International Journal of Food and Fermentation Technology
Citation: *Int. J. Food Ferment. Technol.*, **15**(01): 189-203, June 2025
DOI: 10.30954/2277-9396.01.2025.10

ASSOCIATION FOR AGRICULTURE ENVIRONMENT AND BIOTECHNOLOGY

REVIEW PAPER

Low Methoxyl Pectin of Different Plant Sources and its Food and Pharmaceutical Applications: A Review

Ganesh Balbhim Shinde[1], Shrikant Baslingappa Swami[1*], Suhas Zambre[2] and K.V. Venkatesh[2]

[1]Department of Post-harvest Engineering, Post-graduate Institute of Post-harvest Technology and Management, Killa-Roha. Dist: Raigad (Maharashtra State) (Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli-Campus Roha) India
[2]Department of Chemical Engineering, Indian Institute of Technology Bombay, Pawai, Mumbai, India

*Corresponding author: swami_shrikant1975@yahoo.co.in

Paper No.: 320 **Received:** 10-04-2025 **Revised:** 03-05-2025 **Accepted:** 28-05-2025

ABSTRACT

Pectin is an important polysaccharide with various applications in number of industries. Low methoxyl pectin (LM Pectin) is a type of pectin that has less than 50% degree of esterification and/or less than 7% methoxyl content. Low methoxyl pectins have been manufactured since the 1940s primarily for use as gelling agents. It is used in a variety of products, including dairy, bakery and low-sugar jam as well as in pharmaceutical industries. LM pectin extracted from high methoxyl pectin. Whereas the high cost is the major problem in applications. As the alternative, natural LM pectins are safe and cheap. There are many natural sources available from which we can extract a better quality low methxyl pectin. This review paper give a brief review on natural sources of low methoxyl pectin and its uses in food, pharmaceutical and other industries

Keywords: Low Methoxyl Pectin, Plant Sources

Pectin is a complex heteropolysaccharide that contains 1,4-linked α-D-galacturonic acid residues part of which esterified by methanol (Levigne *et al.* 2002). It is commonly found in the cell walls and middle lamellae of higher plants. This is a secondary food ingredient widely used as gelling, emulsifying and stabilizing agents in food products (Koubala *et al.* 2008a).

Despite being widely found in the majority of plant tissues, pectin can only be produced commercially from a very small number of sources. Because the degree of methoxylation and molecular size determine a pectin's capacity to forming gel, pectins from diverse sources do not have the same gelling ability because of differences in molecular size and degree of methoxylation (Thakur *et al.* 1997).

The key to classifying pectin as high-methoxyl pectin (>50%) and low-methoxyl pectin (<50%) with distinct gelation mechanisms is the degree of methyl esterification (Marenda *et al.* 2019). As well as another criteria to determine whether pectin is LM or HM is pectin having a methoxyl content of less than 7 % is considered a low methoxyl content, whereas 8-12 % lies in the category of high methoxyl pectin (Islam *et al.* 2023).

Methoxyl content plays a crucial role in determining the pectins' setting time, susceptibility to polyvalent

How to cite this article: Shinde, G.B., Swami, S.B., Zambre, S. and Venkatesh, K.V. (2025). Low Methoxyl Pectin of Different Plant Sources and its Food and Pharmaceutical Applications: A Review. *Int. J. Food Ferment. Technol.*, **15**(01): 189-203.

Source of Support: None; **Conflict of Interest:** None

cations, and advantageous qualities when it comes to making low-solid gels, films, and fibers (Shaha *et al.* 2013). Pectin derived from plant resources typically has a methyl content ranging from 0.2% to 12%, depend upon the extraction method and raw material source (Sommano *et al.* 2018).

LM-pectin can form gels at acid pHs or when divalent ions like Ca are present (Capel *et al.* 2006; Gilsenan *et al.* 2000; Lootens *et al.* 2003; Lofgren *et al.* 2005).

Since the majority of pectin derived from fruits and vegetables is HMP with a DE ranging from roughly 60% to 90% (Van Buren, 1991), LMP is often created by de-esterifying HMP. Four different types of agents have been used in the primary methods that have been reported for the preparation of LMP from HMP: pectin methyl esterase, acids, alkali, and ammonia in alcohol or concentrated aqueous ammonia (Renard & Thibault, 1996).

De-esterification of HMP with acid or ammonia in an alcoholic medium yields low methoxyl pectin (LMP), DE ≤ 50% (Axelos & Thibault, 1991). Whereas ammonia results in a blockwise distribution of amide groups and a randomly distributed free carboxyl group, acid deesterification yields LMP with a random distribution of carboxyl groups. Blockwise carboxyl group distribution and minimal depolymerization are the results of pectin deesterification from orange using salt-independent polymethyl esterase (Hotchkiss *et al.* 2002; Str€om *et al.* 2007).

