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TAMARINDUS INDICA SEED EXTRACTION, APPLICATIONS, AND PHYSIOCHEMICAL CHARACTERIZATION: A REVIEW

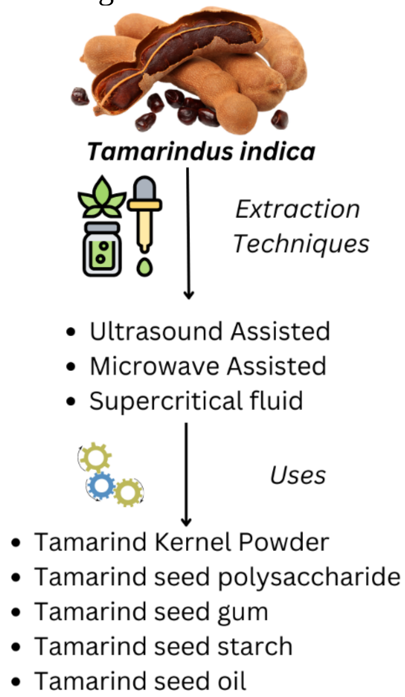
Adan Naeem[1], Rizwana Batool[1]*, Mahwash Aziz[1], Saima Tehseen[1], Madiha Rohi[1], Aiza Zafar[1], Rafia Mubeen[1], Bakhtawar Saleem[1]

[1]Department of Food Science and technology, Government College Women University Faisalabad (naeem@gcwuf.edu.pk; dr.rizwanabatool@gcwuf.edu.pk; dr.mahwashaziz@gcwuf.edu.pk; dr.saimatehseen@gcwuf.edu.pk; dr.madiharohi@gcwuf.edu.pk; aizazafar@gcwuf.edu.pk; rafiamubeen@gcwuf.edu.pk; sbakhtawar098@gmail.com)

***Corresponding author**: - Rizwana Batool
Email: dr.rizwanabatool@gcwuf.edu.pk

ABSTRACT

Aim of the article is to fully compile and synthesize existing knowledge on the removal of various bioactive components from *Tamarindus indica* seed waste. Carbohydrates, proteins, mucilage, alkaloids, lipids, tannins, amino acids, and gums are among the substances that are being targeted. In order to do this, researchers amalgamate traditional and non-thermal extraction techniques, that include supercritical fluid extraction (SFE), microwave-assisted extraction (MAE), and ultrasound-assisted extraction (UAE). This study's main objectives are to investigate various extraction processes, examine the close chemical makeup of the extracted chemicals, and develop approaches to increase the yield of bioactive compounds. This review also aims to offer light on the prospective uses of these derived chemicals in various goods.



Keywords; Tamarind extraction, Tamarind seed-based gum, Proximate analysis, extraction techniques.

