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Emerging improvements in the Characterization and Advanced utilization of Woodland fibres and its Hybrid Composites

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Abstract

Due to worldwide concern for the environment and greater knowledge of sustainable natural resources, efforts have been made to supply environmentally acceptable and compostable material for the next era of composite materials. Besides the advantages of green materials, working with these is challenging, such as poor affinity between natural fibres and matrices, as well as the moisture absorption was higher for natural fibres. Various investigators examined the characteristics of composites of natural fibre. These studies have led to numerous techniques for the modification of fibres from wood and resins. The characterization of woodland fibres composites in terms of its applications as sound and thermal insulation has been investigated. A modern review of the natural fibres classification and sources, processing methodologies, physio- mechanical behaviours, implementations, thermal, cycle of life analysis and other characteristics of green composites is intended to explain the behaviour of bio-composites in order to address the rising requirements for use of environment-friendly materials in various application domains. This chapter provides a variety of well-known natural fibres from woodland trees from different climate zones.

Keywords: Bio-composites, Natural fibres, Sound insulation, Sustainable natural resources, Woodland fibres.

Introduction

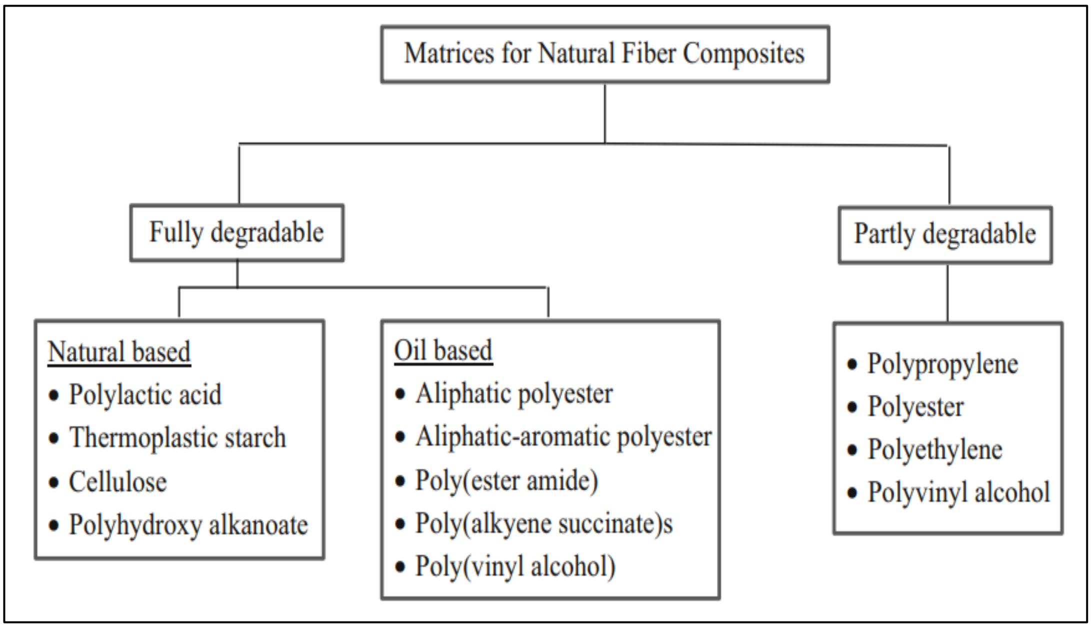
One of the primary goals of forestry is to cultivate trees. Every year, a large amount of sustainable raw material is created. Tree cultivation has a big impact in that it captures carbon dioxide in the atmosphere, which then builds up in the tree cellular structure via photosynthesis (Pasztory *et al.*, 2016). According to the FAO 2019, over 3966 million m^3 of roundwood were lumbered in 2019-2020. The market share of the plant-based fibres was around 5.8% of total global fibre volume of production in 2019, with a worldwide production output of around 6.5 million MT(TextileExchange, 2020). The use of ecologically friendly natural fibres, including certain recyclable, biodegradable, and renewable materials, has lately been proposed as a way to reduce the environmental effect of petroleum-based substances(Alix *et al.*, 2014). Fully natural fibres are bio-composite materials made out of biofibres and resins based on renewable forestry and agricultural feedstock. When this sort of composite reaches the end of its useful life, it is disposed of and composted without impacting the environment (Gurunathan *et al.*, 2015). Natural fibres have several unique qualities that may help their composites in some applications, even though synthetic fibres excel in these areas. Lower density, vibration dump, and blunt fracturing are three of their most huge benefits. In the same way that synthetic materials can be made to withstand creep with load in high temperatures, natural fibres can be made to resist creep under load in high temperatures. When compared to regularly used glass fibres, they also reduce wearing on screws and barrel of plastic manufacturing equipment (Faruk *et al.*, 2012). Fibres can be made from a variety of tree parts, including leaves, bast, stems, bark, and seeds. Harvesting, soaking, brushing, and drying are all steps in this procedure.. In addition, the thickness of a single fibre varies depending on the fibre type (FAO,2014) (Bledzki *et al.*, 2015). Trees are made up of leaves and a trunk when viewed as a whole (which comprises bark and wood). Phase, thickness, density, stiffness, diffusion–surface geometry, porosity, and airflow resistance are all macroscopic properties that influence material performance. The fibre characterisation of a trunk is also represented by the geometries of the bark and wood. At the microscopic scale of fibre cells, the bark and wood structures of different tree species range significantly in dimensions and density (Sağlam *et al.*, 2020). An overall comparison is provided below to show certain advantages of wood vs plant fibres, and vice versa. Likewise, cellulose fibres are contrasted with their synthetic counterparts, glass and carbon fibres. Despite their contrasts, wood and plant fibres have more in common than they have differences. There are a few benefits of cellulose fibres over glass and carbon fibres that may be noted.

Classification of Matrix

A matrix is utilised to keep the reinforcing elements together by adhesion in the composites. The matrix's primary duties are the composite's durability, surface texture, and longevity. When the matrix is strained, it distributes the external load equally to the fibres and is used to avert fractures and breakage from spreading (Campilho, 2015).

Resins derived from petrochemicals

A petro - chemical matrix is a petroleum-based compound produced from energy sources such as coal and natural gas (Faruk *et al.*, 2012). Thermoplastic resins are made up of fluid polymers that may be readily moulded and solidified after cooling (physical change). Thermosetting polymers have ten times the impact resilience of thermoset resins, are more reformable, have a greater wear resistance, and can be processed at high temperatures (Baeurle *et al.*, 2006). Fig.1 shows the classification of natural fibres composites.The intravenous and insoluble substances resins are thermoset resins which are cured with heat or catalyst. Thermosets vary entirely from thermoplastics, they cannot be melted and heated. This kind of resin has a higher module, enhanced creep resin tendency, more thermal stability and stronger



chemical resistance than

Fig.1. Polymeric matrix classification for natural fibre composites Source :(Campilho, 2015)

thermoplastic resins, thanks to three-dimensional covalent links between polymerization (chemical change) (Mohammad, 2007).

Bio- based resins

Organic resins are polymers produced in whole or in part from sustainable substances. Plants (e.g. starch and cellulose) or plant-based sucrants or oils (e.g. polylactic acid (PLA), polyethylene terephthalates and polypropylene) can generate biologically based polymers. The benefits of bio-based polymers are different from those of petrochemical resins: effective manufacturing energy (65% less energy required to produce), secure (no toxic as degradation occurs), compostable (faster energy break down), fully renewable (as biomass-refined) and environmentally sustainable (68% less greenhouse gas). Their manufacture cost, however, is around 10% over that of petrochemical resin (Ahmed, 2018).

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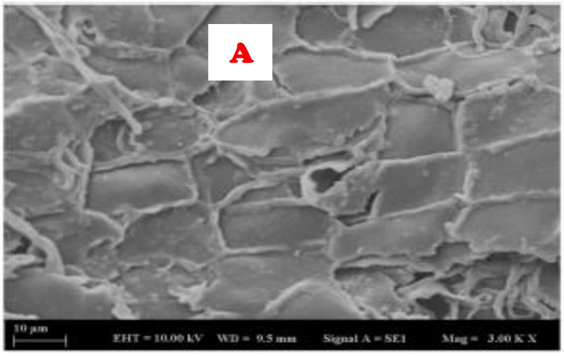
The disadvantages of wood fibres are

1) These fibres are hydrophilic in nature which are available at a cheap rate.
2) Sustainable and inexhaustible.
3) Anisotropic and
4) The composites from wood fibres are light, and they have good particular characteristics, which are significant in auto motives and packaging (Mochane *et al.*, 2019).

Structural anatomy and characterization

Trees are spermatophytes, and they are classified as gymnosperms which are seeds produced in a wooden cone or angiosperms (seeds grown in a flowering plant). Gymnosperms are classified as softwoods, while angiosperms are classed as hardwoods.



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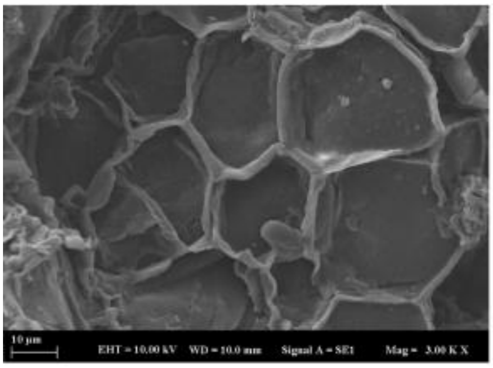

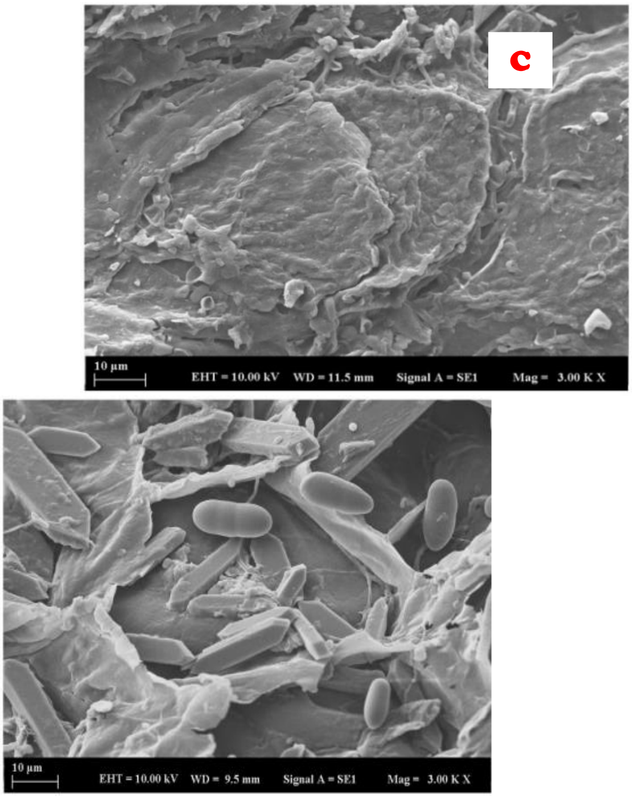

Fig.2. SEM pictures of the bark of trees in surface view; A)Silver bar bark(3000X), B) Sessile oak (3000X), C)Stone pine(3000X) and D) Maritime pine (3000X). Source:(Tudor et al., 2021)

Softwood

The wood of "softwood" (coniferous trees, e.g., pine, spruce, etc.) is mostly made up of one cell type, the longitudinal tracheid (which accounts for approximately 90% of the wood by volume). These tracheid are hollow cells with elongated, fairly thick walled wallstapering to rounded or pointy ends. Softwood tracheid are about 3-4 mm long with average diameters of 30 to 40 mm (the l/d ratio is about 100:l). Chemical pre-treatments, which removes the lignin and some or all of the hemicellulose, can be used to obtain single fibres from wood.

Hardwood

Vessel elements are unique water-conducting cells found in hardwoods. These vessel components (sometimes referred to as "pores") are typically wide in diameter (>100 µm; range, roughly 20-300 µm), short in length (often well below 1 mm), and stacked end-to-end to form longer water carrying conduits or vessels. Fibres can also be found in hardwoods. The tracheids present in softwoods are similar to this cell type. Fibres are smaller than softwood tracheids (typical diameters of 10-20 µm, length 1-2 mm) and have less visible pitting. The wood's mechanical strength is provided by fibres.

Morphology, Chemistry, and Ultrastructure of Fibres

Cellulose (45- 50 percent by weight), hemicelluloses, and lignin are the three main structural components of wood fibres (20-25 percent) as well as lignin (20-30 percent).

Cellulose, hemicellulose

Cellulose is a long, straight chain homopolymer (d.p. 5,000-10,000) made up of anhydro d-glucopyranose connected together by β 1,4 glycosidic linkages. Hemicelluloses have a lower polymerization degree (150-200) and can be straight or branched. These are made up of five- and sixcarbon sugars, respectively. Although the type and quantity of hemicellulose in wood varies by species, most hardwoods have a glucuronoxylan preponderance, which is made up of a linear backbone of xylopyranose with a 4-O-methyl-glucuronic acid residue on around 10% of the xylose rings. Cellulose, which ensures the fiber's strength, stiffness, and structural stability. P-D-mannopyrmose, P-D-glucopyranose, and a-D-galactopyranose are the main components of galacto-glucomannan found in softwoods. Free hydroxyl groups in cellulose and hemicelluloses give wood its natural hygroscopicity (Pettersen, 1984).

Lignin

Lignin is a vast, amorphous polymer made up of various ratios of phenyl propane precursors connected primarily by ether bonds, with the remainder by C-C bonds (Sjostrom, 1993). The entire aggregation is cemented together with lignin, again in methods that are not well understood, but some models suggest that lignin is deposited in a lamellar form, whereas others propose that lignin is deposited radially across the cell wall (Larsen et al., 1995).

Inorganic Ash and Extractives

Extractives are substances that do not belong to the classifications of cellulose, hemicelluloses, or lignin. They are also known as extraneous materials, secondary components, non-skeletal polymers, or non-framework polymers. Temperate woods have a total extractives content ranging from 4 to 10% by weight(Pettersen, 1984). Extractives may account for more than 20% of the weight of tropical woods. Inorganic ash content in household softwoods ranges from 0.2 to 0.5 % by weight and from 0.1 to 1.4% in domestic hardwoods. The ash content of bark and some tropical hardwoods may be significantly higher. Silica concentration is typically insignificant in domestic wood species, but can reach up to 9% in some tropical woods. Alteration in extractive biochemical structure as a result of most environmental exposure leads in a reduced surface tension and a less polar nature.

Extraction process of fibres

Several treatment processes applied to cellulosic biomass aim to break down the brittle fibre structure, allowing disintegration of the cellulose fibrils by lowering their crystalline structure or removing a significant amount of lignin, depending on the kind of substrate (Rosa *et al.*, 2020).

Retting process

For around 2 months the newly-grown stalks have been taken out of the parts of the woods and immersed in water and water has been changed periodically throughout that period. The stalks were smashed by light; individual fibres were first dried for a week in the sun. The fibres were then held for 2 hours at 600°C-700°C in a hot air oven to eliminate moisture (Madhuri et al., 2018; Eltahir *et al.*, 2020).

Chemical treatment

The wood components were cut off, debarked and put in a 50 mL acetone capsule. The samples had been left at room temperature for 2 days, the acetone dried out and substituted. The process of extraction was repeated at 48-h (Costa et al., 2017).

Kraft pulping method

The fibres are suspended and processed in a stainless digester in an alkaline sulphate solution. For the hardwood and for the softwood, the maximum temperature of the digestion was 165°C and 172°C. The period of heating was 120 minutes, and heating was likewise 120 minutes at maximum temperature. With cool tap water, the temperature dropped to 22±10 °C. After the delignment, the material had been rinsed with deionised washed repeatedly, and the leftovers of the alkali soluble portions were incubated in distilled water during the night (Małachowska and Dubowik, 2019).

