Comparative Investigation of Chemical Composition of the Two Indigenous Bamboo Species Yushania alpina and Oxytenanthera abyssinica Grown in the North Part of Ethiopia

Fikreariam Haile, Mahilet Tegaye, Yihun Bekalu, Amsalu Tolosa and Sisay Feleke

Abstract: This paper studied the comparison of chemical composition of the two indigenes Bamboo species (Oxytenanthera abyssinica, Yushania alpina) which grown in lowland and highland arias in the north part of Ethiopia. The experiment was conducted to determine extractive yield, Cellulose content, Lignin content and ash content. Chemical characterizations were employed according to the standard outlined in ASTM except Kircjmer-Hoffer. The results were analyzed by using SAS Statistical Software. From the study it showed that except Lignin content at bamboo culm position, The main effect of species with the parameter of extractive and lignin content, while the main effect of culm position with the parameter of cellulose and ash content were observed highly significantly (P<0.001) varied. Interaction effect between bamboo species and culm position highly significantly (P<0.001) influenced on Cellulose and ash content, subsequently significantly (P<0.05) influenced on Lignin content. In view of the results, it was observed that Bamboo spices type, Bamboo culm position and interaction of the two factors have clearly impact on all chemical composition parameters and most of findings in the study which were in agreement with the literatures.

Key words: Chemical Composition · Cellulose · Lignin · Oxytenanthera abyssinica · Yushania alpina

INTRODUCTION

Bamboo is a perennial grass belonging to the Poaceae (Gramineae) family Bambusoideae subfamily. The highest diversity and area coverage of bamboo is recorded from the Asian continent, followed by America and Africa [1]. Africa possesses about 43 species on over 1.5 million ha of land; 40 of these species are primarily distributed in Madagascar while the remaining three species are found in mainland Africa. Ethiopia possesses considerably wider bamboo cover. There are two indigenous bamboo species in Ethiopia [2], namely Oxytenanthera abyssinica (lowland bamboo) covered about 1,070,198 hectares and Arundinaria alpina (highland bamboo) covered approximately 31,003 hectares [3, 4]. The two indigenous bamboo species found in the country have been applied to different uses by the community since time immemorial. Highland bamboo is considered as bank account of the communities, providing ready cash required for households and purchasing agricultural inputs [5]. Lowland bamboo is used in the day to day life of bamboo growing regions. In their traditional application, the two species are used for house construction (wall, rafters, floor mats) and house materials (shelves, baskets for different uses), furniture, bed, farm implements, load carrying beams, fuel (that is used in daily basis), fencing (homesteads, irrigated and rain feed farms), piling bed for grain before trashing, storing grain, etc. The two indigenous species are also used to maintain the environment by safeguarding loss of other species and ameliorating environmental conditions in lowland and highland areas of the country. Currently there is better awareness about the potential advantages of the bamboo resource for economic development and environmental protection in Ethiopia. Moreover, currently there is critical shortage of wood.
products from other forest sources in the country. Combined with the created awareness about the potential of bamboo for economic development, this critical shortage of wood may create a good opportunity for the bamboo sector to develop.

The chemical composition of bamboo is similar to that of wood. The main constituents of bamboo culms are cellulose, hemicellulose and lignin, which amount to over 90% of the total mass. The minor constituents of bamboo are resins, tannins, waxes and inorganic salts. Compared with wood, however, bamboo has higher alkaline extractives, ash and silica contents [6, 7]. The results indicated that the Holocellulose content did not vary much among different ages of bamboo. Alpha-cellulose, lignin, extractives, pentosan, ash and silica content increased with increasing age of bamboo. Bamboo contains other organic composition in addition to cellulose and lignin. Bamboo is known to be susceptible to fungal and insect attack. The natural durability of bamboo varies between 1 and 36 months depending on the species and climatic condition [8]. The presence of large amounts of starch makes bamboo highly susceptible to attack by staining fungi and powder-post beetles [9]. It is noteworthy that even in 12 year old culms starch was present in the whole Culm, especially in the longitudinal cells of the ground parenchyma [10]. Higher benzene-ethanol extractives of some bamboo species could be an advantage for decay resistance [11]. The ash content of bamboo is made up of inorganic minerals, primarily silica, calcium and potassium. Manganese and magnesium are two other common minerals. Silica content is the highest in the epidermis, with very little in the nodes and is absent in the internodes. Higher ash content in some bamboo species can adversely affect the processing machinery.

The internodes of solid bamboo has significantly higher ash, 1% NaOH, alcohol-toluene and hot water soluble than the nodes [12]. However, differences between the major chemical composition of node and internodes fraction of bamboo are small [13]; neither the number of nodes nor the length of internodes segments would be critical to the utilization of bamboo for energy conversion, chemical production, or as a building material. [14]. Investigated the chemistry of the immature Culm of a moso-bamboo. The results indicated that the contents of cellulose, hemicellulose and lignin in immature bamboo increased while proceeding downward of the Culm. The increase of cellulose in the lower position was also accompanied by an increase in crystallinity. Since the amount of each chemical composition of bamboo varies with age, height and layer, the chemical compositions of bamboo are correlated with its physical and mechanical properties. Such variation can lead to obvious physical and mechanical properties changes during the growth and maturation of bamboo. The rational of this study was comparison of culm position and age on chemical properties of the two bamboo spices (O. abyssinica and Y. alpina) and also generating holistic production and utilization use promising raw material for chemical and biochemical based industries in Ethiopia.

