ABSTRACT
Owing to the increasing demand and stagnant production of vegetable oil from conventional sources, non-conventional sources specially the tree borne oil seed plants are gaining importance in the industry in recent years. Considering the vast plant wealth and with an objective to explore untapped potentialities of vegetable oil sources of North-East India, a research programme was undertaken. The present communication is based on the investigation of seeds of two species of the family Moraceae viz. *Artocarpus chaplasha* and *Artocarpus heterophyllus* for fats and oils. Both the species exhibited oil yield at 9-10% level on dry weight basis. Physico-chemical properties and fatty acid compositions of the oils of both the species were analyzed. Saponification (131.6) and Iodine (96) values were found higher in *Artocarpus chaplasha* than that of *Artocarpus heterophyllus*. Gas liquid chromatography analysis of methyl ester extracted fatty acid indicated dominant fraction of linoleic acid in both the species viz. 31% in *Artocarpus chaplasha* and 28% in *Artocarpus heterophyllus*, followed by palmitic acid, stearic acid and oleic acid in 10% and 11%, 3.2% and 1.7% and 4.7% and 5.2% concentrations of their total oils respectively. The higher amount of linoleic acid content in the oils suggested that the species may serve as valuable raw materials for vegetable oil which can be explored as substitute for industrial feasibility. Trace elements like Ca, Fe, Mg, Na, K, Zn, Al, Mn, Cr, Pb were also determined by using atomic absorption spectroscopy (AAS).

KEYWORDS: Artocarpus, Fatty oil, Linoleic acid, Trace elements, Tree borne oil seeds.

INTRODUCTION
Vegetable oil has always been an integral part of human diet. The vegetable oil industry in India is now the 2nd largest after petroleum industry and its annual turnover is about Rupees One lakh crores (Pan et al., 2008; Debdeep De, 2011). The country was once, one of the
major producers of vegetable oil in the world. However, out of the 150 million tonnes of present global production, the country presently produces about 8-9 million tonnes and has to import more than 50% of the domestic requirement of vegetable oils (Pan et al., 2008; Hedge D. M., 2012). The production of oil seeds is almost stagnant at about 8-9 million tonnes for the last few years. Hence, in order to make India self-sufficient in the sector, vegetable oil from non-traditional sources is gaining importance in recent years (Kotoky et al., 2001).

India’s forest base is rich in a variety of tree-borne oil seeds and there were no serious efforts to exploit the less known oil seeds of the forest origin. At present among the tree borne oil seed plants of India, the seeds of the plants like Shorea robusta Gaertn.f. (Sal), Madhuca indica J.F.Gmel. syn. M. longifolia var. latifolia Macbr. (Mahua), Azadirachta indica A. Juss. (Neem), Pongamia pinnata Pierre (Karanj), Schleichera oleosa (Lour.) Oken. (Kusum), Salvadora oleoides Decne (Khokan), Calophyllum inophyllum Linn. (Undi), Sapindus mukorossi Gaertn., (Ritha), Simarouba glauca DC. (Paradise Tree) are utilized for the extraction of fatty oils on commercial scale (Bringi et al., 1987; Dev et al., 1979; Jain et al., 1988; Satapathy et. al., 1984). It is estimated that if the country properly utilize its available seed potentials of forest origin there is a possibility of acquiring 11.23 lakh tonnes of fatty oils in the country (Gulati et al., 1982).