Mechanical method

The bark was dried with a vacuum kiln drier with a moisture level of 100 to 9%. At a pressure of 200 to 250 mbar, the drying temperature was 60°c. Subsequently, the bark was snapped in a 4-spindle shredder and screened again and again for distinct particle size distributions (Tudor et al., 2021; Escócio et al., 2017).

Steam explosion method

The steam explosion, in which the microstructure of the wood fibre is disrupted to make its microfibrils more susceptible, is the most recently researched combination technique(Stelte, 2013). The direct interaction of the biomass with saturated steam at high pressure for a certain residence period in the reactor is the basis for this process, which operates both chemically and physically in the composition of the lignocellulosic biomass. An explosion occurs as a result of the reactor's rapid decompression. The product is then readily defibrated, resulting in an increase in contact surface area and a decrease in cell wall rigidity (Pielhop et al., 2016; Auxenfans et al., 2017).

Characteristics of wood fibres and its interaction with other materials

Natural fibre dimensions and physical and mechanical performance can be extremely varied due to different species, natural variability within species, and changes in temperatures and growth seasons. A substantial research effort is aimed at developing methods for manufacturing fibres with more repeatable characteristics (Clemons & Caulfield, 2005).

Physical characterisation

Weight and diameter/thickness of samples were measured using a digital weighing balance and Vernier callipers, respectively. The findings revealed that the varying densities of wood samples represent distinct structural topologies as a consequence of various extractive elements in the various wood samples.

Specimen	**Weight (g)**	**Diameter (µm)**	**Thickness (mm)**	**Density (g/cm^3)**	**Volume (cm^3)**	**References**
Hard maple	2.981	28.641	10.237	0.452	6.592	(Kolya & Kang, 2020)
Chestnut	3.458	28.852	10.072	0.526	6.852	
Cherry	3.152	28.814	10.247	0.472	6.678	
Sinensis	3.981	28.874	10.239	0.635	6.683	
Heavy balsa	2.124	28.883	10.269	0.140	6.732	
Platanus	4.242	28.836	10.239	0.635	6.683	
Hackberry	4.831	28.769	10.195	0.729	6.624	
Silver popular	3.173	28.852	10.072	0.526	6.852	
Paulownia	2.143	28.784	10.051	0.328	6.537	
HardwickiaBinata (Narepa)	-	260-300	300	1.5	-	(Madhuri *et al.*, 2018)
Vachellia farnesiana	-	231 ± 2.68	-	1.27 ± 4.48	-	(Vijay *et al.*, 2020)

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Soft woods	-		-	1.5		(Małachowska and Dubowik, 2019)
Light balsa	0.942	28.687	10.420	0.140	6.732	(Kolya and Kang, 2020)
Peach palm	0.53			1.20 ± 0.02		(Escócio *et al.*, 2017)
Papaya	1.28			1.21 ± 0.11		

Table 2. Physical properties of different hardwood and softwood fibres

Fig. 3. Photograph of different hardwood specimens. Source: (Kolya and Kang, 2020)

While hardwood samples are more or less porous on the surface, porosity structures differ with sample variation (Kolya& Kang, 2020). Table 2. shows the physical properties of some hardwood species.

Chemical Components

Table 3. provides a summary of the most important chemical components of natural fibres. The majority of natural fibres are around 1.5 g cm^{-3} maximum in density. Although certain natural fibres, like wood, are hollowed and in their original condition have lower density, they are typically placed and compacted through processing. However, the maximum density of the fibres, for example, is much lower than the maximum density of inorganic fibres. Their low density makes them appealing in applications with concern of weight, as reinforcements (Clemons and Caulfield, 2005). The structure and chemical composition of natural fibres vary widely and relies on the origin

Table 3. Chemical composition of different wood fibres

Samples	**Cellulose**	**Hemicellulose**	**Lignin**	**Wax**	**Moisture content**	**Ash**	**References**
Vachellia farnesiana	*38.3*	12.1	9.2	3.4	11	6.21	Vijay, James Dhilip *et al.* 2020
Peach palm	55.5 ± 0.7	3.1 ± 0.5	8.3 ± 1.5	-	9.5 ± 1.7	0.55 ± 0.2	(Escócio, Pacheco *et al.* 2017)

Papaya	62.0 ± 2.8	5.0 ± 2.4	15.1 ± 0.2	-	9.1 ± 0.7	3.3± 0.5	
Adansonia digitata L.	60.7	21.98	5.91		13	5.32	(Eltahir *et al.*, 2020)
HardwickiaBinata	81.68	7.01	11.28	-	5.25	-	(Madhuri *et al.*, 2018)
Ficus (Peepal Tree)	38.1 ± 1.07	30.5 ± 1.21	23.4± 1.04	-	-	4.5± 0.37	(Reddy *et al.*, 2016)
Eucalyptus tree	45.35 ± 0.18	22.71 ± 0.53	20.50 ± 0.01	10.92 ± 0.33		0.47 ± 0.02	(Pereira *et al.*, 2018)

*All the values are in %wt

Hybridisation of wood fibres and its various applications

Natural fibres have recently resurged in popularity as plastic reinforcements, owing to their superior mechanical properties and claimed environmental benefits. However, difficulties such as

1) A lack of proven delivery channels,

2) Processing complications (filling, gauging, and crossing) owing to the low density of the fibres, and

3) Performance concerns such as odour control are restricting the use of natural fibres as polymer reinforcements(Clemons and Caulfield, 2005).Fibres performance attributes for integrated mechanical-economic-environmental schemes were assessed and carried out with different considerations in mind.

Laminate preparation

Hossain *et al.* (2019) has investigated the effect of fiber content on the mechanical properties of the composite made from pine tree fibres. Conventional hand Lay-up technique is used in composite manufacture. Epoxy resin is used as the reinforcing agents (Hossain *et al.*, 2019).

Effect of fiber length on tensile properties

The tensile strength of the composite is reduced by the increase of the pine fibre weight portion of the composite. It is evident that with the rise of fibre load to 10wt percent, the composite flexural modulus improves substantially, however the fibre load reduces the flexural strength even farther. With the rise in fibre loading from 0wt% to 40wt% fibre loading, the impact strength of composites drops considerably. Likewise, with a change in fibre loading from 0wt percent to 40% of fibres, composite impact strength drops considerably from 20 KJ/m^2 to 11 KJ/m^2. Fig 4A,4B and 4C shows the effect of fiber loading on the tensile properties of pine fibres.

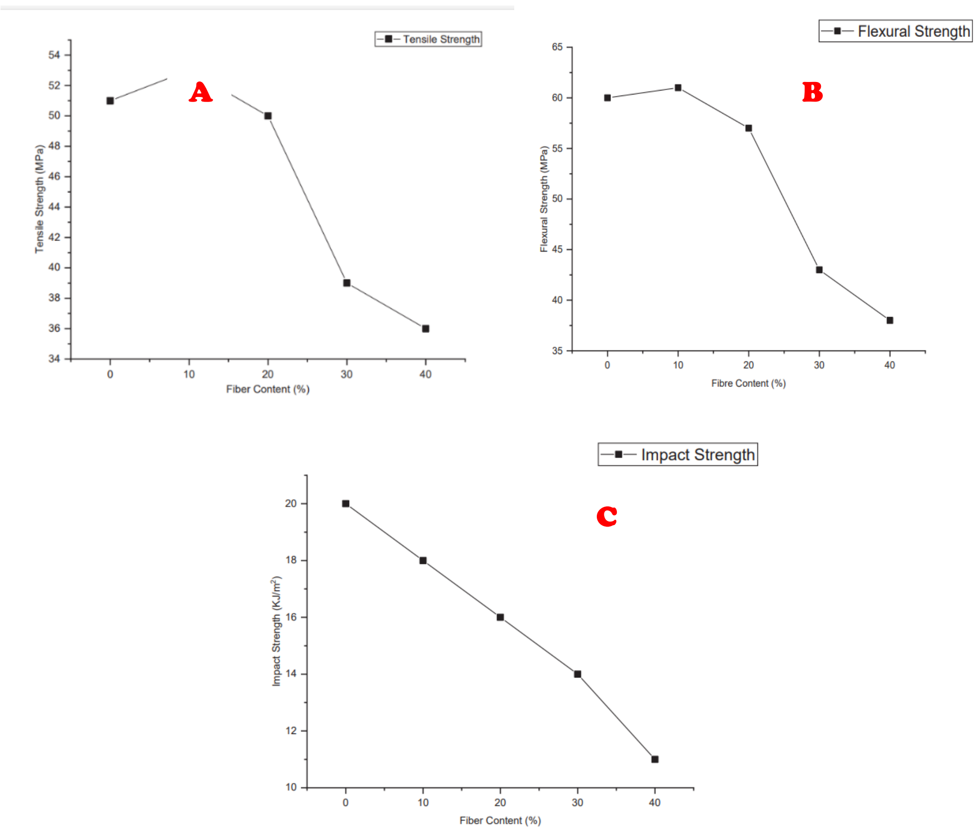

Fig 4.shows the tensile properties of composites from pine fibres A) Tensile strength(MPa) B) Flexural strength(MPa) and C) Impact strength (KJ/m^2). Source: (Hossain *et al.*, 2019).

Kraft methods have proven the excellence of fibres made from slash pines (PinusElliottii) in fibre cement composites produced by both air-curing (naturally aged) and autoclaved procedures. The flexural strength of Unbladed unbleached slash pine was compared commercial Arauco pine unbleached pulp and the results were found that the unbleached slash composites have the high flexural strength of 2.147 kJ/m^2 compared with other three combination(Morton *et al.*, 2010).

The fibres from cypress and pine tree were coupled with 15, 30,45 and 60% of weight fraction with polyethylene resin and the tensile strength and elongation at break were measured. Fig.5.shows the comparison of tensile properties of pine and cypress composites.

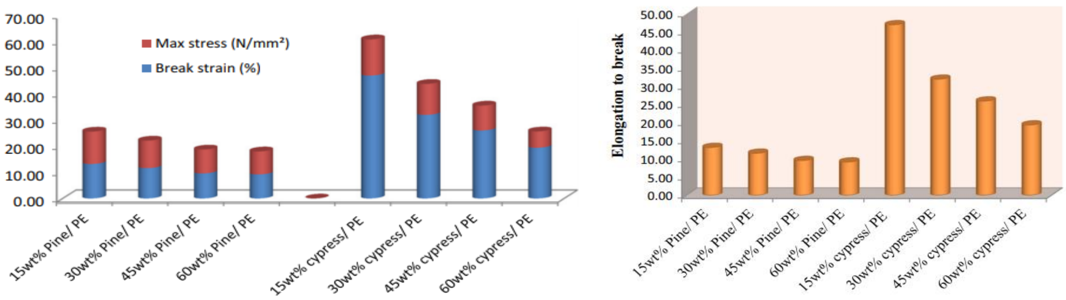

Fig.5 Comparison of different composites (Pine and Cypress) for Tensile strength and elongation at break property with different fibre loads. Source: (AL-Oqla, 2017).

With increased fibre loading, tensile strengths of the composites generated drop. This is because the pine and the polymer are not interfacially linked. In addition, poor dispersal typically arises with the increase in the loading of fibre in fibre agglomeration and decreases the tensile characteristics, which is in line with other cellulosic composite studies(Essabir, Jawaid *et al*. 2017); (Almagableh *et al.*, 2017). The greatest performance of pine/PE (15 wt. percent) in terms of the elongation of the worst cypress/PE fibre loads is clearly less than this performance (60 wt percent). This shows the advantage of the cypress over the pine fibres in structural uses when extension to rupture is necessary(AL-Oqla, 2017). Fig.6. displays the simulation of fiber failure of various composites.

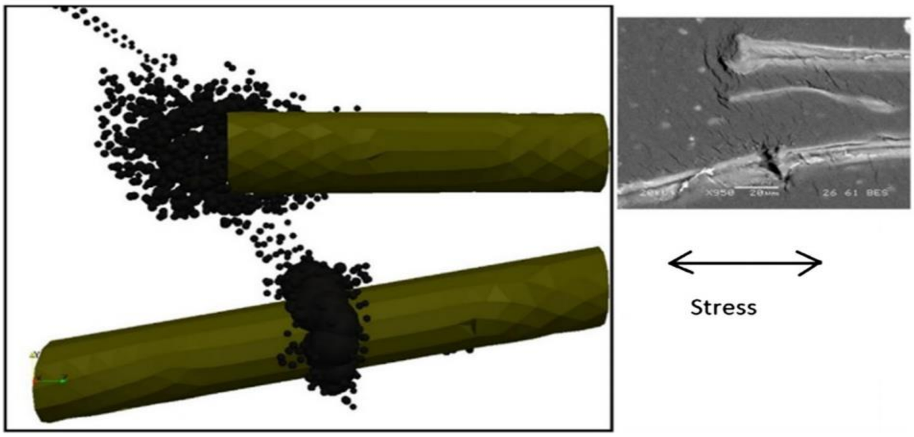

Fig.6. Simulation of the failure process for fibre degradation by utilising the RVE model for simulating the tensile behaviour of the flax / polypropylene composite randomly Source:(Sliseris et al., 2016).

Studies has been made to examine the effect on the physical and mechanical properties of polymer composites of the incorporation at different amounts of eucalyptus fibres generated by thermal - mechanical process. The composites with fiber loading of 0, 5, 10, 15, 20, 25, and 30 wt% were prepared using eucalyptus fibres. The accumulation of eucalyptus fibre reinforcement resulted in a decrease in these properties, but there was no direct correlation between the two characteristics and the inclusion of fibre levels, and a decrease in the values was observed with the addition of 5% of fibres, followed by stabilisation, indicating that the fibres did not harm the composite's properties..

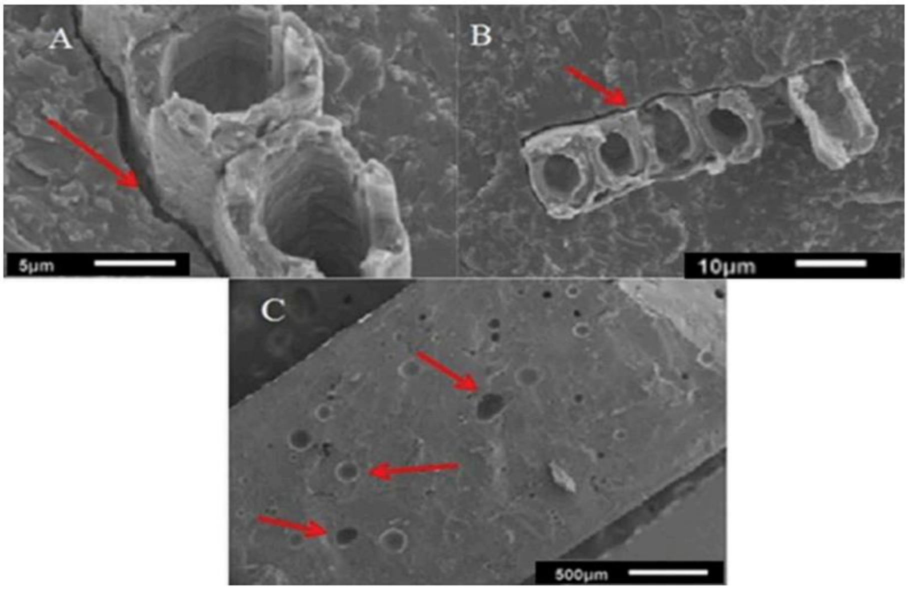

Fig.7. Fractured composite-(a) and (b) Improper anchorage Fiber / matrix identification (C) Evidence for bubbling and voids creation (deficiencies) in the composite.