**MATERIALS AND METHODS**

**Study Area:** The study was conducted in the lowland area at Injibara and the highland area at Pawe in the North western part of Ethiopia. Injibara is about 447 km away from the capital city of Ethiopia. Geographically, Injibara is found in 10°59’ N and 36°55’ E longitude. The highest and lowest altitude of Injibara is recorded to be 254 m.a.s.l and 3000 m.a.s.l respectively [15]. Pawe found in 11°09, N and 36°03, E longitude and has an altitude of 1120 m.a.s.l and mean annual rainfall of 1587 mm [16].

**Sample Collection:** Authentic Representative bamboo culms for the introduced Bamboo species sample tree at the age of 3, 4 and 5 years were collected from the two sites based on considered the culm positions. The strips were dried in an oven 40°C for the period of 8hr and then grounded in Wiley Mill equipped with a No. 20 mesh screen. The grounded material was placed in a shaker and particles that passed through a No.40 mesh sieve (425-μm) yet retained on a No. 60 mesh sieve (250-μm). The resulting material was placed in a polyethylene bag according to the experimental sating for further chemical analysis in the studies. A total of 27 treatment combinations were used for the study, comprising 3 levels of position (Top, Medium and Bottom) and 3 level of bamboo tree ages ( 3, 4 and 5). The design for the experiment was completely randomized design with three replications [17] used in the studies.

**Characterize Chemical Properties on Bamboo Species:** All tests were conducted under the standards of American Society for Testing and Materials (ASTM) except for alcohol-toluene solubility and cellulose determination. There was a minor modification for extractive content test. Instead of benzene solutions, toluene solution was used. The exact standard that was followed for each chemical property is presented in Table 1.
Table 1: Standards of American Society for Testing and Materials (ASTM)

<table>
<thead>
<tr>
<th>Property</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol-toluene solubility</td>
<td>ASTM D 1107-56 (Reapproved 1972) [18]</td>
</tr>
<tr>
<td>Klason lignin</td>
<td>ASTM D 1106-56 (Reapproved 1977) [19]</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Kurchner-Hoffer [18]</td>
</tr>
<tr>
<td>Ash Content</td>
<td>ASTM D 1102-84 (Reapproved 1990) [20]</td>
</tr>
</tbody>
</table>

**Data Analysis:** The statistical analysis was done with SAS software version 9.0 and SAS Studio (which is free university license and very good for assumption checking). The classical general linear model with two-way ANOVA fits the data very well as shown in the results. Mean separation was carried out using LSD at \( P<0.001 \).

**RESULTS AND DISCUSSION**

**Variation in Chemical Properties of the Two Bamboo Species:** The chemical compositions of the study spices are presented in Table 1. The result showed highly significant difference between the indigenous spices in extractives, lignin and ash contents. There was also similarly significant difference for cellulose and ash content among bamboo culm position but lignin content showed no difference for the culm position (Table 2). Moreover, species and culm position interaction effect had shown a highly significant value for extractives, cellules and ash content, subsequently lignin content significantly at probability \( P = 0.05 \) (Table 2). These results have shown Similar tendency with previous study by Fikremariam et al. [3].

**Interaction Effect of Bamboo Species and Bamboo Culm Positions for Chemical Properties of** *O. abyssinica* **and** *Y. alpina** **Extractive Yield:** As shown in Table 3, the study species and culm position interaction effect had a significant difference value on the chemical composition analysis. Maximum yielding of the extractives was found at top and meddle Bamboo culm position on *Oxytenanthera abyssinica* with the value of 7.47% and 7.27%, respectively. The finding of this study comparable with that of *Phyllostachys pubescens* reported by Xiaobo et al., 2004 reneges from 2.86-7.34 % at different age and position [22] and also similar conformity with the discussion reported by Amsalu et al. [23] which is stated that *Oxytenanthera abyssinica* contained more substances like waxes, fats, resins, phytosterols, non-volatile hydrocarbons, low-molecular weight carbohydrates, salts and other water-soluble substances. Wax material attached to the inner layer also contributed to the higher alcohol-toluene extractive content relative to the middle and outer layers. Higher alcohol toluene extractive in bamboo may be advantage for anti-decay and it will provide good strength in fiber processing because of its higher specific gravity.

