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Exploring the chemistry of natural products for textiles applications

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Abstract
Natural products such as fiber and dyes extracted from different natural sources have a wide range of applications in the field of textiles. Consumers are looking for eco-friendly and biodegradable textiles to preserve the natural environment. There are many fiber and dye yielding plants which have the potential for use in textile applications. Exploring the different fields of chemistry helps to produce, a perfect piece of textile material. All natural sources have different properties and varieties of color inherent in different parts of the plant to produce a variety of subtle shades. A highly specialized field of textile chemistry applies the principles of chemistry for the production of clothing and accessories to create marketable new products or to modify existing products. The paper attempt to review the chemistry of different structures of natural fiber and dye for application in various fields of textiles.

Keywords: Natural products, fiber, dye, structure, composition, consumer

Introduction
Nature is full of around 300,000 plant species of the vegetal kingdom that can live in the land as well as in water. They help in the supply of oxygen to the living organism and also protect us from global warming through the absorption of carbon dioxide. The plants along with different varieties of animals, minerals found in nature are contributing to the field of textiles. The properties, composition, and structure of natural products deal with a specific branch of science known as Chemistry. The transformations release and adsorbed of energy are also included in the subject. A form of applied chemistry is textile chemistry which is primarily an applied form of chemistry that helps us to know about different substances either natural or manmade. Textile chemistry is a combination of different areas of textiles like dyeing and finishing, fiber and polymer chemistry, Nanotechnology, etc. Synthetic fibers were gaining importance due to its ability to mold its structure as per consumer desire and to produce different graded fabrics Textile chemistry includes the application of surface finishing, enrichment of fabric through dyeing, printing, etc. It also relates to organic chemistry in the synthesis and formulation of the products used in these processes. The application of different finishes on textiles enhances its performance to satisfy the wearer choice and to induce different properties like stain-repellency, moth repellence, wrinkle-resistance, Antimicrobial, odor-control, etc. Textile chemists are working on the production of fiber, dyes, and pigments, Nano textile, etc. The plant as well as animal fibers are used since time immemorial but only confined to some specific varieties. In recent times different new varieties are exploring and can get different valuable products from it. It can provide opportunities for dynamic and creative applications of chemistry, exploring the different variety of fibers and dyes, use as per the configuration, and can also be modified in the structure for different applications. A textile chemist or a student of textile uses the knowledge to relates the organic structures of fibers to modify the chemical, physical, and aesthetic properties of the end products.

Types of textile fiber
When people start to use fiber for the production of fabric they started with the use of natural fiber only. But after the invention of synthetic fiber, it has gain importance due to the ability to change its property as per desire. During the 20th century, people started to supplemented natural fiber with artificial fibers made from petroleum and another origin. Synthetic fiber properties can be given twist and strength as per requirement from the finest gossamer to the sturdiest canvas. Microfibre thinner fibers less than one denier is also produced for different applications. But now the interest in natural fiber is revived as per its comfortability, eco-friendly character, and the ability to reduce the carbon footprint.