Thermal insulation applications

According to Kain *et al.* (*2013*, 2014) the bark of coniferous tree species (*Pinussylvestris, Piceaabies, Abies alba Larix decidua*), which is ideal for composting, is utilised for insulating purposes in various ways. The thermal and sound insulation qualities of the boards were discovered to be quite good, making them appropriate for the manufacture of shielding panels (Kain *et al.*, 2013, 2014) Pásztory *et al*. (2017) has investigated the suitability of black locust bark(*Robiniapseudoacacia*) for the construction of insulation panels, as well as the thermal characteristics and formaldehyde emissions from the panels as a result of adhesive usage.

Effect of different thicknesses without fractionation and fraction of bark boards on thermal conductivity

The thermal conductivity values decrease somewhat in tandem with the thickness reduction, reaching a low at 20 mm thickness with a thermal conductivity of range 0.0651- 0.0657 W/mK with the different thickness of 10mm to 40mm. The thermal conductivity increases again after exceeding the ideal air gap size because the number of bark granules hitting the surface grows and the thermal conductivity of bark particles prevails.The fine particle board showed a lowest thermal conductivity with 0.132 W/mK with less porous space within the panels. The barkboards have an insulating capacity of about the value of additional insulation materials (hemp and flax: 0.052 W/mK; wooden fibre: 0.048 W/mK, wood chips 0.076 W/mK)(Volf *et al.*, 2015).

Comparison of thermal conductivity of wood fibres composites with other synthetic composites

Panels from wood fibres have thermal conductivity similar with other insulation panels. These panels can be classically split (such as expanded polystyrene, extruded polystyrene, stone wool, glass fibres).These materials exhibit many diverse possibilities and have great thermal characteristics with easy setup. On the other side, these composites have lesser mechanical characteristics than synthetic boards and are petrochemical and environmentally concern as is their low fire and resistance to attack of fungi /bacteria. The chemical treatment of the surface that diminishes the environmental benefits of these materials can overcome these challenges (Aditya *et al*., 2017);(Sari *et al.*, 2016). The thermal conductivity of the wood fiber insulation boards is similar to that in most natural products. Good thermal insulation needs superior heat diffusiveness. Wood insulation boards are among the finest materials in this field due to their very low thermal diffusiveness. Wood boards with these characteristics offer a very strong heat inertia and heat storage, all with a good insulating behaviour from other insulating materials. In comparison with materials with greater densities that provide less thermal insulation, these combinations lower the maximum temperature values within a building (Moresová *et al.*, 2019).

When examining the acoustic parameters of tree fibres, it is important to note that the measured macroscopic characteristics are almost comparable; this includes the bark shape, which is affected by porosity, the average thickness of the bark, and the internal diameter. Nonetheless, stone pine and maritime pine have microscopically distinct aberrant cell architectures. The outer bark surface pieces contain distinguishing cell features such as tracheids, ventricular rays, fibre groups, and vascular bundles walls(Sağlam et al., 2020).

The use of wood fibres for acoustic purposes

Various research investigated at the acoustic performance of insulating materials consisting of lignocellulosic materials. Many natural materials, such as kenaf, coir fibre, reeds, sisal, flax, bamboo fibres, and maize husk, have been researched and tested for acoustic purposes (Asdrubali *et al.*, 2012; Asdrubali *et al.*, 2017).A new trend in architecture is the use of natural insulating materials with little manufacturing processing. A key element for promoting a sustainable environment is the use of

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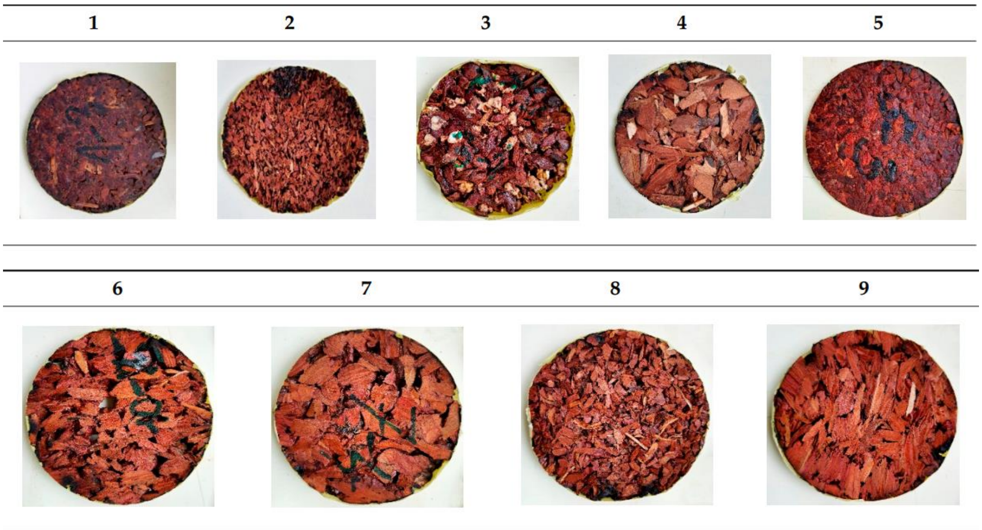
biodegradable and recyclable materials. Many research looked at technical and environmental advantages from the usage as fundamental parts of eco - friendly materials (natural or recycled) (granular or fibrous)(Novák *et al.*, 2020);(Souza *et al*., 2018);(Moresová *et al*., 2019). The larch bark fibres of different fiber sizes of 4–11 mm, 10–30 mm and 10–45 mm and with board thickness of 30mm and 60mm was made using urea formaldehyde as a resin material. The noise reduction coefficient and sound absorption coefficient was measured at different frequencies 250, 500, 1000 and 2000 Hz. At frequencies above 750 Hz with a thickness of 60mm, the sound absorption coefficient for the best samples, 2 and 8, varied from 0,5 to 1. We know that an increase in the density of fibre improves the coefficient of acoustic absorption (Neithalath, Weiss, Olek 2004) and lignin is acknowledged to be beneficial in decreasing sound transmission (Essien *et al*. 2017).



The more dispersed permeable structures in the wood, the higher the gas permeability. In general, the existence of loose fibres and the structural orientation of wood were shown to be more important than any other routinely studied characteristics in determining permeability (Tang and Yan, 2017). The axial flow of gas and liquid is inhibited by loose fibres, and transverse air permeability is determined by the sample dimensions, thickness, orientation, and surface conditions(Bramhall, 1971). The bark shape, which relies on porosity, medium bark thickness and diameter of the trunk is included. However, stone pine and marine pine have many aberrant cell structures in the microscope. Partial cell features such as tracheids, medullary rays, fibre groups and lignite walls are included on the outer bark surface.

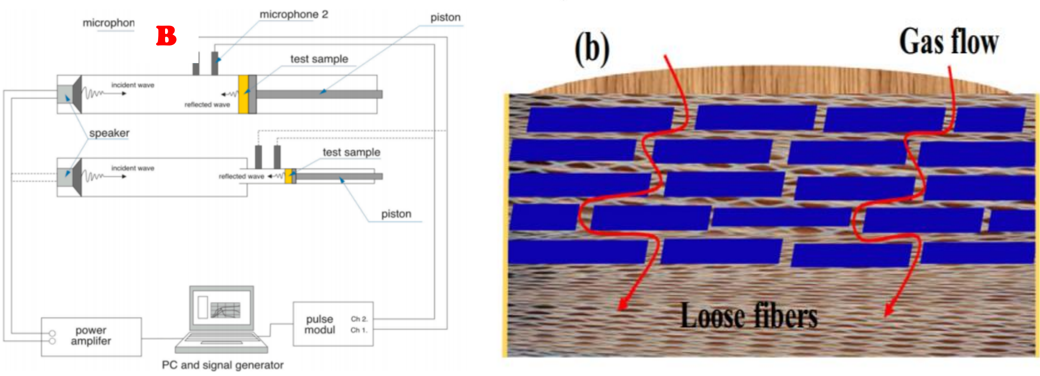


Fig.8A) shows the larch fibres composites of different thickness and fiber content and B) displays the apparatus for measuring the sound absorption coefficient and C) represents the Gas flow mechanism inside the fibres and matrix. Source:(Tudor *et al.*, 2021).

7.4 Structural characterisation

SEM analyses were carried out using composites of wood fibres in order to evaluate the interface between fibre and matrix and the fracture surfaces and the overall moral features of the composites. The fracto-graphy of the microstructure is rather ductile in the direction of loading associating continuously deforming the microfibrils, illustrated by the arrows.

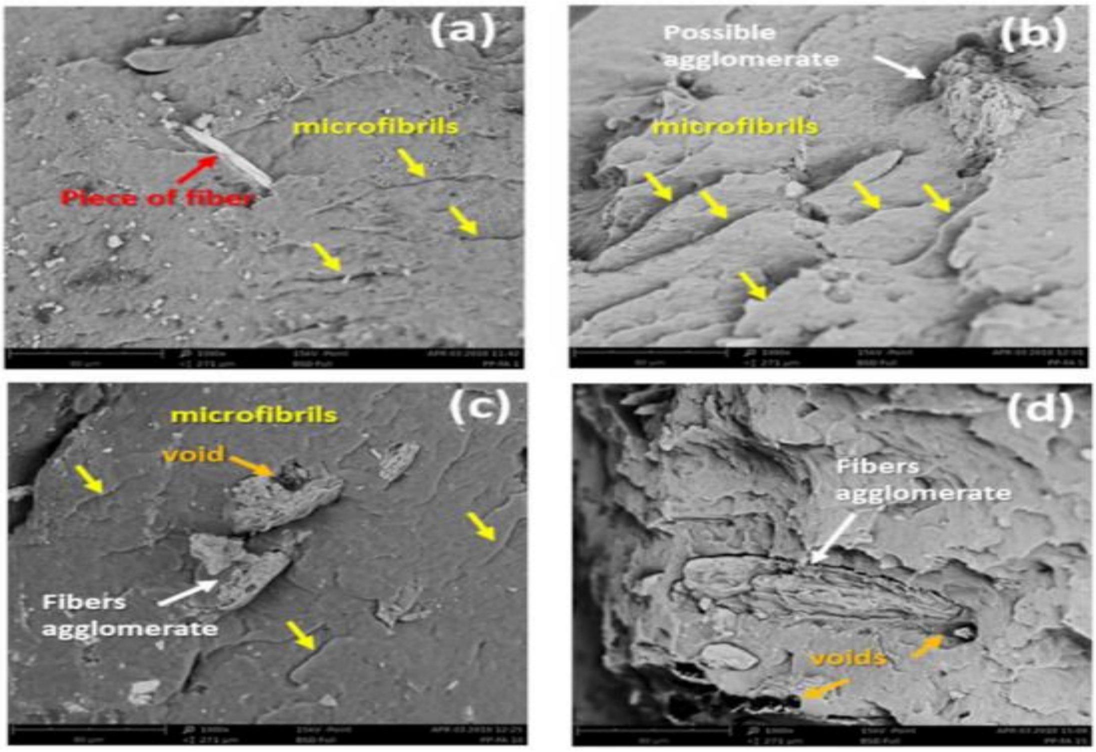


Fig. 10.SEM micrograph of wooden fibre-polyethylene composite surfaces a)1% of fibre wt, b) 5% of fibre wt c)10% of fibre, d) 15% of fibre wt of wood. Source: (Rosa *et al.*, 2020)

Table 4. displays the acoustic properties of some tree species. Source:(Sağlam, 2020)

Wood fibres	Thickness (mm)	Diameter (mm)	SAC	NRC
Black locust	13.7	265	0.010- 0.190	0.155 ± 0.002
Sweet chestnut	5.8	200	0.010- 0.240	0.175 ± 0.003
Stone pine	17.0	220	0.090-0.490	0.302 ± 0.005
Silver lime	9.0	255	0.010-0.330	0.185 ± 0.003

Maritime pine	13.0	255	0.020-0.220	0.095 ± 0.002
Sessile oak	7.5	200	0.010-0.260	0.130 ± 0.003
Cedar	19.0	510	0.010-0.450	0.233 ± 0.004

*SAC-Sound absorption coefficient; NRC- Noise reduction coefficient.

Conclusion

Wood fibre composites are an excellent replacement to carbon, glass, and other synthetic fibre composites due to their simple accessibility, low density, relatively low cost, strong acoustic and thermal insulation, developing sustainability, composability, degradability , and reasonable mechanical performance. Natural fibre composites are presently has been used to reduce carbon emissions in the designing and constructing, packaging, logistics, armed services, sporting goods, and healthcare industries, and it is expected that this category of reinforcement will be widely used in other applications in the near future. Nevertheless, disadvantages such as poor interfacial interaction between natural fibres, hydrophilicity, poor fire resilience, low fracture toughness, and limited durability have kept them from being regarded a consistent substitute to traditional composites. Because of the differences in fibre behaviour, selecting the best appropriate fibre type to produce green goods becomes more difficult. This is evident in the comprehensive assessment criterion scheme, indicating a substantial need for creating better evaluation tools for natural fibres over a broad variety of metrics in attempt to face more realistic features of their effectiveness. For its first time, the expense per waste-volume proportion is offered as a new sustainable and environment indication for natural fibres. Incorporating several variables to provide fresh assessment perspectives has significant benefits. It can make more informed judgments about identifying fibre abilities and characteristics in a holistic approach, as well as improve acquiring significantly better fibre performance. It may be concluded that comprehensive analyses of natural fibres that take into account economically integrated, physical, biological, and other positive aspects might result in more rational decision judgments. Furthermore, via improved assessment systems that contribute to improvement usage of current residues and resource, prospective new fibre types may be found and appropriately exploited, reducing pollution and promoting sustainable performance parameters.Based on this study, more research into the effects of matrix alteration and fibre length on the characteristics of wood fibre composites is advised.

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Value addition of special horticultural commodities in North East Region

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Abstract

India is blessed with varied Agro-climatic situations and due to the continuous efforts of farmers and scientific interventions; India is the second largest producer of fruits and vegetables in the world. Fruits as well as vegetables ranging from tropical to temperate climatic conditions are produced in entire India and North East in particular. Though a major share of fruits and vegetables are consumed as fresh but a proportion is also diverted towards home stead processing in the form of pickle and chutney making and often simply used in dried forms and sometimes utilized for commercial purpose. However, only approximately 1.5% of the total output of fruits and vegetables are exploited by the organized processing industries for commercial purpose for making value added products. The reason is generally due to the traditional food habits where higher percentage is consumed fresh, besides some of the other important issues like the packaging and transportation cost being high. However, of late the demand for processed fruits and vegetables has been growing at a rapid rate, approximately 20% per annum, which may be attributed to the change in the socio-economic factors amongst the growing population. Some of the feasible value added products of North East are highlighted here.

Key words: Value addition, Products, Processed, production site, market

Introduction

Value addition is associated with economic term to specify the distinction between the worth of products or the value of raw materials utilized in manufacturing the end product. It means adding worth to a raw product by taking it to, at least, next stage of production. It is a study of economic activity that involves the value of sale price gained by utilization of product owned by some organization or person in the form of raw materials or services provided by others. Value addition is outlined as the gross receipts of a firm minus the price of products and services purchased from other firms. It is the additional value which is created in comparison to its original value of the product. "Value" can be increased by specialized manufacturing, Processing, Marketing etc.

These are some of questions that comes while going for value addition

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•Quality - will the final product or service meet or exceed clients expectation?

•Functionality - will the product perform the function required from it?

•Form - is the product in a worthy form?

•Place - is the product within the right place?

•Time - is the product in the right place at the proper time?

•Ease of possession - is that the product simple for the client?

A product should have one or a more of these qualities to come up with extra price.