1. Introduction

Tamarind seeds are a by-product of agriculture and a possible source for cheap extraction of natural fragrance compounds. *Tamarindus indica* is made up of cellulose based backbone which is a branched polymer with galacto-xylose and xylose carrier. Galacto-xylose residues contained about 65-72% with the combination of glucose-xylose and galactose with the molar ratio of 3:2:1 (Alpizar-Reyes et al., 2022; Nagar et al., 2022). The tamarind seed gum molecular weight was about 720–880 kDa (Nagar et al., 2022). A set of naturally produced polysaccharides and carbohydrates from a natural resource, such as chitosan, seaweed polysaccharide, and plant extractive gum, are collectively referred to as "gum."(Tahir et al., 2019). Native to equatorial Africa, India, and Southeast Asia, the tamarind (*Tamarindus indica*) fruit plant thrives in tropical and subtropical climates with an ideal average temperature around 25 C (Shao et al., 2019) Although it cannot tolerate extremely cold temperatures, it is regarded as the ideal tree for semi-arid regions as it can survive 5 to 6 months of drought. The seed is frequently utilized as the primary ingredient in the production of oil, glue, and polysaccharides (Xie et al., 2020) Tamarind (*Tamarindus indica* L.) is made up of 70% kernel and 30% hard brown seed coat, with the substance containing a lot of gum (TSG), which is mostly made of a galactoxyloglucan polymer (Prabhu et al., 2014). Among the richest sources of xyloglucan is tamarind seeds, which are also frequently utilized to store commercial products of polysaccharides. This biopolymer has a heteropolysaccharide structure with a 1,4-D-glucose chain. Three each of the four glucose molecules in the backbone—or around 70% of the glycosidic residues—are altered with 1,6-D xylose. Depending on the source of the xyloglucan, further metabolites in the form of 1,2-D galactose may also be linked to the xylose (Koziol et al., 2015) Gum extraction techniques typically produce mixtures of components in their fluids that can be purified using a variety of techniques. Gum purity has a significant impact on its physicochemical, biological, and rheological qualities (Razmkhan et al., 2016). TSP may create a very viscous gel with a wide pH tolerance, heat and shear durability, and a high water-holding capacity. TSP offers a wider range of uses in the food sector than other commercialized gums because of its high stability. Additionally, it possesses strong adhesive and biocompatible qualities (Xie et al., 2020). Functionality and physical properties characteristics, such as solubility in water or gelling ability, are determined by the variety of functional groups that can be attached to a xyloglucan backbone (Koziol et al., 2015). TSG is regarded, as a potential biopolymer having uses in the food and pharmaceutical as a stabilizer, emulsifier, viscosity, drug carrier, consistency enhancer, release retardant, gelling and binding agent (Crispín-Isidro et al., 2019). Current review discusses different techniques used to extract various bio active compounds from tamarind seeds, as well as its characteristics and possible uses in the food business. This will also give XG a justification for expanding its line-scale as the food industry turns to substitute hydrocolloids like pectin, cellulose and starch.

2. Extraction Techniques

Multiple conventional and non-thermal analysis were used such as ultrasound assisted, microwave assisted, hot water, high -pressure processing and supercritical fluid extraction techniques for the extraction of different bio-active compounds.

2.1 Boiling water extraction

A water-based extraction process was used, gum was extracted from tamarind seed with a yield of 18.39% w/w (Singh et al., 2011). The produced gum had no flavor, was light brownish in color, gritty in texture, and had a broken surface (Singh et al., 2011). The use of boiling for xyloglucan extraction has various restrictions, including a longer extraction time, the use of a large volume of solvents, a lower extraction yield, and changes in the characteristics (Kulkarni et al., 2017). To upgrade the xyloglucan synthesis process, a novel technology, such as subcritical water extraction, is required (Limsangouan et al., 2019).

2.2 Subcritical water extraction

In the manufacture of xyloglucan, a subcritical water extraction method was applied. They reported a maximum yield of 62.28% at an extraction temperature of 175°C, which was greater than other researchers' approaches (Limsangouan et al., 2019).

2.3 Microwaves assisted techniques

Tamarind seed is a product of the tamarind pulp business that is under utilised. Decorticated tamarind kernel powder (TKP) is utilized as a sizing material in a few industries, including textile, paper, and jute. Because TKP includes a valuable ingredient (xyloglucan), it can be used as a supplement in food formulation. Non-ionic, neutral, hydrophilic, mucoadhesive, and highly branched polysaccharides found in the main cell wall of dicotyledon plants, particularly *Tamarindus indica* seeds (Thivya et al., 2021). Tamarind seed decortication was achieved using microwave treatment, and the decorticated seeds then ground and utilized for xyloglucan extraction (Nguyen et al., 2015). The results showed that microwave treatment provided a high result obtained yield and a suitable color of decorticated seeds (Nguyen et al., 2019). To reduce fat to 0.5%, tamarind kernel powder (TKP) was defatted using a TKP: Hexane ratio of 1:10 (wt/vol) (Nguyen et al., 2019). The xyloglucan component powder isolated from defatted TKP utilizing 95% ethanol in a precipitation procedure with protease enzyme administration for 3 hours had comparable sugar, xylose, and galactose contents to xyloglucan standard which is commercially available (Nguyen et al., 2019). Total production yields for defatted TKP, TKP and xyloglucan component powder with good quality were 40.2 %, 45.6 % and 25.8 % recorded (Nguyen et al., 2019)

2.4 Protease enzyme and Ultrasonic-assisted extraction

TSP was isolated from TKP using a protease enzyme and a high-intensity ultrasonic method. Polysaccharide yields ranged from 59.11% to 72.80%, with purity ranging from 75.87% to 93.96%. Even with a shorter protease digestion time, the combination of high-intensity 2.5 ultrasound and protease treatment improved yield and purity of polysaccharides (Xue & Li, 2023).