North-Eastern region of India, due to its varied topography, climate and soil is rich in plant diversity representing about 50% of the total flowering plants of the country. The region also endowed with a vast treasury of tree borne oil seed plants many of which are even used by the native people for edible purposes. However, in-spite of ample scope, excepting a very few work (Kanjilal et al., 2001; Kotoky et al., 2001; Kotoky et al., 2007) adequate attention has not so far been paid to utilize these resources in the vegetable oil sector. The quality of edible oils is generally detected by the composition of fatty acid and several physico chemical properties. But the determination of the inorganic profile of oils is important because of the metabolic role of some elements in the human organism. Since the importance of trace elements in human health was observed during the recent years (Parmar et al., 1982). The various trace elements present in edible oil such as Na ,K, Ca, Mg, Cu, Zn and Mn are essential micronutrients for human growth (Parmar et al., 1982) Pb and Cd are toxic elements responsible for various disorder in human health are well known (Anjali Ruikar et al., 2009). The analysis of these metals require accurate, reproducible and rapid analytical method for quality control. Atomic Absorption Spectrometry, one of such rapid analytical methods is currently considered as an accepted tool for quality control aspect of oils and fats too.
Thus, as a part of an ongoing R & D programme of vegetable oil from the tree borne oil seed plants of North-East India, we investigated two plant species of the Moraceae family viz. Artocarpus chaplasha and A. heterophyllus based on their edible and medicinal characteristics and the results encountered are presented in this communication.

MATERIALS AND METHOD

The matured seeds of Artocarpus chaplasha and A. heterophyllus were collected from the areas in and around Jorhat of upper Assam. The time of fruit maturity and the average seed yield per annum of the plant species were recorded during the field studies. The weight of each seed in gram was also determined. The collected seed samples were properly cleaned to remove foreign materials, dried and powdered. The seed powders of the species were separately subjected for quantitative extraction of fatty oil using 60ºC - 80ºC petroleum ether in Soxhlet apparatus. The oil samples thus obtained were immediately analyzed, where delay is anticipated, oils are stored in refrigerator. Physico-chemical properties like refractive index, saponification value and acid value of the oils were determined following the method, IS: 548 (1964). Refractive index was determined by Refractrometer. Fatty Acid Methyl Ester (FAME) was prepared from the oil using the method IS: 548-part 3(1976). The FAME was identified by comparison of the retention time and peak enhancement with known FAME mixture. The Gas Chromatography analysis was carried out on a Chemito 8310 FID/GC coupled to a HP integrator for data processing. A NUKOL (SUPELCO) wide bore column(15m × 0.63 mm id × 10µm film thickness) was used to separate sample components with oven temperature programmed from 90 to 160ºC @ 3.0ºC per minute and 160 to 230ºC @ 3.5ºC per minute. Hydrogen was used as the carrier gas with flow rate of 7ml/minute. Injector/detector temperature was maintained at 235ºC and area normalization method was applied for quantitative estimation of the sample components.

The oil samples obtained from the oil seeds were further analyzed for their trace elements. The oil samples were transferred to a digestion vessel and weighed (approx. 0.3gm) accurately. The samples were digested using a mixture of supra-pure conc. HNO₃ and H₂O₂ by microwave digestion system (Model- START-D Milestone, Italy) for 10-30 minutes at 210ºC. The aliquots thus prepared were used for trace metal estimation using atomic absorption spectroscopy (Model-A Analyst-700, Perkin Elmer). The analysis was performed using the software Win Lab 32 (version G.S.O.0266, Perkin Elmer Inc.). Most of the metals were estimated by ICP-AES technique. The Flame technique is used to determine various
metals like Cu, Ca, Fe, Mg, Na, K, Zn, and Mn. Graphite Furnace is used to determine other few elements like Cr, and Pb.

RESULT AND DISCUSSION

Data on distribution, flowering and fruiting of the species along with their seed availabilities and weight are presented in Table 1. The flowering of both the species commence during rainy season and their fruits mature in summer season. In general the studied species are found throughout the North-East India up to an altitude of 7000 m. However, as regards their availabilities in the study area, it was observed that the production of *A. heterophyllus* seed is estimated at 9,649 kg/hectar which is at per the report of Govt. of Assam (2010). Likewise, the seed production of *A. chaplasha* is estimated at 1,230 kg/hectar/annum which are also at per the reports of Bisht and Ahlawat (1999). The seed weight is however higher in *A. heterophyllus* than that of *A. chaplasha* (Table 1).