**Cellulose Content:** Maximum percentage cellulose content recorded for the experiment was found at bottom culm position on *Oxytenanthera abyssinica* with the value of 51.05% and in agreement within the value cellulose content of soft woods (40-52%) reported by Fengel & Wegener [24] Similar result was obtained for *Oxytenanthera abyssinica* with the value (52.06%) reported by Amsalu et al.[23] and comparably low cellulose content (46.08-47.91%) reported by Xiaobo et al. [22]. The next higher value of cellulose content were found statistical similar at top, meddle and bottom culm position with the value of 47.22%, 47.46% and 46.96% on *Yushania alpina* and at meddle culm position with the value of 47.79% on *Oxytenanthera abyssinica* (Table 3). These results are comparable to with other studies reported by Xiaobo et al.[22], which was much closed (46.08-47.91%) on chemical and mechanical properties of bamboo and its utilization potential for fiberboard manufacturing. The smallest cellulose content (45.05%) was attained for *Oxytenanthera. abyssinica* at top culm position and in agreement with the value cellulose content of soft woods (40-52%) reported by Fengel & Wegener and Dence [24].

Table 2: Analysis of Variance (ANOVA) for chemical properties of *O. abyssinica* and *Y. alpina*

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>DF</th>
<th>Extractives</th>
<th>Cellulose</th>
<th>Lignin</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
<td>2</td>
<td>4.95***</td>
<td>2.53*</td>
<td>38.11***</td>
<td>0.75***</td>
</tr>
<tr>
<td>Position</td>
<td>2</td>
<td>0.28*</td>
<td>12.33***</td>
<td>0.35ns</td>
<td>3.32***</td>
</tr>
<tr>
<td>Culm position*position</td>
<td>4</td>
<td>3.86***</td>
<td>14.89***</td>
<td>3.31*</td>
<td>0.29***</td>
</tr>
<tr>
<td>CV</td>
<td></td>
<td>4.04</td>
<td>1.61</td>
<td>3.23</td>
<td>1.94</td>
</tr>
<tr>
<td>R²</td>
<td></td>
<td>0.94</td>
<td>0.88</td>
<td>0.82</td>
<td>0.99</td>
</tr>
</tbody>
</table>

*** = Significant at \( p <0.001 \); ** = Significant at \( p < 0.01 \); *= Significant at \( p < 0.05 \); ns= Non significant at \( p < 0.05 \)
Table 3: Interaction effect between Bamboo species and Bamboo culm position on different chemical properties of the two indigenes Bamboo species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Extractives</th>
<th>Cellulose</th>
<th>Lignin</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Top</td>
<td>Medium</td>
<td>Bottom</td>
<td>Top</td>
</tr>
<tr>
<td><em>Y. alpina</em></td>
<td>5.69c</td>
<td>5.10d</td>
<td>6.62b</td>
<td>47.22b</td>
</tr>
<tr>
<td><em>O. alpina</em></td>
<td>7.47a</td>
<td>7.27a</td>
<td>5.83c</td>
<td>45.05a</td>
</tr>
</tbody>
</table>

= Significant at p < 0.001; †= Significant at p < 0.01; ‡= Significant at p < 0.05; ns= Non significant at p < 0.05

**Lignin Content**: Maximum and statistical similar percentage lignin content were observed at top, meddle and bottom culm position with the value of 29.04%, 29.91% and 28.92% for *Oxytenanthera abyssinica*, respectively. This is larger by 19.93% to earlier results reported by X.B. Li *et al.* [22] and also maximum by 23.20% to the previous results reported by Amsalu *et al.* [23]. The least lignin content was found at middle culm position with value of 25.29% for *Yushania alpina* (Table 3).

**Ash Content**: As shown in Table 3, the interaction effect indicated that significantly lower ash content were observed at top culm position for the two indigenes Bamboo species (*Yushania alpina*, *Oxytenanthera abyssinica*) with the values 1.44% and 1.50%, respectively (Table 3). This result is very closed to earlier results reported by *Phyllostachys heterocycla* 1.3% and *Phyllostachys reticulate* 1.9% [25] and *Phyllostachys pubescens* ranges from 1.26-1.94% [22] at different position and age. Maximum percentage ash content recorded for the experiment was found at bottom culm position on *Yushania alpina* with the value of 3.19%, which was followed by *Oxytenanthera abyssinica* (2.73%) in the same culm position. In general these results are comparable to with other studies lower than *Oxytenanthera abyssinica* from Assosa which yield 5.3% [23] and similar with studies by Razak *et al.* [26], which were reported to be 0.88% to 2.84%.

**CONCLUSION**

From this research, we have found significant increases in cellulose content from the top to the base of the culm at *Oxytenanthera abyssinica* but on *Yushania alpina* were observed statistical similar at all three culm position. Alcohol-toluene extractive content increased in *Yushania alpina* and decreased in *Oxytenanthera abyssinica* crossways from the top to the bottom of bamboo stems. The value of ash content was increased across from the top to the bottom of the culm at both species and Klason lignin contents have highest at *Oxytenanthera abyssinica* than *Yushania alpina* with the value of each culm positions have revealed statistical comparable. In general, main and interaction effect of the two factors have clearly impact on all chemical composition parameters and most of findings in the study which were in agreement with the literatures. Therefore, *Oxytenanthera abyssinica* and *Yushania alpina* grown in Ethiopia have better chemical composition and has a great potential for different industrial applications such as pharmaceuticals, biochemical and beverages products.

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**REFERENCES**


17. Gomez and Gomez Dual Language Enrichement (DLE) model was originally developed in 1995 and first implemented in 1995 in the pharr-san juan-Alamb.