2.5 High pressure processing method and Conventional method

When the yields of the two xyloglucan extraction methods (conventional and high-pressure processing) were compared, the high-pressure processing method yielded 51.6%-53%, which was greater than the traditional method's yield of 46.4%. The functional parameters of gum extracted by high pressure processing (water absorption index, viscosity, and mean molecular weight) were much lower than those produced by the usual approach (Limsangouan et al., 2020).

3. Physio chemical characterization of Tamarind Seed polysaccharide

3.1 Tamarind seed polysaccharide

A naturally occurring polysaccharide extracted from seeds of tamarind, has discovered usage in the culinary and pharmaceutical as well as textile industries. It accounts for around 65% of the tamarind seed (Karnena et al., 2022). This natural polysaccharide has a molecular weight of 700-880 kDa (Sheikh et al., 2022). Its chemical structure is made up of 2.8:2.25:1.0 xylose, glucose and galactose (Nagar et al., 2022). These seeds included 86.2% neutral polysaccharides, 5.4% uronic acid, and 1.3% protein. TSP had a molecular weight of 1735 kDa when mixed with xylose, glucose and galactose in a molar ratio of 2.9:1.8:1.0 (Nagar et al., 2022)

3.2 Proximate Analysis

Ash content, tap density, bulk density, cars index, moisture content, compressibility index, hausner ratio, solid %, melting point and water retention were investigated for both non chemical and chemical polysaccharides from tamarind seeds (Manimaran et al., 2022).

Table 1: Proximate analysis of tamarind seed polysaccharide(%)

Sr. No	Properties	Chemical method	Non chemical method	References
1	Ash content (%)	8.16 ± 0.26	13.72 ± 0.45	(Manimaran et al., 2022)
2	Moisture content (%)	9.12 ± 0.29	6.71 ± 0.03	(Manimaran et al., 2022)
3	Tap density	3.43 ± 0.03	2.57 ± 0.06	(Manimaran et al., 2022)
4	PH	6.25 ± 0.20	6.72 ± 0.07	(Manimaran et al., 2022)
5	Bulk density	0.95 ± 0.03 g/cm³	0.83 ± 0.02g/cm³	(Manimaran et al., 2022)
6	Compressibility index (g/cc)	0.728 ± 0.01 g/cc	0.743 ± 0.01 g/cc	(Manimaran et al., 2022)
7	Solid percent (%)	57.30 ± 0.82 %	64.2 ± 1.62 %	(Manimaran et al., 2022)
8	Hausner ratio	2.12 ± 0.02	3.09 ± 0.03	(Manimaran et al., 2022)
9	Water retention	16.60 ± 0.54 mL	19.8 ± 0.04 mL	(Manimaran et al., 2022)
10	Swelling index (%)	73.20 ± 2.29 %	82.2 ± 1.85 %	(Manimaran et al., 2022)
11	Surface tension	$4.72 \pm 0.06\ Nm^{-1} \times 10^{-7}$	$3.34 \pm 0.11\ Nm^{-1} \times 10^{-7}$	(Manimaran et al., 2022)
12	Carrs index	7.56 ± 0.16	6.27 ± 0.20	(Manimaran et al., 2022)

Tamarind seed produces amber-colored oil that is odourless and sweet flavour, similar to linseed oil. Tamarind seeds are high in minerals such as calcium, phosphorus, and iron, magnesium and potassium (Pal et al., 2020). Tamarind seeds contain a variety of minerals, including calcium, phosphorus, magnesium, and potassium. Potassium is the component with the highest concentration in all mineral analyses (Pal et al., 2020).