Plant Textiles

The natural fiber is a type of renewable source and is well known for its biodegradability, non-carcinogenic, and eco/health-friendly nature. The natural fiber products are emerging material that can replace synthetic materials for the benefit of environmental applications (Joshi *et al.,* 2004, Vastrad *et al.,* 2012) [15, 24]. Rigveda showed the reference of producing of cotton and process through different stages like ginning separating of seed, Spinning and weaving for use as the textile is found in the religious text of India which is around 1000 BC (Dantyagi, 1974) [8]. Cotton belongs to the family Malvaceae. Cotton waste from post industries and post consumers is also used for the production of yarn, fabric, and textile products. Raw jute produce from *Corchorus capsularies* (white Jute) and Cochorussolitorius (Tossa Jute) is commercially used for the packaging industry about 200 years back. Jute yarns are directly used for the manufacturing of hessian, sacking, carpet backing cloth, twin, etc. Nowadays Jute is considered to be a high strength fiber used for blending with different fibers. Flax fiber has 1800 degree of polymerization which indicates that it has 18,000 cellobiose units and has more crystalline region than cotton which reduce its elastic character. A total of 184, 000 MT. Flax is cultivated in India during 2017 but till now, the 'Diara' variety is used for textile application. Hemp is one of the fastest growing bast fiber composed of 77% cellulose, 1.4% pectin in lamella and 1.0% waxes obtained from stems of *Cannabis sativa* L plants and were used before 10,000 years ago. Roselle and Ramie fiber has high cellulose content and exhibit high tensile properties almost(45-88 cN/tex) and are suitable as reinforcing composite (Nadlene *et al.,*2016 [19]. PALF is a lignocellulosic fiber obtained from the leaves of pineapple composed of inorganic substances, colouring matter, polysaccharides, lignin, and other organic compounds *viz*., fat, wax, pectin, uronic anhydride, pentosan, etc (Goel, 2019) [11]. Kenaf fibres are coarse, brittle with 45-57% cellulose, 8-13% lignin, 3-5% pectin and 21.5% hemicellulose. Due to coarseness the kenaf fiber is difficult to process which requires blending with other fibers. The sisal fiber is a "hard" fiber obtained from decortication leaves which produce fiber 0.6 to 1.5 meter in length. Recently attempts have been made to produce textile fibre from bamboo which is also known as 'green gold' considering its length up 2 mm besides other uses in agriculture, handicraft, paper, etc. Abaca a member of the banana family produces strong, flexible, delicate fiber Rastogi *et al.,* 2017 [20]. Bhindi fiber is also an emerging fiber obtained from the waste plant of Abelmoschus esculanta L. harvesting after collecting of vegetables with a cellulosic content of 65.5%, lignin 13.8%,Ash 15.8%, fatty wax matter 3.9% and 1.0% pectin content (Gogoi *et al.,* 2017) [13].

Table 1: Properties of Natural Fiber

Fibre	Length (mm)	Width (μm)	Crystallinity (%)
cornhusk	0.5-1.5	10-20	48-50
pineapple leaf fibre	3-9	20-80	44-60
coir	0.3-1.0	100-450	27-33
bagasse	0.8-2.8	10-34	-
banana	0.9-4.0	80-250	45
wheat straw	0.4-3.2	8-34	55-65
Jute	0.4-3.4	4-16	40
Ramie	0.8-1.2	30-80	-
Bhindi	2.4-2.8	80-255	-

Source: Gogoi *et al*., 2017 [13], Nadlene *et al*., 2016 [19], Banik *et al*., 2017 [4].

Cellulose, the world's most ubiquitous and abundant natural occurring polymers composed of a long chain polymer produce by plants and microorganisms (Ghosh *et al.,* 2018) [9]. The cellulosic fibers are usually bound by lignin, a natural phenolic polymer. Vegetable fibers are mostly lingo cellulosic fibers except for cotton. The basic unit of cellulosic fiber is cellobiose which contain a long chain of a glucose molecule. It is a polymeric sugar or polysaccharide joint each other by hydrogen bond arranged in a parallel way to form cellulose micro fibrils. Van der Waals force is used to form polymer chains and the moisture absorbency properties are influences by the hydroxyl group. The moisture absorbency properties of cotton which make comfortable to wear are due to the presence of free hydroxyl group which attracts the oxygen atom of water. The wrinkling effect which is said to be a disadvantage of cotton is due to the broken hydrogen bond in cellulose. The hygroscopic nature of cotton fiber can absorb moisture is due to the presence of polar-OH group which can attract water molecules towards it (Goel and Vilensky, 1983) [10]. The entre of the water molecule is restricting to the amorphous region only as there is little space among molecules in the crystalline region. Due to this property of cotton fiber absorb moisture from the skin. It also prevents the development of static electricity due to the attraction of the hydroxyl group by the polarity of water molecules. Cotton fiber burnt when exposed to sunlight which is attributing to the presence of countless hydrogen bond and long fiber polymer.