In contrast to HM pectins, LM pectins are less sensitive to pH, generate gels regardless of the amount of sugar present, and require a regulated quantity of calcium or another divalent cation to gel (Sundarraj *et al.* 2012). The gel-forming capacity of LM pectin is enhanced by amidation (Kim *et al.* 1978). Often employed as a thickener and stabilizer in the manufacturing of low-calorie meals and drinks, such as fruit juices, dairy products, and dessert fillings, LMP is more valued than HMP (Ciriminna *et al.* 2022).

While LM-pectins are more stable and should not significantly lose their gel-forming ability after a year of storage at room temperature, powdered HM-pectins gradually lose this ability if stored in warm or humid environments (Hercules Incorporated, 1999).

These reactions also proceed faster with increasing temperature. Pectic acids and LM pectins are resistant to neutral and alkaline conditions since there are no or only limited numbers of methyl ester groups. LM pectins form gels in the presence of calcium. In addition, the Sugar beet pectin can form gels through cross linking of the ferulated groups. The calcium-LM pectin gel network is built by formation of the "egg-box" junction Zones in which Ca++ ions cause the cross-linking of two stretches of polygalac turonic acids (Ni *et al.* 2010)

NATURAL SOURCES OF LOW METHOXYL PECTIN

Sunflower

HMP produces artificial LMP through chemical processes that involve the depolymerization of these polysaccharides. This ultimately affects the gel's strength, resulting in a weaker gel (Chan *et al.* 2017). Because of their high natural LMP content and the potential to use the leftovers as a by-product, sunflower heads are seen as having significant industrial relevance in this regard, helping to prevent environmental issues (Adetunji *et al.* 2017).

Fresh sunflower heads (7 mL/g) were processed for 20 minutes at 120 °C and 8 bar, yielding a maximum pectin yield of 6.57% with strong thermal stability. Low methoxy pectin was indicated by the degree of esterification value (Plaza and Turner, 2015).

Passion Fruit

When Yapo and Koffi (2006) isolated pectin from yellow passion fruit, they discovered that the pectins had a low degree of methyl esterification and were high in anhydrogalacturonic acid. Additionally, they have comparatively low levels of neutral sugar and acetyl groups. Additionally, they included a little amount of proteinaceous material. According to the SAG and small amplitude oscillatory shear tests, respectively, their gelling ability and viscoelastic qualities match with those of a commercial citrus low-methoxyl pectin. As a result, yellow passion fruit rind is a naturally low-methoxyl pectin source that may be beneficial.

Cashew Apple Pectin

The pectic components of cashew apple pomace were examined by Yapo and Koffi (2013) under various acid extraction conditions. High concentrations of galacturonic acid (GalA: 69.9%–84.5%) and a few neutral sugars, primarily galactose (Gal: 4.7%–8.6%), arabinose (Ara: 2.6%–5.4%), and rhamnose (Rha: 1.3%–2.5%), were found in the extracted pectin. The isolation of naturally low methoxy pectins (LMP) was indicated by the degree of methoxylation (DM), which ranged from 28% to 46% and was only marginally impacted by the extractant strength. Compared to commercial citrus LMP with similar DM, cashew apple pomace pectin produced firmer Ca2+-mediated LMP gels in terms of gelling capacity. Therefore, cashew apple pomace seems to be a promising source for the potential development of "non-chemically or enzymatically-tailored" LMP.

Jackfruit

From different natural sources Jackfruit is one of the natural sources of low-methoxyl pectin. Pectin was extracted using a water-based extraction method by Ahmmed *et al.* (2017). The extracted jackfruit pectin is classified as low-methoxyl pectin based on its methoxyl concentration, and it can be used in low-sugar goods like low-sugar jam and jellies.

Additionally, Islam *et al.* (2023) isolated pectin from jackfruit, which had a low DE of methoxyl pectin. According to their classification, pectin is low methoxyl pectin if its methoxyl content is less than 7% and high methoxyl pectin if its methoxyl level is between 8 and 12%.

Pomelo

Liew *et al.* (2018) used a subcritical water extraction approach to extract pectin from pomelo peel. The production of LM pectin rather than HM pectin is facilitated by the lack of acid and extended exposure to pressure under dynamic subcritical water extraction conditions. Instead of the traditional two-stage extraction-deesterification procedure, LM pectin may now be produced from pomelo peels in a single extraction phase.