Table 2: Minerals content in tamarind seed mg/100g

Sr. No	Minerals	Content	References
1	Copper	1.6-19.0	(Pal et al., 2020)
2	Potassium	272.8-610.0	(Pal et al., 2020)
3	Magnesium	17.5-118.3	(Pal et al., 2020)
4	Phosphorus	68.4-165.0	(Pal et al., 2020)
5	Calcium	9.3-786.0	(Pal et al., 2020)
6	Iron	6.5	(Pal et al., 2020)
7	Manganese	0.9	(Pal et al., 2020)
8	Zinc	2.8	(Pal et al., 2020)

Tamarind seed contains protein. Oil or fat accounts for 4.5-16.2% of the total makeup. The seed coat is high in fiber, with the remaining 50-57% being carbohydrate. Except few all amino acids such as leucine, isoleucine, methionine, lycine, valine, and phenylalanine are abundant in tamarind seeds (Bagula et al., 1998).

Table 3: Amino acid content in tamarind seed (mg/g)

Sr. No	Amino acid	Content	References
1	Leucine	531	(Bagula et al., 1998)
2	Isoleucine	313	(Bagula et al., 1998)
3	Methionine	113	(Bagula et al., 1998)
4	Lycine	475	(Bagula et al., 1998)
5	Phenylalanine	318	(Bagula et al., 1998)
6	Cysteine	106	(Bagula et al., 1998)
7	Threonine	200	(Bagula et al., 1998)
8	Tyrosine	287	(Bagula et al., 1998)
9	Glycine	331	(Bagula et al., 1998)
10	Valine	306	(Bagula et al., 1998)
11	Histidine	143	(Bagula et al., 1998)
12	Arginine	450	(Bagula et al., 1998)
13	Aspartic	768	(Bagula et al., 1998)
14	Alanine	312	(Bagula et al., 1998)
15	Glutamic	1056	(Bagula et al., 1998)

Natural antioxidants are plant chemicals that decrease the body's capacity to absorb essential nutrients. All natural antioxidants have no negative health impacts. Certain anti-oxidants, such as phytate and tannins, are beneficial to health. Tannin, phytate, trypsin inhibitor, alkaloid, saponin, and oxalate are all anti-oxidants found in tamarind seeds (Richa et al., 2018).

Table 4. Anti-oxidant content in tamarind seeds per 100 g

Sr. No	Anti-oxidant	Content	References
1	Alkaloids	0.2 ± 0.04 %	(Richa et al., 2018)
2	Saponin	1.01 ± 0.01 %	(Richa et al., 2018)
3	Tannins	20.1 ± 0.01 (mg/100g)	(Richa et al., 2018)
4	Oxalate	0.7 ± 0.05 (mg/100g)	(Richa et al., 2018)
5	Phytate	1.7 ± 0.06 (mg/100g)	(Richa et al., 2018)
6	Trypsin inhibitor	10.7 ± 0.04 (TIU/g)	(Richa et al., 2018)

4. Applications of tamarind seed gum in Food and Non-Food products

Different products obtained from tamarind processing industry finds various uses and, if tapped properly, can add to the income of growers and processors.