As per the report of Nakamure *et al.,* 1983 the tensile strength of cotton increases, the relative Young modulus decrease due to the formation of stable structure and relaxation of internal stress concentration with wetting. The tensile properties of cotton are dependent on the amorphous region not on the crystalline region. The rearrangement and more mobile amorphous chain due to bonded water increase strength in wet condition than the dry ones (Miyake *et al.* 2000) [16].

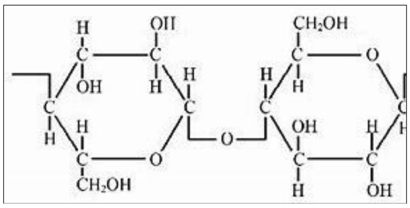

Fig 1: Cellulose

Animal textiles

Animal textiles in the form of skin, hides, nails, teeth's along with leaves were worn by primitive people to cover and ornamenting their bodies. Wool refers to the hair of the domestic goat or sheep, which is used to produce fabric for winter application. Wool is a natural protein fiber that has keratin polymer and amino acid as their repeating unit which is linked to each other by a peptide bond. During the relax stage wool fiber occur as the helical configuration is known as alpha keratin and Beta Keratin or the unfolded configuration can be seen during stretch stage. The inheritance of different desirable characters of wool diversified it uses from fire resistant product to high fashion garments and also for heavy duty products. Wool has a very different structure with different micro and macro layers. The cuticle cell pointed towards the top slip over each other when agitating in water which made the scale interlock by preventing it to come back to its original position and this process is known as felting. Different fabrics are produced by this method. The pH of the felting solution affects the pH rate. As the pH of solution decreases the rate of felting increases. The rate of felting also increases due to the use of nonionic detergent. (Schumacher *et al.*, 2001) [23]. The smallest component of the compress cuticle cell has spring like structure which give wool flexibility and elasticity.

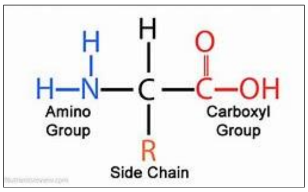

Fig 2: Amino acid

Silk

Silk, the glorious gift of nature is an inimitable natural fiber synonymous with splendor, sibilant with luster and spectaculate in vision. Silk is an obsession with a fashion conscious people of todays' world as we are now going back to nature and started showing increased preference to ecofriendly fiber like silk which was discovered in 2500 B.C and it passed 4000 years standing proudly today braving well, keeping the high flag of naturalism and proclaiming herself as the 'Queen of textiles (Anon, 2003) [3]. The richness and variety in texture, the intricate design of the fabric55567. Nuances of shades and rich hue of silk fascinate everyone. Silk can be obtained from varieties of silkworms mainly mulberry, eri, muga, tassar, spider silk, etc. Silk, spells luxury, elegant, class, comfort from the moment Chinese Empress Shi-Ling shi discovered it in her tea cup (Gogoi 2004) [7]. Due to the look, strength, elongation, absorbency the fiber has diverse applications.The structure of this silk is composed of amino acids comprise of 83.4% with others in trace amount. A total of up to 2592 different amino acids is found in silk but frequently glycine, alanine, and tyrosine are found. The chemical structure of this polymer chain of silk is composed of glycine and alanine in a percentage of 75%.

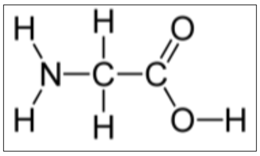

Fig 3: Glycine Chemical Structure

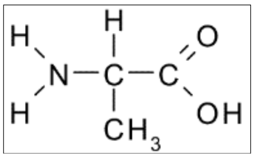

Fig 4: Alanine Chemical Structure

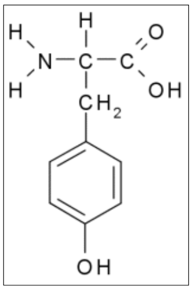

Fig 5: Tyrosine Chemical Structure
Source: Church D, 2018 [7].