Agribusiness, significantly the food sector, is responding rapidly to the consumer's tastes, choices and preferences. With the increases of income levels amongst consumers resulting to an higher living standards, consumers are interested more on quality, variety, services, convenience, health and social consciousness. People nowadays are more focussed on utilizing the time at their best or in other words increasing the value of time as per the demand. In short, the consumers are conscious of sophistication, comfort, luxury and value addition than ever before. The factors of rising disposable incomes and market fragmentation caused by high competition within the market leads to opportunities and scopes to the producers to add value to the products.

Some of the important horticultural value added products with tremendous scope for expansion with special references to the North East India are,

Fruit Beverages

Fruit based beverages are enjoyed particularly during summers and are usually used chilled. Beverages are not only appetizing but also nutrition rich containing the benefits of fresh fruit, delicious, easily digestible and quenches thirst. The fruit based drinks or beverages are much superior to many synthetic drinks. The quality fruits and vegetable beverages are in the form of appetizing cold drinks and these fruit base drinks are source of vitamins (A, B and C) minerals (calcium, iron etc). Fruit beverages are consumed during the major part of the year in Indian context. They are not only served indoors at home but also consumed on special occasions by all the people irrespective of their caste and traditions. The various types of beverages are pure or natural juice, ready to serve (RTS), nectar, squash, crush, syrup, cordial, barley water, fruit juice concentrate and fruit juice powder and carbonated beverages. The North East being a store house of varied fruits ranging from tropical to temperate with outstanding flavour and taste such as strawberry, kiwis, green apples, plum, peach, passion fruits, Sohiong, Jackfruit. These fruits can be utilized for preparation of both fermented as well as unfermented beverages. Small scale and cottage industries should be set at the fruit production and marketed to the urban areas, thus generating employment and minimizing post harvest losses.

Fruit Jams Jellies and Marmalades

Jams and Jellies are products which are prepared by boiling the extracted pulp from the fruit with calculated amount/quantity of sugar to a consistency which is moderately thick. The most popular and available variations of jam are pineapple, mango, mixed fruit, strawberry, grape, apricot,papaya and among jellies, guava, Jamun, Plum and apple(Sour). Rosselle (a species of Hibiscus) which is locally available in abundance is a rich source of pectin and used for Jelly making. These product are not only used by spreading on bread but also added along with puri ,chapati, or similar products. Jams, jellies and marmalades approximately contribute to 20% of the total value added fruit and vegetable products. Marmalades also has a tremendous scope considering the availability of various citrus species in the entire North Eastern region.

Semi-processed products

There are ample opportunities for establishing processing unit to manufacture products like puree, pulp, Pastes dehydrated powders and juice concentrate from fruits and vegetables like orange, banana, tomato, jack fruit etc. These will act as subsidiary units supplying raw materials to the big food industries which are already established in markets.

Dehydrated vegetables and fruits

As we all know that vegetables are perishable in nature and available only in one season. Dehydration is one of the processing methods to preserve them and make it available at reasonable cost and in hygienic conditions all throughout the year. The dehydrated vegetables are always easy to transport and meet the demand and needs of large catering centers. They can be utilized in varied preparations at any time of the year. Sundrying an age old traditional practice is time consuming, less hygienic and climate dependent. The steps such as grading/sorting, washing, peeling/ trimming, size reduction, blanching, chemical treatment; dehydration and packing in unit are the processes for controlled dehydration of vegetables. Such kind of establishments of processing unit can be a great boon for the region. Carrot, cauliflower, green peas, leafy vegetables, chillies, bitter gourd, okra are the vegetables which can be dehydrated retaining its nutritional values. Similarly fruits like raw mango, ripe mangoes, can also be converted to dehydrated products.

Prepackaging of fruits and Vegetables

Prepackaging is a simple technique involves the basic packing house concepts of cleaning, trimming, cutting of the fresh produce and packing the products in unit packages in polyethylene bags. Vegetables like bean, carrot, brinjal, green chilli, root crops, leafy vegetables, and fruits like orange, lemon, banana, grape, and flowers like gerbera, chrysanthemum can be prepacked in polypropylenes to obtain an extension of shelf life to an extent of 1 to 2 times under ambient conditions without any refrigeration process. The produce which sustain prepacking is more presentable and attractive, better in terms of consumer appeal, extended shelf life and has a considerable advantage during transit and marketing. The heat which is accompanied in the field itself during harvesting of the produce known as field heat, needs to be removed to reduce the rate of respiration and extend the storage life. Therefore the vital facility of a packing shed at the farm level or in orchards is a prime requisite.

Osmo-air dried fruits

Osmo air-dried fruits are based on concept of dehydration. Slices of pineapple, jackfruit, mango, etc. are processed in two stages. The first phase is using sugar syrup as an osmotic agent used for the removal of most of the water from the fruits.. The second phase aims at further reduction of moisture to about 15% by simple method of air drying. The osmo-air dehydrated product retains the quality attributes such as colour, flavour, texture and is almost like the fresh produces. The product can be spilled over /used in ready-to-eat type foods *eg* ice cream, fruit salad, kheer, cakes and bakery products. Such types of osmo-air dried fruit based units can be set up in areas near fruit orchard

Waxing of Fruit & Vegetables

The shelf life of fruits can invariably be extended using edible waxes. Near the production area in villages a large number of small units can be set up with a aim in extending the shelf life of fruits and vegetables through waxing and other means and then proceeded for marketing in the urban areas. The wax emulsion can be used by various ways, such as dipping of fruits, spraying, foaming, and brushing. It not only enhances the shelf life but also gives a glossy appearance, checks transpiration and seals any injuries existing in fruits and thus protects from any fungal attack and avoids physiological loss in weight. The emulsion is harmless and imparts a gloss to fruits and vegetables. Also the entire technique is a simple and economical process.

Pickles and Chutneys

Pickling is the simple method of preservation of fruit in class 1 preservative such as common salt (NaCl), vinegar or edible oil. Also the addition of spices and condiments is followed. Pickling is considered to be one of the oldest practices of preservation of fruits and vegetables. The preservatives used in pickle making are salt, vinegar, edible oil and lactic acid. Several kinds of pickles are available in the Indian market. Mango pickle ranks first followed by lime, lemon, mushroom, aonla, jackfruit and karonda pickles.

Good quality chutney should be palatable and appetizing. Mango chutney is an important food product exported from India to many countries.

Both pickles and chutneys act as appetizers and is almost an essential item in Indian menu in lunch or any other important feast. Though the basic method in pickling is salt curing of fruits and vegetables, acidifying, addition of vinegar / oil and the spices, however the preparation varies amongst the different fruits.

Considering the abundant availability of indigenous fruits and vegetables in the region small units can be set up for packing in pouches, bottles, cans etc. This will ensure employment generation and furnish economic boost up.

Instant Pickles

With the advent of time new technologies and concepts are emerging rapidly. Refinements of technologies for convenience of human beings are increasing by many folds. Instant pickle is an example of the latest concept which replaces the traditional pickle making with the demerits of time consumption and cumbersome process. An example of mixing lime and mango, which by simple addition of oil and water can be restructured into a delicious pickle. This dry product is convenient, with better shelf life and economic in terms of cost of production, packaging and transportation. Thus by adopting suitable strategies both domestic market as well as export sectors can be well exploited with the growing demands and growth of small scale industries of pickles and chutneys.

A simple process which involves phases like fruit selection, cleaning, washing, peeling, curing and slicing/ dicing. The excess water is removed from fruit slices through osmosis by steeping in sugar solutions. At the end sugar solution is drained off, after which the slices are dried in driers and packed in flexible pouches.

Potato/Tapioca Flour

Many ready-to-eat products are prepared from potato. Varied potato products can be prepared and the market can be exploited in urban and semi urban centres, hence units based on such products can easily be established in rural areas. Usually for the preparation of instant foods, soups etc. as binding materials and also for preparing kheer, tikki, chops, pakoda, cutlets, stuffed parotha, kofta and other products potato flour, granules and mash are used in the region. Similarly, these products can also be made from tapioca which is abundantly grown in the region. Production of the flour can be taken up easily using indigenous equipments. The process involves peeling, cutting, pre-treatment with salt and permitted preservatives, soaking, granulating and drying. The dried product is grounded and packed. The flour obtained by this process can be easily reconstituted with boiling water to get the mashed potato/tapioca and used for making a variety of products.

Banana Chips

Bananas are grown extensively in the northern region of India. During the glut season, growers do not get remunerative prices. Therefore it is advisable to utilize the surplus produce by preparing chips under hygienic conditions. This will not only help minimize the post harvest losses but also supplement the dietary requirements. Banana chip processing is very simple and can be easily adopted at rural areas for establishing of Agro based industries.

Mushrooms

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Mushroom cultivation is broadly done in controlled conditions with the advent of advanced technologies. Mushrooms are rich supplement of easily digestible protein and minerals; it is not only low in calories but also almost fat-free. Rural areas are rich source of agro-wastes which can be utilized and converted for profitable mushroom cultivation. Its cultivation can provide gainful employment generation. Mushrooms are highly perishable. The unmarketable surplus of fresh produce can be preserved and processed into value added products by dehydration, canning, dehydration, brine preservation, conversion into pickles, soup and ketchup in small scale processing units near the site of production.

Fruit Toffees

Fruit toffees can be made from pulp of many local fruits along with certain ingredients. It is a highly nutritious and palatable product as compared to the simple sugar boiled confectionery. Sufficient employment generation avenues can be achieved by setting up of small and cottage scale manufacture of fruit toffees in the areas where fruits are available or from the production site in the rural areas. Although fruit toffees are being made in the organised sector, there exists a vast potential for production on cottage scale also.

Fruit Bars

Fruit bar is a concentrated fruit product which can be used as ready to eat and meant for ready consumption. It has a good shelf life. Any variety of pulpy fruits, e.g. papaya, banana, pineapple and other indigenous fruits etc. singly or in combination can be used for manufacture. Fruit bars are preferred highly amongst the consumers gaining popularity day by day due to good keeping quality, taste, flavour and texture.

Improved murabba making

Preserves (murraba) are made by cooking the entire fruit or its slices/pieces in sugar syrup of higher concentration (68-70^{0}Brix). Aonla, bael, apple, pear, mango, cherry, karonda, strawberry, pineapple, papaya, carrot citrus peels etc. can be popularly used for making Murabba and it is one of the original groundwork of sweet preparations of the country. The conventional murabba preparation protocol required a long processing time, with inadequate keeping quality of the product and hence resulted to microbial fermentation and spoilage rapidly. The method has been amended by CFTRI to obtain murabba in a less time and much better keeping quality, attractive translucent appearance and desirable texture.

Tutty fruity

Tutty fruity is an important dehydrated ready to use product which can reduce the post harvest losses to some extent.. The demand of this product is increasing, due to gaining popularity amongst consumers throughout the world. Fruits generally used for making preserves/ candies are papaya, mango, pear etc. Osmotic dehydrated mature green raw fruits of papaya is largely used to make tutty-fruity which is used in bakery products, sweetmeats, ice creams, salads and pan. The candied fruits and vegetables are quite popular food items. The consumption of these products is fast increasing. Thereby small scale processing units near the site of fruit production in rural areas should be established.

Tomato Products

Tomato is grown extensively in the entire North East not only in household kitchen gardens but also on commercial scale. It is used for the preparation of different products like puree, paste, ketchup, sauce, cocktails, chutneys, canned and ready- to- eat products. There is a good domestic and export market. Since the lifestyle of people are changing and consumers interest towards fast food sector is expanding rapidly the demand and requisite, particularly for tomato ketchup and sauces, is also increasing.

Natural Colorants

The concept of utilizing plant pigments as food colorants in not new. From the time memorial, people are using natural colors in food in one way or other. However, of late, due increased concerned and anxiety of consumers over the ill effects of synthetic food colorants, there has been a renewed thrust on the use of these novel colorants. Food industries in developed countries are actively searching for efficient and stable plant sources of food colorants. These colorants get their unique properties because of presence of pigments like anthocyanin, carotenoids, betacyanin, chlorophyll etc.

There are various obvious plant sources in NER including Assam which have highly pigmented leaves, flowers, fruits etc. Some of these sources are mulberry (*Morus alba*), jamun (*Sizygium cuminii*), phutuka (*Melastoma malabathricum*), puroi (*Basella rubra*), banana male bud, annatto (*Bixa orelana*), krishnasura (*Delonix regia*), turmeric etc. There exists a possibility of establishing pigment extraction plants utilizing solvents or super critical fluid technology.

Oils and oleoresins

Keeping in view the production statistics of ginger, turmeric and chillies in the region, establishing oil and oleoresin plant in production areas will be a feasible proposition.

Minimal Processing of Fruits and Vegetables

In order to meet today's health conscious consumers' demand for more fresh, natural, and convenient foods, concerted effort has been made to develop new methods for minimally processed and modified atmosphere packaged fruit and vegetable products. Minimally or lightly processed foods are those which are processed through operations like washing, sorting, trimming, peeling, slicing, chopping etc. without affecting fresh-like quality of the fruit or vegetables. These products are gaining popularity as convenience foods among consumers. Local fruits like pineapple, jackfruit, other indigenous fruits; vegetables and spices like cucumber, tomato, garlic, ginger etc. can processed to manufacture minimally processed products.

Conclusion

The growth in demand for fruits and vegetables in developing countries combined with growing export demand creates new opportunities for poor farmers in the developing world, but developing countries need assistance in adapting policies, institutions, and infrastructure to take advantage of these trends.Consumers are showing strong interest in increasing their overall produce consumption and continue to be wowed by the time and work savings offered by pre-cut fruits, vegetables, and salad greens. Most importantly for the future outlook of the produce industry, many more consumers expect to increase rather than decrease their use of value-added fruits and vegetables in the coming years.

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Nutrition Garden: A sustainable model to improve Food diversity and security

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Abstract

Food security is a global issue and remains as a foremost challenge for developing countries. Food security is multidimensional and is presumed exists when there is adequate and continuous food availability, access, and utilization in a sustainable manner. Agriculture is an important determinant of food security. However, despite of modern technological innovations in agriculture for maintaining the food security, millions of people remain food insecure and malnourished. This calls for a prompt and effective response to address food security and

family nutrition as well as reducing poverty and improving standards of living of the poor and marginalized people around the world. In this context, the nutrition garden is bio-intensive and innovative approach which can provide year round availability, access and consumption of adequate amount and varieties of nutritious food which not only fulfil the calorific demands but also the requirements of micronutrients. With addition to nutritional security and diversity, there are so many other social benefits that have emerged from nutrition gardening practices viz., better health and nutrition, women empowerment, increased income, employment, and enhance in community social life.

Keywords-Food diversity, Food security, Malnutrition, Nutrition garden

Introduction

Food is for satisfying hunger, Nutrition is for maintaining good health. Food is our necessity, Nutrition is essential for our body. Food is required for our body; Nutrition is required for the soul. Nutrition is the nourishment or energy obtained from the food consumed to perform our daily activities. Satisfying the hunger or gratifying the taste doesn't necessarily mean that it can also meet the nutritional requirements of the body. A 'Nutritious food' is not only safe for the body but also provide long-tem good health. A 'junk food or packaged food' on the other hand has poor nutritional value despite its palatability and capacity to satisfy hunger. 'Malnutrition' implies to an overall and marked nutritional deficiency in the body. However, excess of nutrition can also cause health issues such as obesity. Therefore the concept of 'balanced diet' is promoted which is essentially based on the nutritional requirements that may vary individually according to age, gender, profession etc.