4.1 Tamarind seed coat

Tamarind seed coat is an essential byproduct of the value addition industry for tamarind seeds. As with any agro-based business, appropriate utilization would be preferable in terms of increased economic value and reduced waste disposal into the environment. The seed includes 20%-30% testa or seed coat on average (Ramish et al., 2018), and extracted from the shell by roasting or soaking the seed in water and drying it. It can be used to dye and tan different materials such as leather and textiles, as well as a raw substance in the production of plywood adhesives (Prabhu et al., 2014). The strong anti-oxidative activity of tamarind seed coat crude extract has a synergistic anti-oxidative impact with citric acid (Razali et al., 2015; Lourith et al., 2009) and has the potential to be used in chemically and physically stable cosmetic applications (Lourith et al., 2009). Tamarind seed coat is high in fiber and can thus be used in livestock feed. The tannins in the seed coat produce a bitter flavor; the taste and feed value can be improved through physical (drying, wilting, and boiling), chemical (urea, calcium hydroxide, and hydrochloric acid), and microbial detannification processes (Nagar et al., 2022; Makkar, 2003). Tamarind seed coat also possesses some important anti-nutrients, such as tannin and phytate; there have been some reports on the use of tamarind seed coat tannin, but little published information on applications of phytate derived from tamarind seeds is available. This seed coat includes 38% to 40% water soluble materials, with the remaining 80% made up of tannins and coloring substances (Nagar et al., 2022; Kumar & Bhattacharya, 2008). The bulk of studies extracted tannin from tamarind seed coats using a hot aqueous extraction method (Saker et al., 2020; Prabhu et al., 2014). This extracted tannin was used effectively as a mordant (Sarker et al., 2020). Natural dyes are used to color wool and silk textiles (Prabhu et al., 2014). Tanin structural formula is given in figure 1.

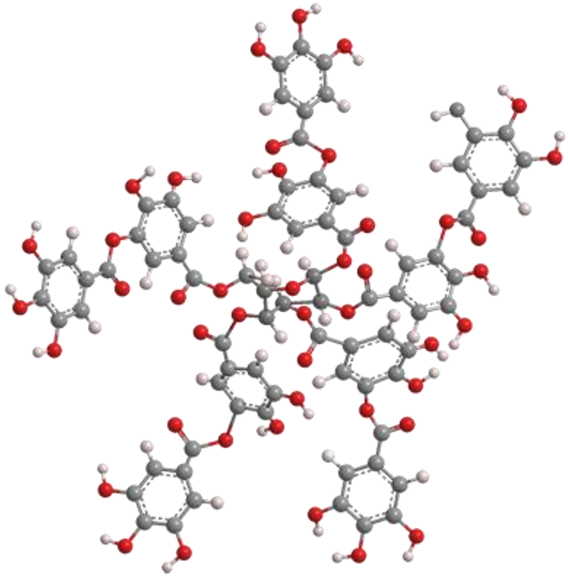


Figure 1: Structural formula of Tanin

4.2 Tamarind seed oil

Because of its composition, thermal stability, and phase behaviour, tamarind seed oil has a high potential for use in a variety of food sectors. The oleoresin derived from tamarind oil is a high-value substance with a promising pharmaceutical application. The residue (de-oiled cake) from oil extraction is used in medicine and for starch extraction, which is used in the creation of biodegradable packaging materials. This seed oil is also used in the creation of high-quality organic fatty acids and can be used as food-grade vegetable oil after refining. The chances and potential of biodiesel derived from tamarind seed oil have been investigated (Kumbhar et al., 2022). When used as engine fuel, biodiesel made from tamarind seed oil is ecologically safe and can help reduce carbon emissions. Biodiesel made from tamarind seed oil has the potential to become an alternative transit fuel (Kumbhar et al., 2022).

4.3 Tamarind seed starch

Tamarind seeds contain a lot of starch, which can be used as a filler in culinary films (Ghoshal et al., 2022). Spice powders were combined with tamarind seed starch to create an edible film with antibacterial and antioxidant qualities. Edible films infused with Syzygiumaromaticum and (high in phenolic content of 29.31 0.31 mg GAE/g) and *Cinnamomum cassia* (high in antibacterial properties) were discovered to be high in antioxidant and antibacterial properties. It has the potential to be an excellent edible packaging material for food and meat products (Rakhavan et al., 2016). Tamarind seed starch/gelatin (TR/GE) and 1% apricot essential oil were used as an edible coating on fresh fruits in various TR/GE ratios of 1:5, 1:4, 1:3, 1:1, 3:1, 4:1, and 5:1(Goshal et al., 2022). Coating and low-temperature storing increased the commodity's shelf life and quality. After 20 days in refrigerated storage, weight loss in coated and uncoated grapes was determined to be 7.17% and 18.61%. The equivalent values for ambient storage were 41.55% and 56.59%, respectively. After 20 days of storage, the overall firmness reductions in the coated and uncoated samples were 31.42% and 62.78% (refrigerated storage), respectively, and 38.06% and 62.84% (ambient storage), TR has antimicrobial qualities, but adding 1% apricot oil improved those properties (Ghoshal et al., 2022).