Dyes

Man has always been interested in color from prehistoric times and they consider color as a spiritual necessity with equal importance as the physical need of food (Dantyagi 1974) [8]. The art of dyeing with natural dye stuff was mentioned in Ramayana and Mahabharata-sacred book of the Hindu. The rock- cut caves of Ajanta and Ellora proved the antique of dyeing in India (Gupta *et al.*,1989) [14]. The dyeing of textiles is also mentioned in Vedas (Bhuyan and Saikia, 2004) [5]. Natural dyes can produce different color but behind the color there exist a chemical structure which helps to produce, promote, and give variations to the color. Dye produces color due to the ability to absorb visible light between 400- 700 nm. The dye should have at least one chromophore group and a chemical structure with bonds and exhibit resonance of electron (Abrahart, 1977) [2]. Some dyes have no or less substantively towards textile fiber especially cellulosic based fiber. In such case, mordants are used to create the bridging link between the fiber and dye molecules as a metallic salt anchoring the fiber will attract the organic pigments and thus color is produced in the fiber (Samanta, 2011) [21].

Indigoid Dyes

The Indigo class of dye is used from time immemorial and it has a bright attractive blue colour. The indigo dye is extracted from the leaves of a blue color plant belong to the Indigofera species. The indigotin (C.I.Natural Blue1, C.I. 75780) and is the main compound which is found in the largest concentration in the leaves of the plant group which impart blue color to the substance. But as leaves are natural product it also produce a light tint of red color due to the presence of Indiburin but for synthethic indigo(C. I. Vat Blue1, C.I. 73000) we are able to get pure blue color.

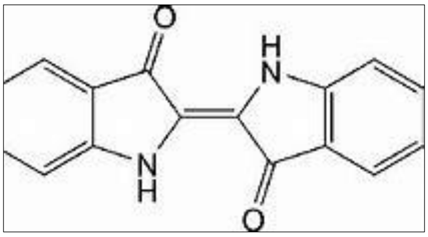

Fig 6: Indigo

Anthraquinone Dyes

Anthrquinone dyes are mostly in the shades of red color. The natural dye in this category are alizarin, Indian madder, Safflower, etc.

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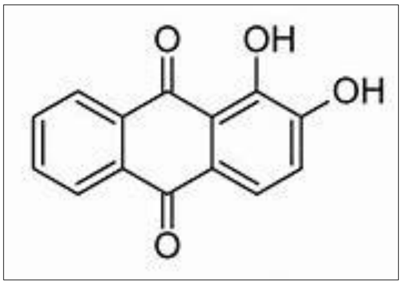

Fig 7: Anthraquinone

Naphthoquinone Dyes

The Napthoquinone dye produces color somewhat similar to the anthrquinone dyes from red, brown such as henna, walnut shells, and so on.

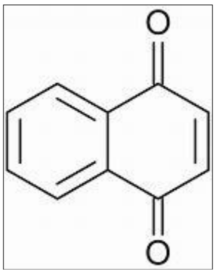

Fig 8: Naphthoquinone

Flavonoid Dyes

Generally the flavonoid have two phenyl ring and one heterocyclic ring with 15 carbon skeleton structure. Flavonoids are observed in more than 85% of the yellow natural dyes (Samanta and Konwar, 2011) [22]. Some research finding also suggests that UV and blue light are absorbed by flavonoids. Flavonoids are bound with sugar hence make it convenient to easily attract by water which makes it easily extractable (Britton, 1983). To increase the longevity flavonoid should treat with metallic mordant to form flavonoid metal complexes.