Dual burden of malnutrition is a complex global problem; millions of people are suffering from malnutrition. According to WHO (2020) report, 1.9 billion adults are overweight or obese while 462 million adults are underweight or undernourished. India is fighting against the problem of both communicable and non communicable diseases. India presently has 72 million diabetic people and is estimated to have 80 million by 2025, in this manner India will become the next diabetic capital of world (IDF, 2017). Among children, 52 million children under five are suffering from wasting. Interventions are needed in the entire food system from production to processing, transport, consumption and waste management to address the critical situation of dual burden of malnutrition (WHO, 2015). Although every country in the world is influenced by malnutrition, progress towards reversing this disaster is very slow. At this pace, it seems impossible to achieve the SDG goal-2 to mitigate the concern of zero hunger, which would end all forms of malnutrition (SDG report, 2019). Global climate change poses an additional serious threat to sustainable development and can undermine advancement toward eradicating hunger, malnutrition, and poverty. According to the FAO, 2020 access to nutritious food or balanced diet is the key to food security but now-a-days the expenditure on 'convenience' food is increasing at a large extent, which is deficient in vitamins and minerals, is a major cause of concern. Zero hunger and good nutrition have the power to transform and make powerful present and future generations. Stunting, wasting, anaemia and other micronutrient deficiencies inhibit productivity, proper psycho-social and cognitive development and health outcomes. With proper investments in nutrition related initiatives; the country can go forward on the development path with healthy, skilled human resources (FAO, 2020). *Poshan Abhiyaan* for holistic nutrition targets to reduce stunting (low height for age), wasting (low weight for height), underweight (low weight for age) and anaemia by 2 per cent , 2 per cent, 2 per cent and 3 per cent per annum respectively by 2022 (*Suri and Kapur, 2020).* The prevalence of stunting, underweight and wasting among the under-5 children in India is 38.4 per cent, 35.8 per cent and 21 per cent respectively (NFHS-2015-16). Around 53.1 per cent women aged 15-49 years and 58.6 per cent children aged 6-59 months are anaemic in the country. It is a matter of concern that in adult's obesity and overweight is also increasing in India, 20.6 per cent women and 18.9 per cent men are obese (NFHS-2015-16). The Global Nutrition Report (2020) revealed that malnutrition continues to be one of India's biggest challenges and It also highlighted that the COVID-19 pandemic could well reverse the progress in reducing malnutrition and hunger achieved so far. Micronutrient deficiencies existed before COVID-19 pandemic as a form of 'hidden hunger' but the implications of such deficiencies have been brought to the front in the current pandemic situation.

Emerging evidences also suggests that people with pre-existing non-communicable diseases such as obesity, heart disease, and diabetes suffer more serious consequences of COVID-19 (Global Nutrition Report, 2020)

To combat the issue of malnutrition and for a sustainable food security, there is a need to look at multiple strategies. Dietary diversification is a key strategy for this and nutrition gardening can be a beautiful option for improve nutrition. Nutrition gardening is an innovative way to ensure food security, and diversity, gender empowerment and create employment which ultimately leads to better life. Nutrition gardens are a micro-solution and effective and sustainable means of improving nutritional standards of low-income rural families through integrated household food production (Bhattacharjee *et al.*, 2006). Nutrition gardens have had positive impacts on citizens, at one hand it provides steady incomes to the family and on the second hand, it helps in prevent diet related diseases. It can produce variety of fruits and vegetables high in micro-nutrients, and address food insecurity and malnutrition issues.

Nutrients for the body

Macronutrients - Needed by the body in larger quantities

- **Carbohydrates -** These are usually identified as sugar, and are a resource of instant energy. Source: rice, wheat, yam, potato, etc.
- **Fat and Essential Fatty Acids -** These provide energy and also support cell growth, protect organs, and help keep the body warm. Source: Vegetable oil, ghee, butter, etc.
- **Dietary fibre -** Dietary fibre is mainly required to keep the digestive system healthy. It provides bulk in the diet which provides satiety. Thus, prevents overeating. It also contributes to other processes *viz.*, stabilising glucose and cholesterol levels. Source: whole grains, fruits, vegetables.
- **Protein-** It helps in the body building and repair tissues, and also to make some important body chemicals like hormones and enzymes which is very important for body functioning. Source: Beans & legumes (pulses), fish, meat, egg, milk, cheese, etc.

Micronutrients- Needed by the body in lesser quantities

- Micronutrients are one of the most important groups of nutrients your body needs. They include vitamins and minerals. Vitamins are needed by the body for energy production, important immune function, blood clotting. In the meantime, minerals play an essential role in growth, bone health, fluid balance and several other processes.
- Source: Nuts, beans & lentil, dark green leafy vegetables, milk (calcium) etc. Vitamins like Vitamin-A, Vitamin-B, and Vitamin-C etc. are organic substances required by the body to maintain the normal process of metabolism. Their deficiency can cause various diseases. The important sources vary according to the vitamin, like citrus fruits for Vitamin-C and cod liver oil for Vitamin-A.

Understanding Nutrition Garden

Nutrition gardens may have different purposes and accordingly their components and landscaping or design may vary. Nutrition garden is a home garden that essentially prioritizes seasonal vegetables and fruits for regular household consumption. Nutrition Garden is an improved form of kitchen garden where selected vegetable crops are grown more or less systematically following scientific procedures so as to meet the nutritional requirements of the family. Thus, where a normal kitchen garden may have randomly selected crops mainly based on external factors of preferences such as palatability and feasibility, a nutrition garden takes into consideration more nutritional preferences and needs which strengthen the food security of the families in general.

Advantages of Nutrition Garden

It is a source of fresh, seasonal and nutritious vegetables for the family throughout the year. It helps to ensure quality control in the production so as to maintain the food and nutritional safety of the products. For example, it is easy to go for a fully organic home garden. Availability of perennial crops like drumstick leaves can meet the nutrition requirement even at the odd hours of the day. Moreover, it reduces the expenses in buying vegetables and fruits. Also, helps in effective use of the available land and kitchen waste. Above all, it can work as refreshment for the mind and inspires a positive attitude and give a very satisfactory feeling.

Designing a Nutrition Garden

Designing a nutrition garden is mainly required proper planning. The design is to be based on the these factors: available space, water source available, specific crops needed to be grown, human resources available to take care and for proper maintenance, perceived risks (such as theft, animal grazing, etc.). For example, crops like tubers and ground nut etc. may give good production in a small space. If there are risks of theft or animal grazing, then adequate fencing may be required. Different types of nutritional garden can be designed as per the space availability and preferences.

Vertical garden

If there is more vertical space (such as the boundary wall or house wall) available than the horizontal space, then vertical gardens can be developed which need less space. For the hanging type, crops comfortable in that position can be selected such as bitter gourd. Raising bottle guard and pumpkin etc. by side of the wall and diverting their growth to the thatched roof is a familiar traditional practice in rural India that also corresponds to the concept vertical gardening.

Horizontal gardens

Raised beds are ideal to avoid soil compaction, where the area often gets waterlogged during the wet season. The preferable size is 5-6 ft X 2-3 ft with a height of 1-1.5 feet. The beds unite crops or vegetables with different root depths and light requirements. Spread of rice husk/ hull, and vermin-compost on top of the bed is suitable. The multi-season, multi-use and nutritionally rich plants are given more importance. Bricks can be used to make the structure for such beds, but timber can also do if termite is not an issue. Raised beds help in easy maintenance of the garden. The inter-bed spaces can be kept clean either through cement flooring or through gravel-spreading. Each raised bed can be used either for a single crop or for multiple crops.

Circle garden

The basic point of such a design is to harvest vegetables from different patches on a rotation basis. If there are seven major segments (called pathways) in the circle, and one starts from harvesting in pathway number 1, then he/she will harvest in pathway number 2 the next day, and accordingly will come back to pathway number 1 after seven days. A perfect size for circle bed is 750 sq.ft.to800 sq. ft. A circle of radius of 15 ft is then drawn with a stump at the centre. The layout is marked with lime or ash. The 15 ft long radius can be divided into segments at 1 ft, 1.5 ft, 2 ft, 3.5 ft and 5.5 ft (one can decide this according to preferences) and circles are to be drawn with each radius-segment. This way each pathway has a number of patches to grow multiple crops. However, if there is less space, then the structure can be modified according to the need & feasibility. The target is to have at least 14 beds (2 patches per pathway) in place.

Key-hole garden:

This special design helps maintain the moisture & nutrients in arid conditions because even a bucket of water can help the plants survive for 5-6 days. This is possible because the design promotes a process known as reverse osmosis and capillary action. There are two concentric circle beds of 3 metre and 0.5 metre diameter. The area between the outer circle and the inner circle is dug up to a depth of 4 inches and then filled with a thick mulch(decaying leaves primarily) layer of 18 to 24 inches, followed by

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making a heap from a mixture of soil and compost. The central hole of the garden is used for water and bio-waste supplement. Ridges and furrows are prepared in the circle like spokes to plant tubers / root plants, carrot, radish, beat etc. The outer fence consisting of natural insect repellents like coriander (*dhania*) and marigold etc. is to be raised whereas the remaining beds are used for cultivation of leafy vegetables. Alternative spokes are used for plantation of tomato and brinjal like vegetables etc. Three numbers of such key-hole gardens can ensure year-long supply for vegetables to an average household.

Selection criteria

The vegetable or fruit crops selected for the nutrition garden are usually based on these preferences: quick-yield crops (such as leafy vegetables), long-time fruiting/productions (such as lemon), crops which need less care (such as drumstick), crops compatible with the daily dietary habit (such as potato and brinjal). Some other considerations in crop-planning can be: long-term and multi-useable vegetables, selection of crops from which good seeds could be extracted, substantial yield in short duration(s).

Crop Selection

Selection of vegetable crops for nutrition garden depends on the size of the area available and the choice of family members. It will be desirable to produce all kinds of vegetables that the family members like, if the available area is large enough and provided that they can be grown satisfactorily in the region. If land is limited, it is advisable to grow crops that produce large yields per unit area and time. For example, tomato, brinjal, chilli, cucurbits (ridge gourd, bottle gourd, bitter gourd, and cucumber), beans, leafy vegetables, radish, carrot, beet root, cabbage, cauliflower, okra, onion and garlic are the main crops for an average-size nutrition garden. If land is sufficiently available, then crops such as banana, papaya, guava, and lemon can be grown in a nutrition garden.

Managing Productivity

The productivity in nutrition garden is obviously dependent on selection of species, fertility of soil, availability of required moisture in the soil and pest management etc. Since the products are expected to be organic, hence all management practices also need to be compatible with that. Therefore, organic manures and organic insecticides play a major role here. Organic manure enriches the macro-nutrients in the soil like NPK (Nitrogen, Phosphorus, and Potassium) and also improves the soil texture and fertility which ultimately increase the water-holding capacity.

Irrigation

The irrigation should be properly planned in order to avoid moisture load till the germination. Later on, irrigation can be done once in 10 to 15 days depending upon the soil type. There will be drop of flower when the soil is too dry or wet. Hence, optimum level of moisture should be maintained.

Disease Control:

Different plant protection measures should be taken up based on the need at appropriate intervals to control particular pest or disease.

Harvesting:

The harvesting should be done at right stage in order to get the best quality products according to requirement.

Conservation of Nutritional Value of Vegetables

Producing nutritional food crops is the first step only, for it has to be followed by efficient management for balanced availability of nutrition in the diet as well as protecting measures to prevent nutrition loss during cooking. The balanced diet is ensured through inclusion of a variety of different food items, like rice, dal, and curry in a single intake so that the nutritional deficiency of one is fulfilled by the other. Patients may need to follow a specific diet chart prescribed by the nutritionist or dietician. Like, diabetic patients have to limit/avoid rice, ripe banana, and bit root. The balanced diet may vary according to the age, so what is good for the infants may not suit the older persons. Girls or women in general and pregnant and lactating mothers in particular need special care in ensuring nutritional diets required for them given the health issues specific to them like iron deficiency. During the lean period when vegetables are not much available, the focus should be on millets which are also very nutritious and healthier.

Conclusion

Nutrition garden can be great possibilities in the time of a global food crisis and the elevated food prices as it emphasize on enhancing and building local food systems. By keeping in view, the varying local opportunities and challenges, the nutrition garden forms a great solution that can address food insecurity and bring in self reliance, sovereignty and dignity. Hence, in the recent years there has been a lot of interest to strengthen and intensify local food production system not only to make available the home-grown healthy food but also to alleviate the adverse effects of food supply shocks and food price volatilities and improve household food security and nutrition. In the amid of pandemic, lockdowns, shutdowns and imposition of curfews, necessitated to check the spread of COVID-19, have disturbed the food supply chains resulting in food shortages and price volatilities. So, Covid-19 is an opportunity to think and revive the system of producing food items that can possibly be produced at local level by upholding the nutritional benefits.

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Postharvest and Extraction Technology of Annatto

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Abstract

Annatto, commonly known as achiote is a small shrub or tree grown for its fruits. Annatto fruit or capsules contains seeds. The seeds are processed to produce natural colorants. The principal pigment is bixin, a yellow to red-orange pigment (apocarotenoid). Different extraction methods like vegetable oil, solvents, novel extractions like supercritical fluid, ultrasound assisted and microwave assisted extraction are used for the production of higher quality bixin.Various methods and process are followed for preparation of different types of annatto extracts like, oil soluble extract, oil suspension, water soluble extract, emulsion, micro and nano encapsulated annatto extract. It has wide applications in food, cosmetics, and pharmaceuticals. The European Commission has accepted the annatto extracts (E160b) as a food additive. The European Commission panel recommended the Acceptable Daily Intake (ADI) of 6 mg bixin/kg body weight (bw) per day and 0.3 mg of norbixin/kg body weight per day.This chapter discusses agricultural practice, post-harvest operations, chemistry, extraction methods, extract usage standards, and annatto by-product utilization.

Keywords: Annatto, bixin, extractions, chemistry, food additive.

Introduction

Dyes, colors, and pigments are now essential components of the chemical industry. The pigments, dyes obtained from different sources are used in different industries like food, beverages, textile, cosmetics, etc. In concern with food safety,food industriesfollow the rules and regulations over the source and the concentration of the colors used in different food items. Colored food items are used to attract and appeal the consumers. Synthetic and chemical-based industries are facing a falling rate due to the demand for natural food colorants. This is mainly focused on the restriction put forth by the World Health Organization on the use of synthetic dyes.The natural food colorants are caramel, carotenoids, anthocyanins, curcumin, chlorophyll, etc. These are used in Beverages, Bakery, Confectionery, Dairy & frozen, Meat products, and others.

Bixin, a yellow to red-orange pigment (apocarotenoid) obtained from annatto seeds is a natural, safe, and easy to use colorant that ranks second in economic importance (Satyanarayana *et al*. 2003, Kumaran, 2014). The annatto or achiote belongs to the family Bixaceae. The most common species existence is *Bixa orellana* L. is a tropical small tree or shrub indigenous to tropical Central and South America.The treeshave been spread widely throughout the tropics as an ornamental and commercial plantmainly for its seeds. Other tropical countries that own the cultivation and production of annatto are Asia and Africa. In India, it is widely distributed in the southern regions of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, and in the Northern states of Orissa, West Bengal, Gujarat, Maharashtra, Madhya Pradesh, and Chhattisgarh. Brazil, Guatemala, India, Peru, the Philippines, and a few African countries are the world's major producers of annatto seeds (Smith and Walliams, 2006). Among them Peru is the leading producers and exporter of annatto seeds (Satyanarayana *et al.* 2003).

