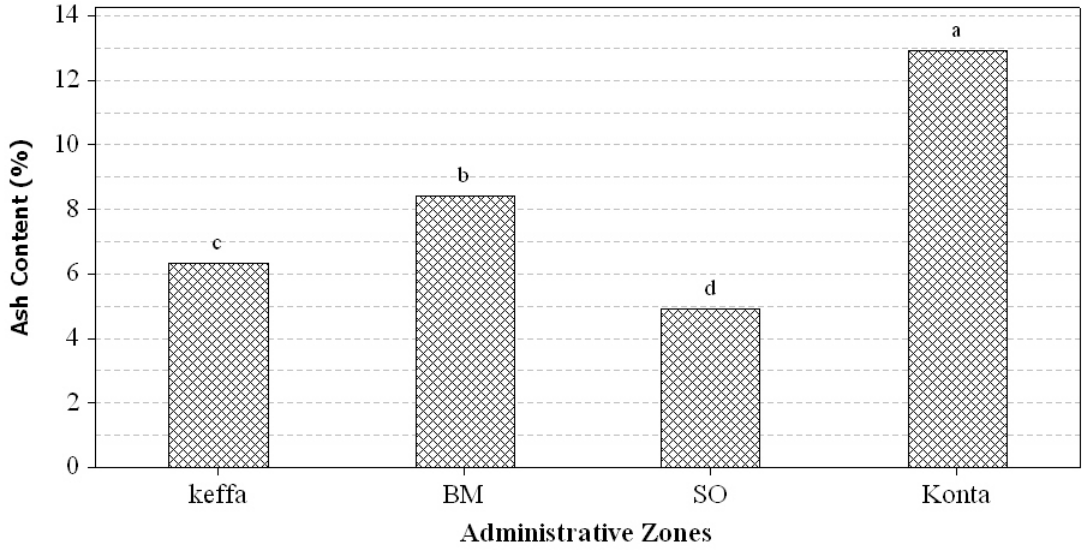
CV (%) = 3.48
LSD ($p<0.001$)

Appendix Figure 3. Variation in crude protein content of korarima from four Administrative zones



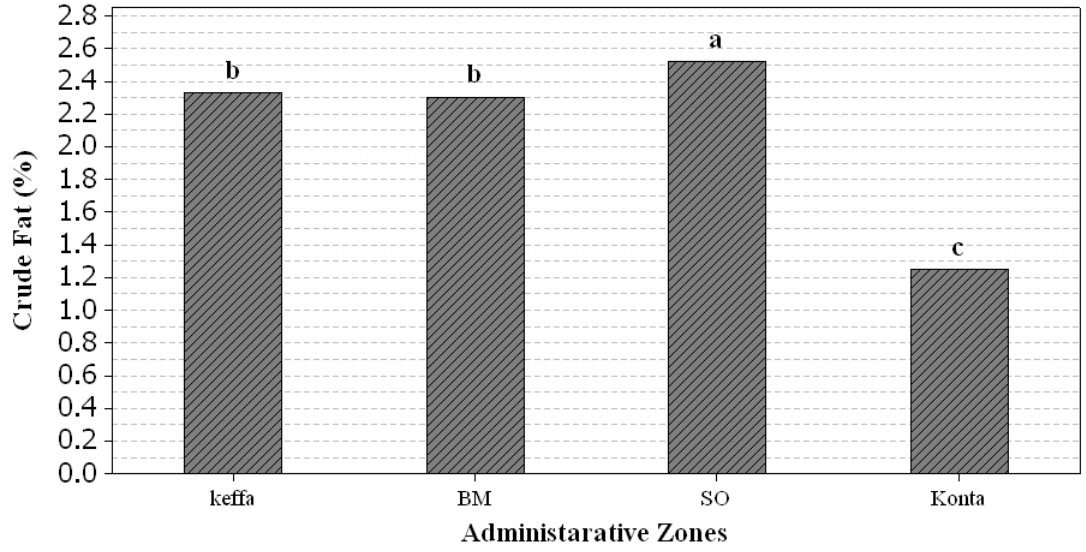
CV (%) = 6.85
LSD ($p<0.0001$)

Appendix Figure 4. Variation in crude fiber content of korarima samples from four Administrative zones



CV (%) = 38.97
LSD ($p<0.0001$)

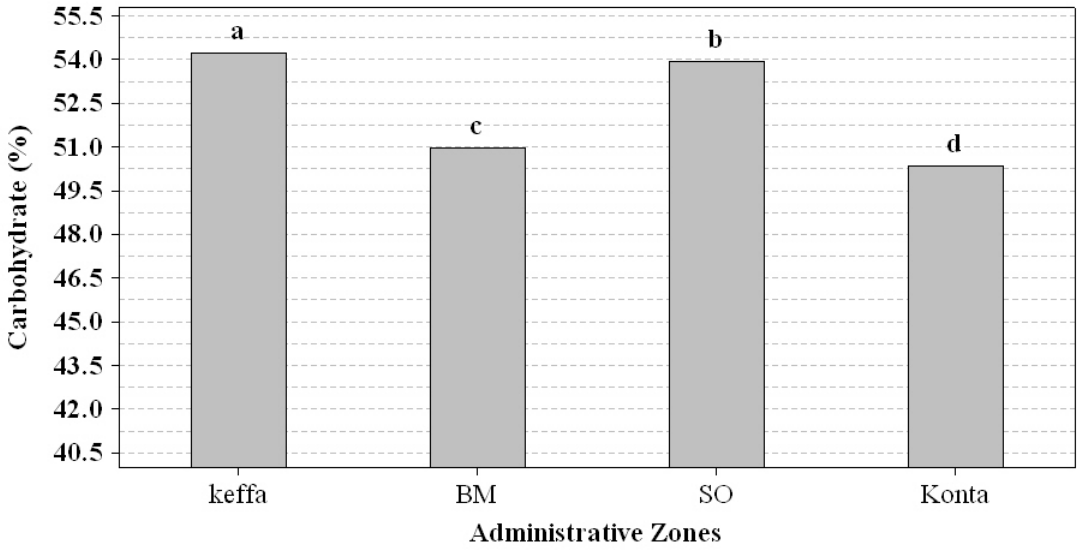
Appendix Figure 5. Variation in ash content of korarima samples from four Administrative zones



CV (%) = 25.46
LSD ($p<0.01$)

Bars with different letters are significantly different

Appendix Figure 6. Variation in crude fat content of korarima samples from four Administrative zones



CV (%) = 3.46
LSD ($p<0.001$)

Bars with different letters are significantly different

Appendix Figure 7. Variation in carbohydrate content of korarima samples from four Administrative zones