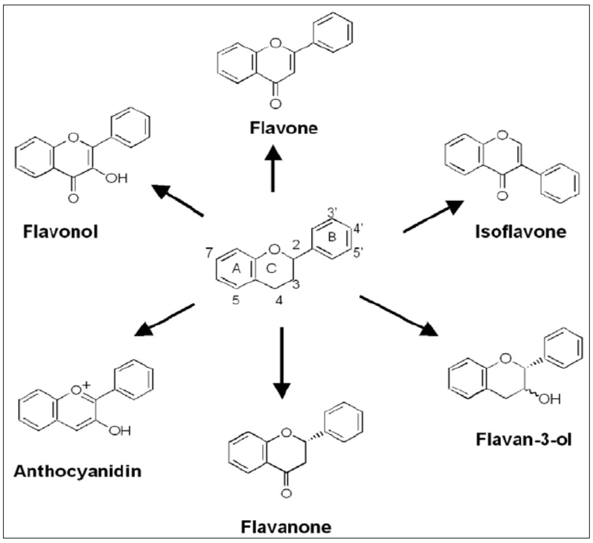

Fig 9: Flavonoid

Carotenoid Dyes

The carotenoid was named after β-carotene isolated from carrot and is abundantly found in annatto seed, bacteria, algae, etc. Annatto is extracted from the outer layer of the orange color seeds of *Bixa Orellana*. Carotenoids are linear long-chain molecules of methylated polyenes with ring structures at the ends in some structures.

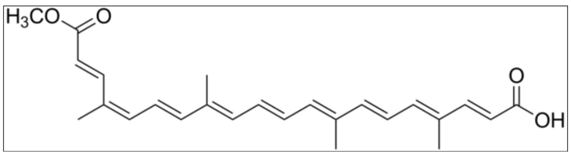

Fig 10: Carotenoid

Curcuminoid Dyes

The yellow colour dye from rhizome of turmeric contain curcuminoid pigments. Besides imparting color the dye has medicinal and antimicrobial properties due to its phenolic content and have ability to absorb ultraviolet to light blue parts of the spectrum. The curcuminoids are classified as diarylheptanoids, with a pair of aromatic rings linked by a seven-carbon chain. Some 19 diarylheptanoids have been identified in turmeric (Pintea 2007),

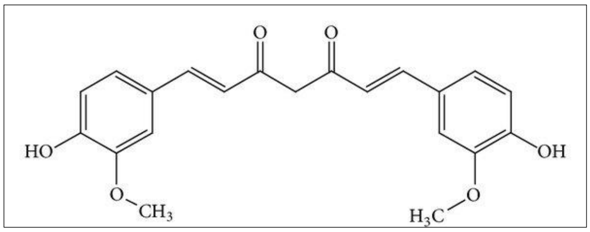

Fig 11: Curcumin

Tannin-Based Dyes

Tannins are present in most of the dyes like acacia bark, Tea leaves with more polyphenolic compounds in the natural resource. The tannin can be used as both dye as well as mordant for other natural dyes.

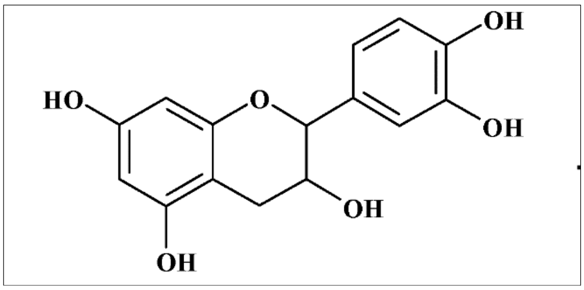

Fig 12: Tanin

Conclusion

The branch of textile chemistry deals helps us to know about the internal structure of the fiber and dye. The variety of color product from different plant sources produce vibrant, non - toxic, non-allergic compounds. The combination of natural products like dye yielding plants, fiber extracting plants for production and coloration help us to conserve the environment, reduce carbon footprints, and help to developed different varieties of value added finished products.

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