4.4 Tamarind seed gum

Tamarind gum (Xyloglucan or XG) has characteristics that allow it to be used in the food, pharmaceutical, and textile industries as an emulsifier, gel former, and viscosity modifier (thickener). It is used in the food business as gelling agents, starch modifiers, stabilisers, and ice crystal stabilisers. Structural formula for tamarind seed gum is in figure 2. At low water activity, it creates a gel-like structure (pectin) and can be used to make jams, jellies, marmalades, and mayonnaise. It is also used in confectioneries, thickening sauces, ice cream dressing, and tablet integration binding materials. Tamarind kernel xyloglucan has been proposed as a non-food-based biopolymer alternative to starch, as well as an exceptional film-forming material capable of producing films with high tensile strength (Kochumalayil et al., 2010). Tamarind xyloglucan emulsion films with varying levels of sesame seed oil were produced (Rodrigues et al., 2018). (SSO) using three methods: magnetic swirling alone, magnetic stirring followed by either high-shear homogenization or sonication (Rodrigues et al., 2018). They found that as SSO levels increased from 0 to 20% by weight, oil droplets in the films expanded, reducing the tensile strength of the films (Rodrigues et al., 2018). The impact of different levels of tamarind seed gum incorporation (0.2%, 0.4%, and 0.8%) on gluten-free layer cakes made with rice flour was investigated. They discovered that adding 0.4% tamarind seed gum to a cake improved its proximate composition, water activity, color, total phenolic content, textural characteristics, and shelf life when compared to a cake prepared with wheat flour and rice flour (Wu et al., 2020).