Table 1: Distribution of *Artocarpus* species and their seed availability in the study area

<table>
<thead>
<tr>
<th>Sl no</th>
<th>Name of the species</th>
<th>Local Name</th>
<th>Distribution</th>
<th>Flowering Time</th>
<th>Fruiting Time</th>
<th>Weight per seed (gm.)</th>
<th>Availability (kg/hector / annum)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Artocarpus chaplasha</em></td>
<td>Sam-kothal</td>
<td>Wild and fairly common</td>
<td>March-April</td>
<td>July-August</td>
<td>0.6-1.1</td>
<td>1,230</td>
</tr>
<tr>
<td>2</td>
<td><em>Artocarpus heterophyllus</em></td>
<td>Kothal</td>
<td>Cultivated and common</td>
<td>March-April</td>
<td>July-August</td>
<td>2.4-4.5</td>
<td>9,649</td>
</tr>
</tbody>
</table>

The yield and physico-chemical properties viz. saponification value, refractive index, acid value, free fatty acid, iodine value and ester value of the oils of both the species are presented in Table 2. The oil yield (DWB) of *A. chaplasha* was slightly higher (10%) than that of *A. heterophyllus* (9.1%). The saponification and iodine value were higher in *A. chaplasha* than that of *A.heterophyllus*. In contrast, acid value was found higher in *A. heterophyllus* compared to *A.chaplasha*.

Table 2: Physico-chemical properties of fatty oil of the *Artocarpus* species

<table>
<thead>
<tr>
<th>Name of the species</th>
<th>Moisture content (%)</th>
<th>Oil Yield (%)</th>
<th>Colour of oil</th>
<th>Refractive Index</th>
<th>Saponification value</th>
<th>Acid value</th>
<th>Ester value</th>
<th>Iodine value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Artocarpus chaplasha</em></td>
<td>66.09</td>
<td>10.41</td>
<td>Pale yellow</td>
<td>1.4577°D at 30.7°C</td>
<td>131.6</td>
<td>11.2</td>
<td>120.4</td>
<td>96.7</td>
</tr>
<tr>
<td><em>Artocarpus heterophyllus</em></td>
<td>49.61</td>
<td>8.89</td>
<td>Golden brown</td>
<td>1.475°D at 30.7°C</td>
<td>96.92</td>
<td>20.33</td>
<td>76.6</td>
<td>82.36</td>
</tr>
</tbody>
</table>

Compositions of fatty acids of the seed oils of the investigated species are presented in Table 3. Gas chromatography analysis of the fatty acid methyl ester derived from oils indicated that...
the seeds of both the species contained linoleic, palmitic, oleic, stearic, behenic, arachidic, lauric, myristic and linolenic acid in their oils. Linoleic acid was recorded to be higher in *A. chaplasha* (31%) followed by *A. heterophyllus* (28%) whereas the palmitic acid was revealed to be higher in *A. heterophyllus* (11%) than that of *A. chaplasha* (10%). Minor quantities of stearic, oleic, arachidic, behenic and linolenic acid were also present in the oils of both the species. From this investigation it is recorded that the unsaturated components of fatty oil are more than that of the saturated components in both the species.

### Table 3: Fatty acids compositions of the seed oils of *Artocarpus* species

<table>
<thead>
<tr>
<th>Fatty Acids</th>
<th>Components</th>
<th>Retention time</th>
<th><em>Artocarpus chaplasha</em></th>
<th><em>Artocarpus heterophyllus</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Palmitic</td>
<td>32.0</td>
<td>10.8</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Stearic</td>
<td>36.6</td>
<td>3.2</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>Oleic</td>
<td>36.7</td>
<td>4.7</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>Arachidic</td>
<td>41.7</td>
<td>9.9</td>
<td>5.2</td>
<td></td>
</tr>
<tr>
<td>Behenic</td>
<td>40.0</td>
<td>10.8</td>
<td>8.3</td>
<td></td>
</tr>
<tr>
<td>Linoleic</td>
<td>38.1</td>
<td>31</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>Lauric</td>
<td>22.0</td>
<td>4.6</td>
<td>11.3</td>
<td></td>
</tr>
<tr>
<td>Myristic</td>
<td>27.6</td>
<td>3.5</td>
<td>5.8</td>
<td></td>
</tr>
<tr>
<td>Linolenic</td>
<td>28.7</td>
<td>18.1</td>
<td>13.1</td>
<td></td>
</tr>
</tbody>
</table>