The colorant extracted from annatto used in several ways, largely in food,predominantly in dairy and dairy products and also used in meat products (Shibata *et al.*2008) and also used in some sweets, drinks, sauces, and sausages (Galindo-Cuspinera *et al*., 2003).Oil soluble pigments obtained during extraction are used in high fats foods like margarines, vegetable creams, ice-creams etc (Prabhakara Rao et al.2005; Zarringhalami et al. 2009).Annatto colourants are also utilised in cosmetics and the textile industry (Shahid-ul-Islam et al.2014; Reddy et al. 2005). This pigment has a longstanding experience of use since it is less poisonous, has superior biodegradability, and is environmentally friendly (Shahid-ul-Islam *et al*., 2014).

Annatto is a small tree or shrub that grows from 3 to 5-meter heightand can survive under 28 to 44ºC temperature and rainfall ranges from 800-1500 mm annually (Kumaran, 2014). The fruits are soft and thorny and heart shaped. Fresh fruits are green and soft when they matureit turns reddish-brown in color and brittle with pointed bristles.The fruits bear seeds, the number of seeds ranges from 30-60 on average found on each side of bivalvar capsules.The seeds shapes vary from pyramidal to almost conical. The seeds are the commercial part of the plant. The seed's pericarp is responsible for the red-orange pigment has wide application. About 80% of the pigment from annatto seeds are carotenoids primarily known as bixin (Scotter, 2009). Different techniques and methods are being followed for the extraction of bixin and nor-bixin. The colors may reach up to 7 per cent of the seed's dry mass (Mercadante *et al.* 1997). The percentage of bixin concentration varies according to cultivar and climate. Generally, the bixin content varies 1- 6 % (Vilar *et al*. 2014).


Figure 1. Annatto tree , Figure. 2 Annatto fresh fruit


Figure 3. Annatto Dry fruit;Figure 4. Annatto seeds

Agricultural practices

Soil and climatic conditions

Low lands, well drained lands, mountainous regions and higher elevation areas are the most suitable for annatto cultivation. Red and alluvial soil with pH 6-7.5 are the best soil types. Since, it is a tropical plant it can survive at the temperature ranges from 20-30^{O}C with an annual rainfall of 1250-2000mm. It cannot resist frost. Open sunny and humid condition without shadow is best for the growth of the annatto plant forthe high yield. The economic life span of a plant is 20 to 25 years (Kumaran, 2014).

Preparation of Land

Before planting, the land is tilled, levelled, and prepped. Pits of size 30 cm^3 are dug in early March at 4.5 X 4.5 m spacing and filled with a mixture of soil and compost before the rainy season begins.It can accommodate around 450 to 500 plants per acre. At the onset of rain, the healthy seedlings are planted in the main field (Kumaran, 2014).

Propagation

Propagation can be through seeds or other vegetative methods. Planting material can be purchased from certified and quality sources in the form of seeds, cuttings, and tissue culture plants. March to June is the best time for raising the nursery. Polythene bags with soil, sand, and manure are being used for raising the seedlings. The germination takes about 8-10 days. November to December is the optimum season for this type of method. When the seedlings attain the length of 20 cm they are transplanted. The opted season for planting is June to September. 2-3 irrigations are done immediately after planting. Irrigation must be done according to the soil type, water holding capacity, and temperature (Kumaran, 2014).

Flowering starts after 3 years of planting. From early August to the end of October the blooming happens. After 30 days of flowering the capsules, formation starts. The whole developed fruits may be seen from September to February. To get a better yield of fruit, pruning is done. Every year after harvest it is recommended to prune the branches. Fungicides are applied to avoid fungal attacks after pruning. More than 3 to 5 new shoots sprout results in a better yield of the next seasonal fruiting (Kumaran, 2014).

Fertilizer

During the first year, 300 kg of NPK is applied at planting and again after three months, along with 50 kg of urea per hectare. After the second year, 800 kg NPK and 250 kg urea per ha are recommended.

Weed control

Weeding, mulching, and soil treatment around pits are always ideal for increased yield. Up to the third year, two weeding's are required, one before and one after the monsoons.

Harvesting

Flowers should be nipped off during the growing season to increase the biomass. Roughly after 135-150 days of seeding, the crop is ready for harvest. From the month of October harvesting of fruits may begin. The fruit is manually picked as bunches. The right stage of harvest is determined by dryness (moisture content) and cracks on the capsules. Depending upon the type of plan, soil and climate the seed yield varies. Per hectare an average of 600kg can be produced (Kumaran, 2014; Satyanarayana *et al.* 2003).

Post harvest operations

Drying

Immediately after the harvest the fruit bunches are spread onto a polythene sheet and dried under shade condition for 6-7 days. Sun drying of capsules may take 3-10days. Proper care should be taken on turning of capsules and unpredictable weather conditions. Controlled drying is essential to yield high bixin. Over drying leads to loss of pigments whereas, under drying leads to mould development. Some artificial dryers are recommended within the temperature of 55-60^{O}C to reduce the time consumptions. The dried pods are stored in gunny bags under a dry place (Satyanarayana *et al.* 2003, Kumaran, 2014).

Seed separation

The seeds are separated manually by beating the dried capsules with a wooden stick. The separated seeds are winnowed. The manual separation process is very labor-intensive; for 100kg of seeds minimum of 6 persons are required. After seed separation, the seeds are dried further to reduce the moisture to 7-10% (Satyanarayana et al. 2003); without incidence of direct sunlight and stored in polythene bags under dark and dry conditions. In Peru, a small hand-operated dehusker /winnower was developed to open the pods, separate the seeds and winnow off the pod. A prototype continuous power operated annatto seed separator machine was developed in CFTRI. The machine output was 132.5 kg/h (Math *et al.,* 2014). For large scale operations various modelled machines have been developed.

Figure 5. Manual separation of annatto seeds

Chemistry of Annatto

Annatto extract,(bixin) a red colorant obtained from the pericarp of seeds. Bixin, a small class of apocarotenoids, has the molecular formula $C_{25}H_{30}O_4$ (MW = 394.51) (Vilar *et al.*, 2014). The major coloring component is 9'*cis*-bixin (methyl hydrogen 9'-*cis*-6,6'-diapocarotene-6,6' -dioate), more than 80% of the carotenoid of annatto seed is *cis*-bixin (Preston and Rickard 1980; Lauro,1991).The nine-carbon double is responsible for intense red color. At one end of the chain a carboxylic acid group and on another end a methyl ester group isattached (Scotter, 2009)presented in Fig 6. For commercial value, the seeds must have more than 2.5% of bixin content. In nature bixin occur in *cis* form onextraction process due to isomerization*cis* is converted to *tarns* form which is termed as isobixin presented in Fig7. 9'*cis*-bixin are soluble in polar solvent gives orange color but insoluble in vegetable oil. *Trans* – Bixin are most stable isomer readily soluble in oil and impart red color.Both *cis* and *trans* bixin exhibit similar properties (Satyanarayana *et al.*, 2003).A demethylated derivative of bixin is *cis*-norbixin ($C_{24}H_{28}O_4$)occur in nature during saponification process and referred as saponification product of bixin which is water soluble (Venugopalan *et al.*, 2011) presented in Fig 8. Under Optimized temperature pH bixin can be hydrolysed into norbixin and readily turned into sodium and potassium salts.C*is*- norbixin accountsonly below 5% of the total pigment content (Aguilar *et al*., 2016).

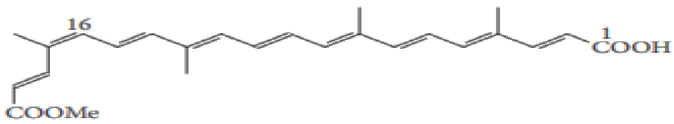

Figure 6 Bixin (*cis*-bixin)

Figure 7IsoBixin (*trans*- bixin)

Figure 8 Norbixin

The other major compositions cellulose (40-45%),proteins (13-16%),sugars(3.5-5.5%), essential oils (3%), pigments (1-4.5%),tannins, saponins and alpha and beta carotene(Taylor,2002).From the extracts of annatto more than 100 volatile compounds have been detected.Dry seeds majorly constitute of oil compound known as geranylgeraniol accounts of 1%. Tocotrienols, predominantly δ-tocotrienol are obtained from lipid fraction of annatto seeds (Parvin et al.2011). Other compounds found in seeds include beta-carotene, cryptoxanthin, lutein, zeaxanthin, orellin, bixein, bixol, crocetin, ishwarane, ellagic acid, salicylic acid, threonine, tomentosic acid, tryptophan, and phenylalanine (Vilar et al.2014). Some hydrocarbon compoundslike α- pinene (9.3%), β-pinene (4.8%), α-elemene (3.3%), valencene (2.7%) and amorphene (0.2%) also found (Satyanarayana et al. 2003).

Annatto Extract

Commonly, water or vegetable oil or solventsare used as suspending agents. To yield higher percentage and pure bixin extracts organic solvents (hexane, chloroform, ethanol, acetone and propylene glycol) are used. Bixin (E160b) are primarily used as food colorant, for the safety of the consumers the Commission Directive 95/45/EC (European Commission, 1995)laid regulations on separation of bixin which is accountable to purity. According to EC three common extraction methods to be followed are(i) solvent extraction for bixin and norbixin formulations an indirect method of extraction, (ii) alkali extracted for conversion of bixin to norbixin and (iii) oil extracted annatto are the direct extraction methods (Scotter, 2009).

Methods for extraction of bixin and norbixin

Before the extraction of bixin, arilsfrom the seeds are mechanically removed by process known as abrading or raspelling in a correct suspending agent, followed by removal of the seeds from the suspension. Bixin can be produced using a neutral liquid such as water or organic solvents, whereas norbixin can be produced using aqueous alkaline hydrolysis with or without acid precipitation. Combinations of these methods leads to produce different form of bixin and norbixin (solution, suspensions, crystals, powders). Since,bixin is partially soluble in vegetable oils alkaline propylene glycol usage helps to use the colorant for both low and high fat foods (Smith and Walliams, 2006).

Oil soluble Bixin:

The seeds are immersed and rubbed in warm oil less than 70^{O}C to remove the pigmentin a raspeller machine. The suspension with the pigmentsis heated under vacuum below 130^{O}C. The filtered solution contains yellow degraded cis-bixin and trans bixin too(Satyanarayana et al. 2003).The concentrationof the bixin will be up to 8%. In replacement of vegetable oils propylene glycol is recommended (Smith and Walliams, 2006). The JECFA 2007 list does not include annatto extract derived from seeds using vegetable oil (Annatto D), which was primarily extracted to obtain bixin.

Manufacturing of bixin

According JECFA 2007, 2015; the bixin can be processed adopting two methods (i) Aqueous-processed bixin (Annatto E) and Solvent-extracted bixin (Annatto B).

Aqueous-processed bixin (Annatto E*):*It begins by abrading annatto seeds in a cold or moderate alkaline solution to remove the outer layer (potassium or sodium hydroxide). The slurry is acidified to precipitate the bixin, which is then filtered, washed, dried, and crushed to produce granular powder.

Solvent-extracted bixin (Annatto B): The exterior covering of the seed is removed using several food grade solvents (acetone, alkaline alcohol, ethanol, ethyl acetate, hexane, methanol, isopropyl alcohol, or supercritical carbon dioxide). To separate the insoluble components, the crude is filtered. Fats and waxy substances are removed further. The resulting solution can be acidified before solvent removal, drying, and grinding.

Manufacturing of norbixin

According JECFA 2007, 2015; the norbixin can be processed adopting three methods.

Alkali-processed, acid-precipitated norbixin (Annatto F): The seed's outer coating is removed with aqueous alkali (potassium or sodium hydroxide). Bixin is hydrolyzed in hot alkaline solution to convert it to norbixin. The resulting solution is acidified to produce precipitated norbixin. To acquire the precipitate, it is filtered, dried, and milled to produce granular powder.

Alkali-processed, not acid-precipitated norbixin (Annatto G): The technique is identical to that of alkali-processed, acid-precipitated norbixin (Annatto F), except that the acidification step is bypassed. The norbixin solution is filtered directly and then dried and milled to produce a granular powder. The extract's main colouring component is the potassium or sodium salt of norbixin.

Solvent-extracted norbixin (Annatto C): The pigments are extracted using organic solvents. Solvent removal, crystallisation, and drying are all part of the process. Aqueous alkali is added to the dry powder and heated to hydrolyze bixin before cooling. To precipitate nor bixin, the solution is acidified prior to precipitation by filtering off the solution. After that, the precipitate is filtered, washed, dried, and milled. The end outcome will be granular powder.

Other extractions methods

Supercritical fluid extraction

Supercritical fluid extraction use carbon dioxide as solvents plays a vital role in the extraction of annatto extract. The supercritical carbon dioxide extraction can be suggested for extraction of cis and trans-bixin. The advantage of using SFE is no pre-treatment is needed, can be used under median temperatures, limit the usage of solvents etc (Albuquerque and Meireles, 2011).

Pressurized extraction, microwave and ultrasound assisted extraction

Rodrigues *et al*. (2014) examined the influence of pressure on extraction and found the low pressurised solvent extraction were significant effect on interaction with temperature, solvent and solvent to mass ratio and as an individual. The yield of bixin was high for pressurized and low pressurized liquid and solvent extraction. Microwave assisted extraction with specified temperature, solvent concentration, solvent to feed ratio may significantlyaffect the extraction of polyphenol compounds and bixin from annatto seeds (Quiroz *et al*., 2019a). Ultrasound assisted extraction can be also used for extraction of bixin by optimizing the solvent concentration, pH, treatment time, and seed-to-solvent ratio conditions (Quiroz *et al*., 2019b). The yield of bixin reached about 85 % with ultrasound and 95 % with dielectric heating (microwave)using ethylacetate, solvent to feed ratio at 0.05 L g-1 and at least 30 min extraction time as ideal extraction parameters for annatto seeds (Bart and Bachtler, 2020).

Types of Annatto extracts

Oil soluble extract:

Extracted bixin with soybean, grapeseed and sunflower oils exhibit color from yellow to orange red. Hot vegetable oil extraction produce orange to yellow tone which is the stable trans-bixin. On further heating a thermal degraded “Yellow C-17” is produces which gives yellow color. On oil extraction only 0.05-1% bixin can be extracted form annatto seeds due the nature of low solubility in oil. This extract can be used in dairy products like cheese, salads, dressings (Hendry and Houghton, 1992). Employed in cosmetic (Giuliano et al., 2003) and paint industries (Lourido and Martı´nez, 2010).

Oil suspension

Oil suspensionsis prepared by adding oil to the annatto pigment powder. Below 100^{O}C of oil temperature impart orange color if the temperature exceeds the limit the color turns yellow. The oil suspensions consist of minimum 4% of *cis* and *trans* bixin (Hendryand Houghton, 1992).

Water soluble extract

Water soluble cis-norbixin may contain 1 and 15% of the pigment. They are mainly used in dairy industries specifically for cheese and also used in beverages. This is preferred in coloring of cheese due to the interaction and association of protein which impart permanent color. Giuliano *et al*. (2003) reported that 1% of norbixin in 1L is enough to color 16 tons of cheese.

Emulsion

To produce emulsion based bixin and norbixin emulsifier like propylene glycol and polisorbates are used (Hendry and Houghton, 1992). It helps the extract miscible for the foods oil and water phase. This emulsion type annatto extracts are used in ice-cream,margarine, mayonnaise, creamy sauces, some candies, andwide range of bakery products. The emulsified pigment contains 1 -2.5% of bixin and nor bixin (Smith, 2006).

Micro and nano encapsulated annatto extract

The pigments are susceptible to temperature,light and oxygen. On thermal degradation the color changes from red to yellow (Mc Keown 1963, 1965) may result in the release of m-xylene and toluene during degradation (Scotter *et al.*, 2000). To overcome the instability to the extremes conditions micro and nano encapsulations are preferred. By spray drying techniques with different matrix like gum arabic or maltodextrin bixin as core material microencapsulated bixin the light stability was analysed by Barbosa, Borsarelli, and Mercadante (2005). The nanoencapsulation of16.92 ± 0.16 lg/mL bixin concentration with mean diameter of 195 ± 27 nm showed 100% encapsulation efficiency. The nonencapsulated bixin found to stable at ambient temperature during 119 days (Lobato *et al.*, 2013).