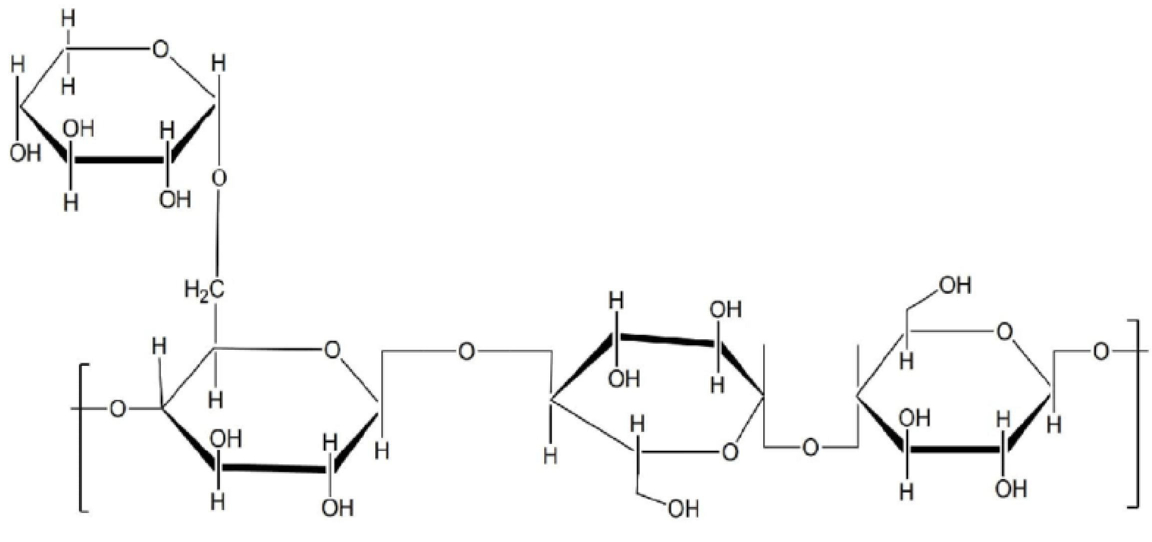


Figure 2. structural formula for tamarind seed gum

4.5 Tamarind seed polysaccharide

TSP has the same properties as food pectin in the formation of acid-sugar jellies and the formation of pectin-like gels in the creation of jam, jellies, and marmalades (Nagar et al., 2022). The alcohol extraction method was used to isolate polyose from TKP (Nagar et al., 2022). It was discovered that 2% polyose supplanted 1% pectin in ready-to-eat jelly preparations (Nagar et al., 2022). This could be a more cost-effective gelling substance than pectin (Marathe et al., 2002). TSPs and litmus lichen dye (LLE) were employed to create a pH-sensing film (Liang & Wang 2017). Tensile strength and elongation at break were reduced from 30.20 to 29.97 MPa and 69.73% to 60.13%, respectively, by adding LLE from 0% to 2.5%. The developed film could detect spoilage in food items such as milk (Liang & Wang 2017).

4.6 Tamarind kernel powder

TKP is also a good source of protein and other minerals, and it can be used to make biscuits, bread, cakes, and a variety of other baked goods (Chakraborty et al., 2016). Food supplements such as instant chutney mix (TKP and coconut, groundnut, and coriander chutney mixes) were created (Sarkar et al., 2018), and TKP incorporation enhanced the nutritional composition of all chutneys, including carbohydrate, protein, fibre, and fat levels (groundnut, coconut and coriander) (Sarkar et al., 2018). In the preparation of mango sauce, TKP functions as a stabilizer (Veerasugwanit & Jittanit 2016). The summary is shown in figure 3.

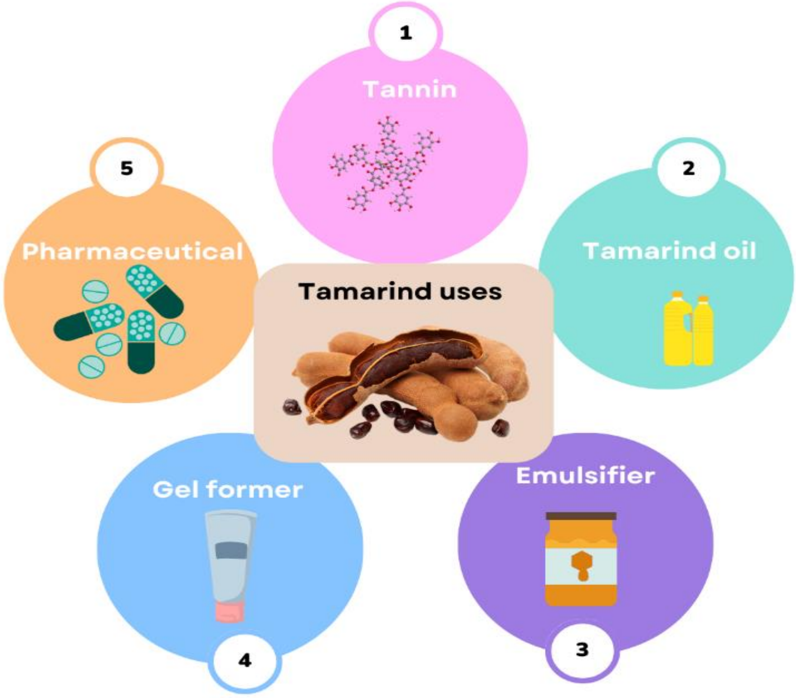


Figure 3: Uses of tamarind and its waste products in daily life

CONCLUSION

This paper provides a comprehensive analysis of the various extraction techniques utilized to obtain bioactive compounds from tamarind seed-based polysaccharides in food waste. The study examines both conventional and non-thermal methods, including ultrasound assisted, microwave assisted, and supercritical fluid extraction. The goal of the study is to find the ideal conditions for extracting bioactive components from tamarind seeds using these innovative techniques. Result of the study aim to improve the efficiency of the extraction process by reducing the time and solvents used while increasing the yield of bioactive compounds such as protein, fiber, carbohydrate, xyloglucon.

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