The quantity of linoleic acid in both the species was found to be more than that of mustard oil (7.1%) (Johnson et al., 2009). The linoleic acid content present in the seed oils of the species suggested their possible usability in edible oil industry as the polyunsaturated fatty acids are more suitable for edible purpose. Diet with increasing intake of linoleic and linolenic acid increases HDL-cholesterol and decreases LDL-cholesterol, while higher intake of oleic acid decreases LDL-cholesterol without affecting HDL-cholesterol levels (Zambiazi et al., 2007).

**Fig: Bar-diagram on percentage of Fatty acid composition of the two *Artocarpus* species.**
The results of analysis of the various trace elements in the seed oils of this species are presented in Table 4. Trace elemental analyses reveals that Na, Fe, K, Ca, Mg, Zn, Mn and Cu were present in all the seeds in different concentrations.

Table 4: Trace elements present in the seed oils:

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Plant species</th>
<th>Cu (mg/kg)</th>
<th>Ca (mg/kg)</th>
<th>Fe (mg/kg)</th>
<th>Mg (mg/kg)</th>
<th>Na (mg/kg)</th>
<th>K (mg/kg)</th>
<th>Zn (mg/kg)</th>
<th>Mn (mg/kg)</th>
<th>Cr (mg/kg)</th>
<th>Pb (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Artocarpus chaplasha</em></td>
<td>BDL</td>
<td>20</td>
<td>10</td>
<td>6.7</td>
<td>15</td>
<td>8.4</td>
<td>5</td>
<td>BDL</td>
<td>0.08</td>
<td>BDL</td>
</tr>
<tr>
<td>2</td>
<td><em>Artocarpus heterophyllus</em></td>
<td>BDL</td>
<td>189</td>
<td>11.8</td>
<td>148</td>
<td>31</td>
<td>204</td>
<td>7.4</td>
<td>BDL</td>
<td>0.06</td>
<td>0.07</td>
</tr>
</tbody>
</table>

The results further revealed that Calcium (Ca) was found to be the predominant mineral followed by Potassium (K) and Magnesium (Mg). High concentration of Ca is important because of its role in bones, teeth, muscles system and heart functions. In human body, iron (Fe) is necessary for hemoglobin formation, oxygen and electron transport. Iron deficiency is the most prevalent nutritional deficiency in humans. The zinc concentration in the studied plants ranges between 5-7.4. It is an essential trace element and plays an important role in various cell processes, normal growth, brain development etc. Zinc deficiency results in retardation of growth in children, low blood sugar, brain disorder, high blood cholesterol, (Devi R. K. Bhanisana, 2013)

In contrast, the toxic elements Cr and Pb were detected in a very low concentration in the oils. The findings thus indicated that the oils obtained from the seeds of species which were used by the local people for edible purposes bears promising potentialities for nutritional and other industrial use.

*A. heterophyllus* and *A. chaplasha* are known locally in Assam as “Kothal” and “Sam-kothal” respectively and their seeds are edible and used by the people for food and nutritional values. The seeds of *Artocarpus heterophyllus* were found to be rich in proteins, carbohydrates and minerals with moderate amount of phyto-chemicals and strong antioxidant properties (Gupta et al., 2011). Thus, further studies need to be undertaken for their economic and industrial viability.
CONCLUSION
The seeds of both the *Artocarpus* species are used for edible purposes. The present investigation revealed that the seeds of *Artocarpus* species contain appreciable amount of unsaturated fatty acids. The presence of polyunsaturated fatty acids increases the edible quality of the oil. Further trace elemental analysis by AAS, revealed that both the seed oils contain appreciable amount of essential trace elements which adds nutritional value to the edible property of the oil. Thus, there is a possibility that the seeds of both the *Artocarpus* species may be used for manufacturing vegetable oil for both edible and other industrial applications. However much remains to be done in this regard.

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REFERENCE