Regulations on Annatto intake

According to the evaluation of the Joint FAO/WHO Expert Committee on Food Additives (JECFA) (2006), it was recommended that the Acceptable Daily Intake (ADI) of 6-12 mg bixin/kg body weight (bw) and ≤ 0.6 mg of norbixin/kg body weight (bw). Aguilar et al. (2016) investigated on safety of annatto extracts (E160b) as a food additive. The European Commission panel recommended the Acceptable Daily Intake (ADI) of 6 mg bixin/kg body weight (bw) per day and 0.3 mg of norbixin/kg body weight per day.According to FSSAI 2011, bixin should made only in two types: (a)Solution in oil for use in butter and other food products, and (b)6Solution in water for use in cheese and other food products. Based on the food type the recommended level changes.

By product utilization

Starch and Poultry feed from residual annatto seed

The seed after extraction can be used in animal feed (Santos et al.2015). Due its high nutritional value such as protein,fiber and minerals (Queiroz et al.2011)can be included in cattle feed (Rêgo et al.2010), broilers (Souza et al.2015) and laying hens (Garcia et al.2014). Residual annatto seed meal can be recommended forbirds (Japanese quails)along with sorghum-based diet at 9% which can improve the yolk colorwithout any decline of egg productivity and quality (Mani et al., 2020).Novel starch can be obtained from defatted and depigmented annatto seed. The amylose content was similar to corn starch with higher thermal stability. The starch derived from the annatto residual seeds showed higher peak viscosity which is the main factor giving texture. The lower pasting temperature enable to use in sensible food preparations (Zabot et al. 2018).The starch can beused for preparation of edible films, alternative of fats, preparation of gluten free pasta and as deliverysystem.

Conclusion

Annatto, both as a seed and as an extract, has numerous applications in food, textiles, and pharmaceuticals. Bixin is in high demand as a safe and environmentally friendly product. Increased annatto productivity is encouraged in order to meet the need for a natural colourant. To create superior quality final products, various cultivation, post-harvest technologies, and extraction procedures are used. The extraction residue is also used to create value-added products used as gluten free starch and poultry feed.

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Neem Processing Machinery and Value Addition

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ABSTRACT:

The neem tree (Azadirachta indica A.Juss) is indigenous to indian subcontinent with India being the leading producer of neem seeds (442300 Tonnes/ annum). The physical and chemical properties of neem fruits were analyzed to facilitate designing of neem depulping unit. Nimbidin, Nimbin, and Nimbinin are three main constituents of neem oil, and azadirachtin is the complex secondary metabolite which is another important constituent of neem seed. Azadirachtin is extracted from the neem seed pressurized liquid extraction method (PLE). Since manual depulping is laborious and time consuming, mechanical neem depulper with 98% working efficiency was been developed by ICAR, New Delhi.

Keywords: Azadiracta indica A.Juss, Physical properties, Mechanical properties, Depulping, Pressurized liquid extraction.

INTRODUCTION:

The neem tree (*Azadirachta indica* A.Juss.) is an indigenous to the Indian subcontinent tropical evergreen tree (deciduous in dry regions).Neem is a large tree with a semi-straight to straight trunk that measures 3 metres in circumference and spreading branches that produce a broad crown that reaches a height of 25 metres.Within 3-5 years, neem begins to yield, and by the age of 10-12 years, it will be fully mature. Fruit yields range from 10 to 25 kilogramme per tree each year. The first few years a mature tree yields 35-50 kg of fruit per year.It may yield up to 70 kg of fruit per year after the tenth year(Kumar and Gupta, 2002). According to legend, the plant can live for two centuries. Depulping and decortication of Neem fruits at farm level are two crucial operations that can lead to reduced losses and increased production. It is also envisaged that oil recovery is higher if primary processing of Neem fruits can be done at decentralized level (farm/site).

Azadirachta indica A. Juss, which is endemic to the Indian subcontinent, and Azadirachta excelsa Kack., which is only found in the Philippines and Indonesia (Hegde, 1995; Kumar et al., 1995). In India, Bangladesh, Burma, Pakistan, Sri Lanka, Malaysia, Thailand, and Indonesia, the former grows as a wild tree. Neem trees are now found in around 72 countries across the world, including Asia, Africa, Australia, North, Central, and South America (Ahmed and Bamofleh, 1989; Hegde, 1993; Suri and Mehrotra, 1994). There are an estimated 25 million trees growing throughout India, with 5.5 percent in Karnataka, which is in third position after Uttar Pradesh (55.7 percent) and Tamilnadu (17.8 percent) (Rembold, 1996) India is the world's leading producer of neem seeds, with around 4,42,300 tonnes produced yearly, generating 88,400 tonnes of neem oil and 3,53,800 tonnes of neem cake (Hegde, 1993).The neem seeds are harvested and sun dried between May and July. Traditionally, the fruits were collected by sweeping under the tree or shaking the tree/branches. There is huge potential for neem-based goods in India, which may be fulfilled if the medicinal plant is popularized as part of agro-forestry and the Integrated Rural Development Program (IRDP), and value-added products are sold through village enterprises.Neem fruits are manually gathered and prepared in rural regions for household consumption and sale by marginal and landless farmers.Commercial machines of a considerable capacity are available for use in chemical-based industries.A hopper and an agitation cylinder with horizontal wire mesh of 9 mm were immersed in a water reservoir and rotated by an agitator were designed for depulper at the institution. Mitra (1963) designed a neem fruit depulper consisting of a cylindrical steel drum with a central rotating shaft and bearing blades connected to the drum's wall.Before using neem fruits in a machine, they must first be pre-treated by soaking for 4-5 days. This machine could feed 40 kg of fruit at a time. The machine's large size prevented it from being adopted at the village level.

Depulping should be completed in 3-4 days and dried as soon as possible. Depulped seeds dry faster than undepulped seeds and produce higher-quality oil. Researchers have not paid enough attention to neem harvesting and post-harvest technologies, particularly depulping and decortication. This might be

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related to the meteorological circumstances at the time of maturity, as well as the product's perishable nature. With this in mind, a low-cost, small-scale neem depulper was created to meet the needs of landless and small-scale farmers.

Mechanical neem processing equipment were created by the government of Uttar Pradesh and the Indian Institute of Pulses Research located at Kanpur.

Neem Fruit Collection Methods:

Different neem fruit collection methods and the comparison are shown in the table.1 below **(Solanki et al., 2017)**

Table.1 Neem fruit collection methods.

Variables	Traditional Collection Method	Improved Collection Method	Manual Collection Method
Plucking method	Fallen near tree over night	Branches shaken by pole.	Direct collection from tree by hand
Flooring under tree	Barren earth	200 microns thick polysheet	NA
Time, man per hour	1.5	2.0	3.0
Fruits collected per tree, kg	17.62	20.9	10.5
Time taken in sorting, min/person	33.0	14.5	-
Weight of waste person, kg	5.3	4.6	-
Effective output (neem fruits), kg/h	6	7.27	3.5
Type of waste	Moulds, stone, sticks, leaves,etc	Unripe fruits, leaves and sticks	nil
Start of decomposition	3rd day	4th day	6th day

Source: (Solanki et al., 2017)

Physical and Mechanical Properties Of Neem Fruit:

The evaluation of physical (table.2) and mechanical properties (table.3) was carried in Department of Agricultural and Bio-Environmental Engineering Technology, Federal Polytechnic, Ede, Osun State, Nigeria and results are shown below(ADEDEJI et al., 2020).

Table.2 Physical properties of Neem fruit.

SNO	Property	Range
1	Length	14.89 mm
2	Width	9.22 mm
3	Thickness	8.95 mm

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4	Unit mass	0.75g
5	Geometric mean diameter	10.7 mm
6	Arithmetic mean	11.02 mm
7	Surface area	33.6 mm^2
8	Sphericity	71.91
9	aspect ratio	61.94
10	1000 unit mass	597.8 g
11	Bulk density	0.58 g/cm^3
12	True density	1.06 g/cm^3
13	Percentage porosity	45.42

Table.3 Mechanical properties of Neem fruit.

SNO	Property	Range
1	Coefficient of friction on plywood.	0.19
2	Coefficient of friction on glass	0.14
3	Coefficient of friction on mild steel	0.24
4	Coefficient of friction on stainless steel	0.06
5	Dynamic angle of repose.	47.5 ^{o}
6	Fruits compressive stress for longitudinal loadings	0.12 ± 0.03 MPa
7	Fruits compressive stress for transverse loadings	0.044 ± 0.013 MPa

Chemical Composition of Neem:

The chemical composition of neem is shown in the table below. The three main constituents of neem oil are Nimbidin, Nimbin, and Nimbinin of bitter taste. The seed contains a complex secondary metabolite known as azadirachtin.

Table.4 composition of neem fruit.

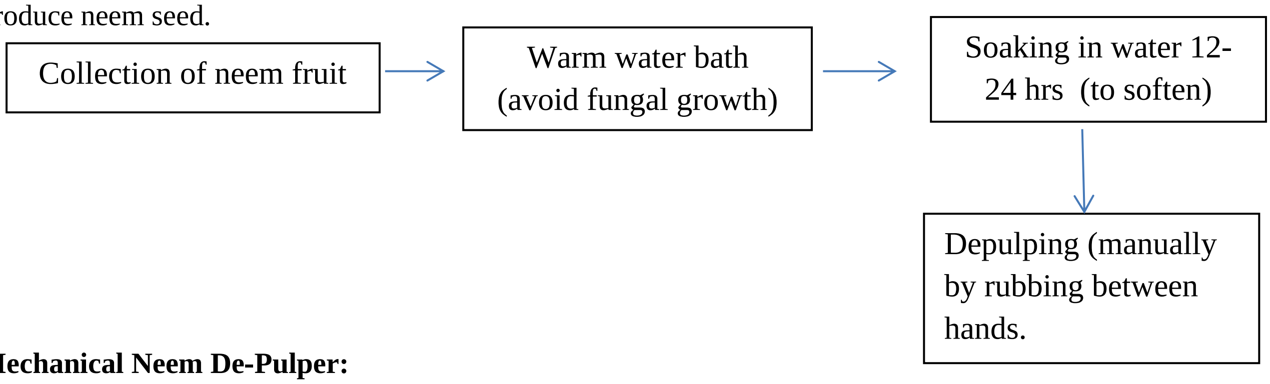
1	Neem fruit fresh	Greenish brown kernels	30%
		Other shell, pulp etc..	70%
2	Neem seed	Shell	55.3%
		Kernel	44.7%
3	Neem kernel oil content	Kernel oil content	46 - 48%
4	Other ingredients	Azadirachtin	0.3%
		Nimbidin	1.2 – 1.6%
		Ni Nimbin	0. 0.1%

		Ni Nimbinin	0. 0.01%
		V Veepinin	00. 0.15%

Source:(Rao, Kowale et al. 2003)

MANUAL NEEM DEPULPING:

Depulping of neem fruit is a process of remove fruit coat and pulp from the neem fruit in order to produce neem seed.



Mechanical Neem De-Pulper:

The neem depulper unit was developed in ICAR-Indian Agricultural Research Institute, New Delhi-110012 in the year 2017(Solanki et al., 2017).

1. Depulping unit:

A high-efficiency axial flow depulping system was developed. The de-pulping unit consisted of,

1. Sieve cylinder
2. Water supply system
3. Rubbing unit and
4. Outer cylinder cover

2. Rubbing unit:

The spiral rubbing structure was formed when the material passed through the rubbing zone between the sieve cylinder and the spiral rubbing unit. It followed a helical pattern with the rubbing surface, allowing for a longer path to the fruits, increased retention time, and easier peel and pulp removal. This technique required less energy since it worked in two directions.

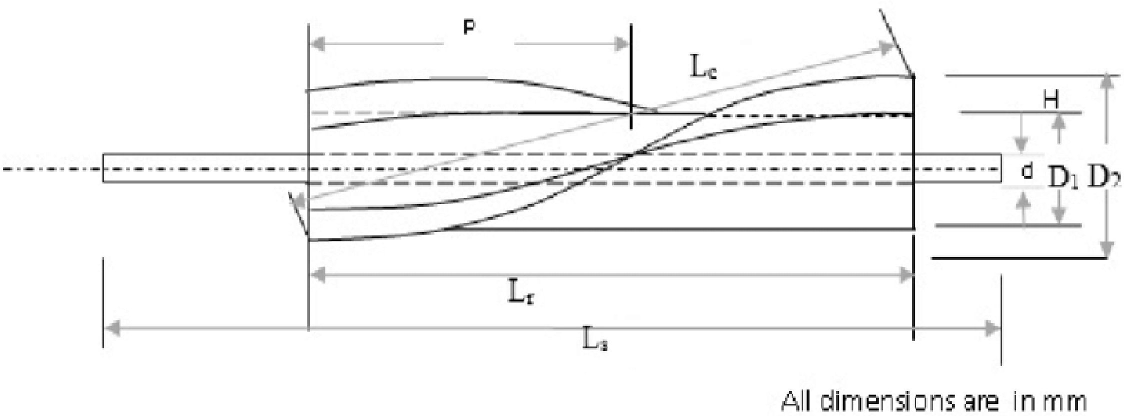


Figure 1. Digramatic representation of spiral rubbing unit.

3. Cylindrical sieve:

It functions as a depulping cylinder with perforations along the length and diameter to provide enough retention time to prevent the transport of un-depulped neem fruits. Depulping requires less overall force because the operation involves sheering.

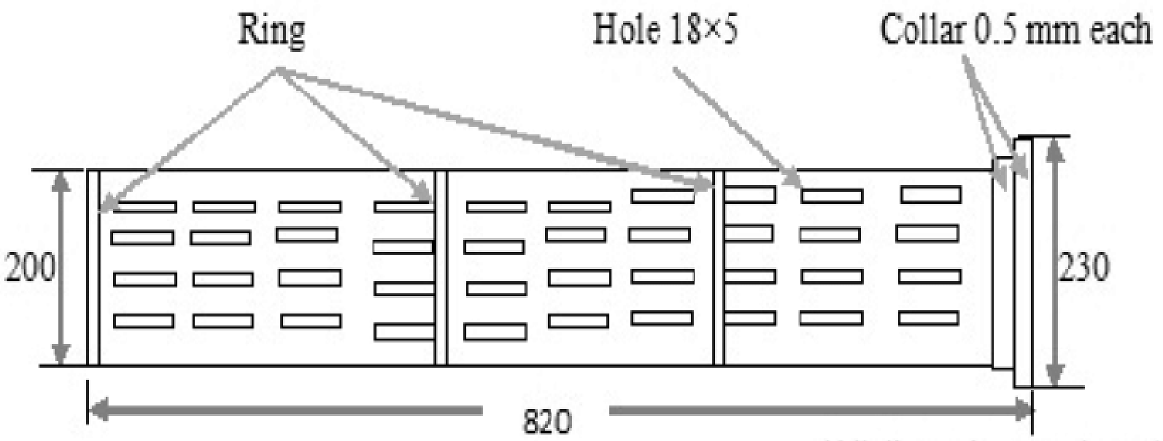


Figure 2. schematic diagram of cylindrical sieve.

4. Outer cylinder cover:

It protects the epidermis and pulp by holding the pulp and water slurry together. The primary cylinder is built of 18 gauge MS sheet rolled to a diameter of 305 mm and a length of 820 mm. The unit's lid is the main cylinder, which holds pulp and skin mixed with water and transports the slurry to the outlet. An inspection box is provided to look into the rubbing mechanism. The slurry of pulp and water had one exit at the bottom of the main cylinder, while clean seeds had the other outlet at the end of the sieve.

5. Watering system:

In order to remove the pulp from the Neem fruit, a water supply system is required. A galvanised iron (G.I) pipe with a length of 860 mm and a diameter of 12 mm was placed within the outer cylinder at the top of the sieve cylinder. A line of 21 holes, each 3 mm in diameter, extends from the end point to 800 mm away, splashing water here on sieve cylinder and aiding in the cleaning and removal of pulp and other waste. A valve at the beginning regulates the amount of water provided.

6. Hopper :

The hopper was designed to handle 5 kg of neem fruits because it is a small machine. The top is rectangular, measuring 180 x 205 mm up to 140 mm in depth, and the bottom is tapered at a 45-degree angle to the machine's input aperture, which poured the material straight into the sieve cylinder's rubbing unit.

7. Handle :

The handle is made out of mild steel and wood. The handle arm is made of mild steel flats with a 40 x 6 mm diameter and a 245 mm effective length (Fig. 3). The primary shaft is fitted with a hollow mild steel rod with an outside and inner diameter of 40 mm and 20 mm, respectively. A 20 mm MS rod connects the handle to the connecting arm, which is 45 mm in diameter and 125 mm long.

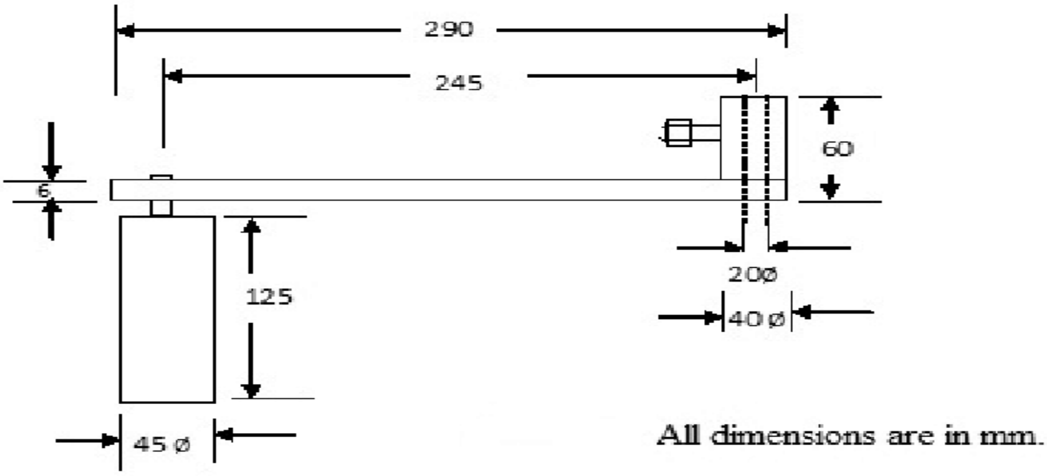


Figure3. Schematic diagram of handle.

Performance Evaluation of De-Pulper:

Table.5. working parameters of neem fruit de-pulper.

SNO	PARAMETERS	RANGE
1	Soaking period of neam fruit	3 days
2	Water flow rate	20 h^{-1}
3	Sieve size	18 x 5 mm
4	Rotor speed	0.32 m/s
5	Clearance in between sieve and rubbing unit.	5mm
6	Number of operators	2 (operating and feeding)
7	Overall output capacity	22.22 Kg/hour at 30-35rpm
8	De-pulping efficiency	98%
9	Breakage range	0.02 – 0.12%

Neem Oil:

Neem oil is a vegetable oil obtained from the fruits and seeds of the neem tree. While neem oil has many of the same characteristics as tea tree oil, it also has a higher fatty acid concentration and a lower terpene level. Mosquito repellant properties of neem oil have been discovered. Because of its medicinal and pest-control properties, the neem tree has gained worldwide interest and treating many diseases in Auyurveda (Bup Nde, Ngu et al. 2013). Neem oil extraction flow diagram is illustrated in the figure.4

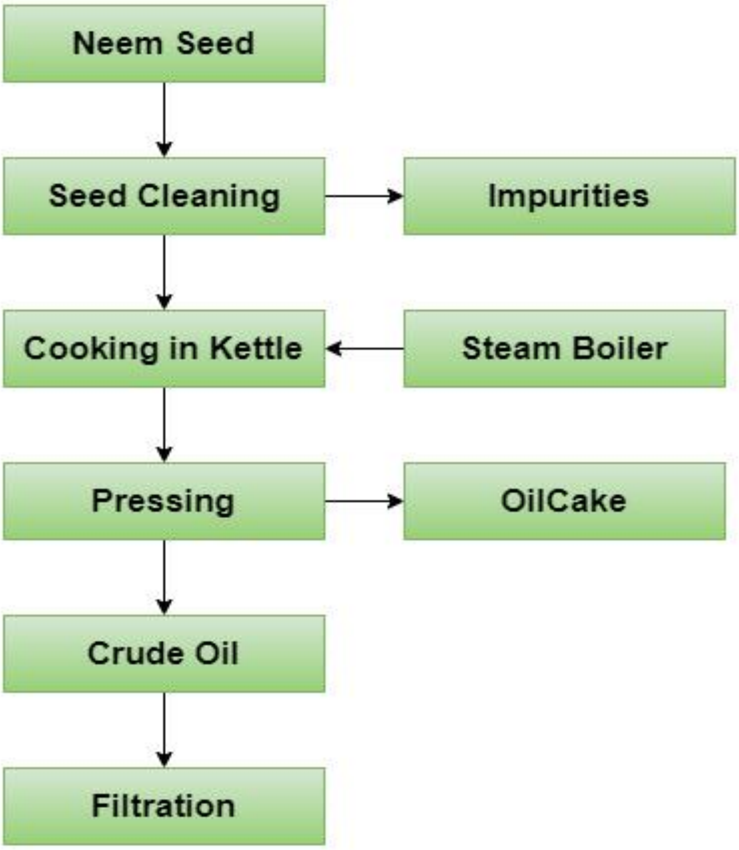


Figure 4. Neem oil extraction process.

Neem-Based Extract Processing in Rit-Pilot Plant

At Rajamangala Institute of Technology (RIT) in Patumtani province, neem-based extract processing entails a long chain of operations and a variety of equipment (Sanguanpong 2003). Schematic flow diagram of neem based extract processing in RIT-pilot plant is shown in the figure.5.

Steps involved:

1. Seed Decoration
2. Crushing
3. Oil Extraction
4. Agitation
5. Filtration
6. Evaporation
7. Formulation

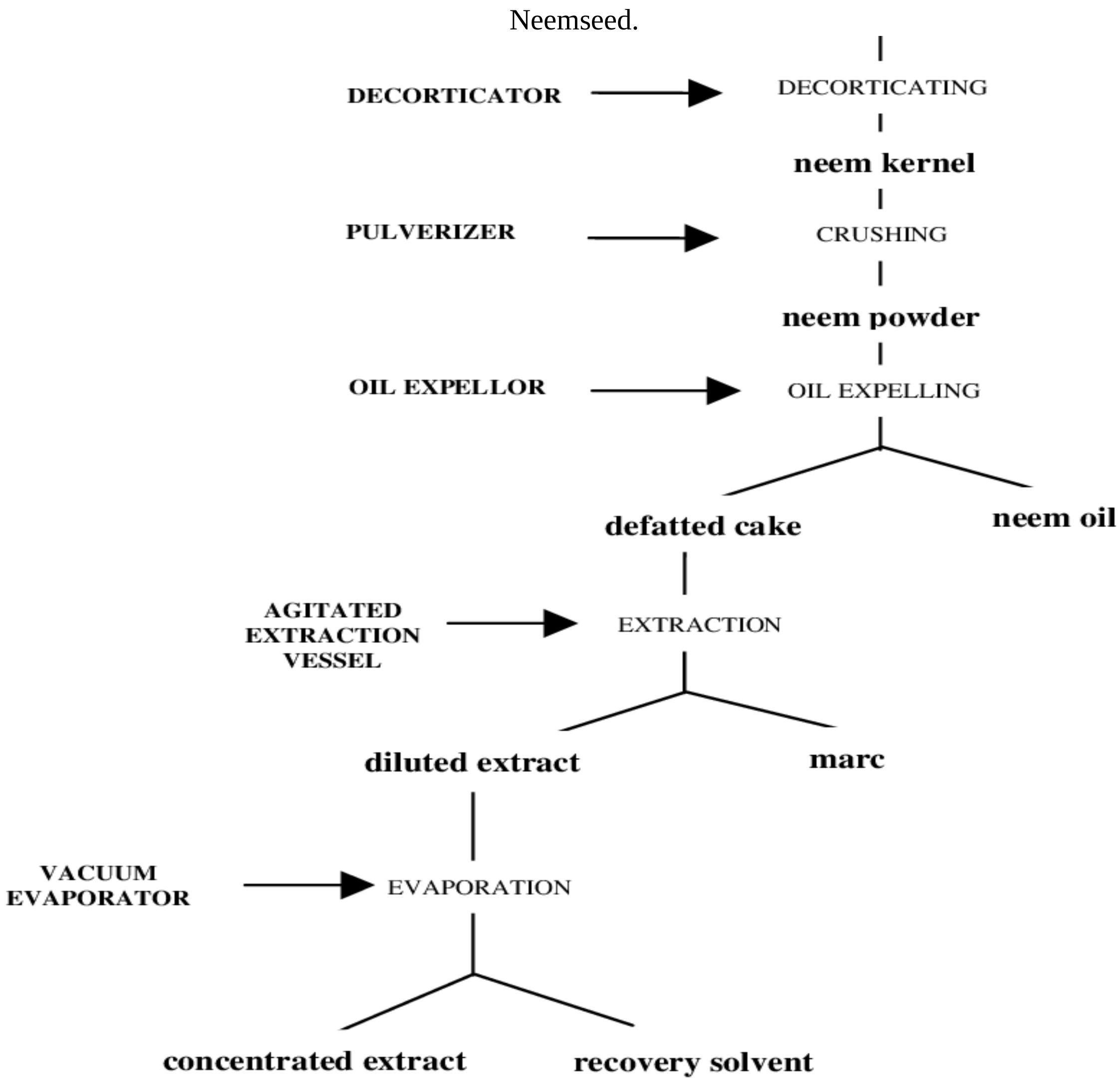


Figure5. Schematic diagram of neem based extract processing in RIT- Pilot plant.

As a source of raw materials, Thai neem seeds (*Azadirachta indica* var. siamensis (Valeton)) are utilised. To separate the neem oil, they are first decorticated to extract the seed kernel, then crushed and then pressed using a screw expellor. The moving-bed contacting extraction technique will be used to extract defatted neem cake with methanol in an agitated extraction vessel.After decanting the crude cake in the mixing-settling tank, the neem solution is drained, filtered, and the process continues. The solution will be evaporated until it reaches a particular volume, resulting in an alcoholic neem-based extract with a high concentration. Before being packaged into containers, the concentrate will be checked for azadirachtin ($C_{36}H_{44}O_{16}$) content using HPLC.Furthermore, the concentrate is purpose-built and available in a range of commercial grades. The product will indeed be bottled and distributed to the conventions at some point. Seed decorticator, filter, pulverizer, agitated-extraction vessel, oil expeller, and evaporator are among the specific equipment required for the stated processes.

Extraction of Azadirachtin From Seed Kernels Using Pressurized Hot Solvent (Jadeja, Maheshwari Et Al. 2011):

Pressurised Liquid Extraction (PLE):

As shown in Fig. 6, Pressurised Liquid Extraction tests were performed in a laboratory-assembled system in semi-batch mode. To avoid material carryover in the outlet tube, a plug of glass wool was placed at the top and bottom of the extractor, followed by a fine wire mesh cloth. The extractor had a 100 mL internal volume and was composed of stainless steel (Type 316). The system was then connected to the loaded extractor, and hot water from a thermostatic water bath adjusted to the proper temperature was allowed to run through the extractor's brass jacket.The temperature within the extractor reached the desired level after around 30 minutes (stationary state). After acquiring the appropriate temperature, the system was pressurised by pumping the extractant (methanol) via a high-pressure air-driven liquid pump. Before entering the extractor, the solvent was warmed to the extraction temperature by passing it via a heating coil that was kept at the same temperature as the extractor.The outlet pressure control valve V2 remained closed during this process. Valve V2 was incrementally opened once the system was pressurised to the proper level, and the dynamic runs for extract collection in vials over a preset time period began. The liquid extracts were then filtered and evaporated at 45°C under reduced pressure in a rotary evaporator. The extracts were dried in a vacuum oven at 30°C until an uniform weight was achieved.

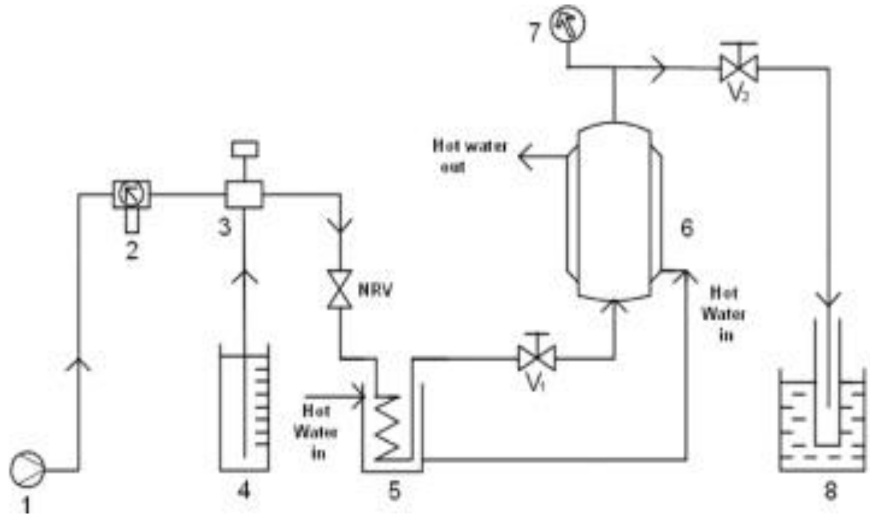


Figure 6. Pressurized liquid extraction of azadirachtin.

Maceration:

It's a cold extraction procedure that requires soaking 30 g defatted kernels in 300 mL methanol in a conical flask. The mixture was agitated intermittently for three days before being filtered and the solvent evaporated under vacuum at 45°C to get the dried crude extract, which had been weighed. The extraction yield was evaluated by gravimetric analysis.

Analysis by HPLC:

The content of azadirachtin in crude extract was determined using a Bureau of Indian Standards-developed external standard calibration method (IS: 14299-1995). A Perkin-Elmer Series 200 pump and Series 200 UV-Vis detector with a 217 nm wavelength were used. To separate the samples, a Purospher-Star RP 18-e column (250 mm id, 4.6 mm id, 5 m) was used. A weighed quantity of crude extract was redissolved in HPLC-grade methanol and vortexed until it was completely dissolved.20 L was injected onto the column after filtering the solution with a 0.45 m syringe filter (Millipore, USA). An isocratic elution (25 minutes) was used with an acetonitrile:water mixture (35:65 percent (v/v)) as the mobile phase at a flow rate of 1 mL/min. The retention time of Azadirachtin was 18.6 minutes.

Conclusion

The optimum conditions for maximizing azadirachtin production were established to be 50°C, 50 bar, particle size of 60 + 80 mesh, and extractant flow rate of 5 mL/min. At optimum circumstances, 210.93 mg azadirachtin was recovered per 100 g defatted NSK after a 100-minute extraction time. The new procedure also resulted in a 1.5-fold reduction in solvent use when compared to the traditional method.

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