Mango

Banerjee *et al.* (2016) study on lemon juice based extraction of pectin from Mango peel, the extractsed pectin was classified as low methoxyl pectin because DE of extracted pectin was around 50%. The results found by Sommano *et al.* (2018) suggest that phase control microwave-aided extraction favors the extraction of "low methoxyl pectin" (LMP) from Sam-pee mango fruit peels, which is thought to be a sign of high-quality pectin for food processing.

Radish

Pectin extracted from Red radish (*Raphanus sativus* L.) pomace by alkali was low-methoxyl pectin with esterification degree of 10.17%, galacturonic acid content of 69.71% (wt), and average molar weight of 78.59 kDa (Tang *et al.* 2024).

Plum

Khan and Nandkishor, (2019) extracted pectin from wild plum. The extraction was carried out by acid extraction method by using HCL, HNO_3 and citric acid. Methoxyl content of extracted pectin was less than 7 and classified as low methoxyl pectin.

Durian

The FT-IR spectra revealed that, under ideal circumstances, durian pectin is an LM pectin (DE 18.99%) rich in polygalacturonic acid. As a result, durian rind is a good source of LM pectin, which may be used to stabilize and thicken low-calorie food and drink products (Jong *et al.* 2023).

Kaffir Lime

Pectin was isolated from Kaffir lime peel by Shaha *et al.* (2013) can be categorized as low methoxyl pectin based on the degree of esterification and methoxyl content. This pectin may find application in the production of low-sugar products like jam and jellies.

Banana

Kukwa *et al.* (2017) used hydrochloric acid to extract pectin from banana peels, the degree of esterification (45.56%) indicated that the isolated pectin had a low methoxyl content.

Mugampoza *et al.* (2020) examined pectin extracted from bananas at five different phases of ripening: 0, 1, 2, 5, and 7, i.e., after every eight hours. Pectin that was extracted at stages 2, 5, and 7 was described. Throughout the ripening stages, the methoxyl content of pectin from ripening banana pulp and peel generally increased and did not differ significantly (p>0.05). Throughout the ripening stages, the methyl content of pectin from banana peel varied from 4.07 to 11.02%, whereas that from banana pulp varied from 3.67 to 8.21%. All three cultivars' methoxyl content of pectin from banana pulp at stage two of ripening did not differ significantly (p>0.05) i.e. Musakala (5.12%), Mpologoma (4.07%), and Nakitembe (5.37%). At stage 5, there was no significant difference in the methoxyl content (p>0.05), which was 4.73% for Nakitembe, 7.27% for Musakala, and 5.73% for Mpologoma. At the seventh stage of ripening, the methoxyl level of the pectin from Mpologoma was 7.88%, Musakala was 8.76%, and Nakitembe was 11.02%. At stage 2 of ripening, the methoxyl level of banana peel pectin was low (4.02% for Nakitembe, 5.86% for Musakala, and 4.03% for Mpologoma). It is evident that all extracted pectin was discovered to be low methoxyl pectin at stages 5 and 7, with the corresponding methoxyl contents of the pectin extracts being 5.87 and 3.67% for Mpologoma, 4.02 and 8.21% for Nakitembe, and 7.13 and 7.75% for Musakala.

Okra

Pectin from okra pods was extracted by Xu *et al.* (2020), and the results indicated that the pectin was low-methoxyl, with a DE ranging from 39.5 to 43.6%. Alba *et al.* (2015) used aqueous extraction to extract pectin from okra pods at pH 6.0 or 2.0. They discovered that both okra pectins had low methoxyl (LM) pectins, with DM of 40.0% 289 and 24.6%.

Watermelon

Watermelon rind pectin was isolated by Abidin *et al.* (2020). Acid extraction and ultrasound-assisted extraction were used in the extraction process. Both extracted pectins had low methoxyl pectin, according to their DE values.

Pistachio Nut

Pectin was isolated and refined from the green hull of pistachios by Chaharbaghi *et al.* (2017). The pistachio green hull pectin can be regarded as LMP, according to the results of the acidic conditions utilized for pectin extraction (DE ranged from 26.00 to 53.01%). With or without the addition of sugar, this kind of pectin forms gel.

Cocoa

Vriesmann *et al.* (2012) used citric acid to remove pectin from the husk of cocoa pods. The resulting pectin is a highly acetylated LM homogalacturonan (DE 40.3%; DA 15.9%).

Grape

A study on the optimization of acid-extraction of the pectic fraction from grape (*Vitis vinifera* cv. Chardonnay) pomace was carried out by Colodel *et al.* in 2020. According to the findings, Chardonnay grape pomace naturally contains low methoxyl pectin (18.1% degree of methyl-esterification).

Carrot

According to Jafari *et al.* (2017) the pectin production from carrot pomace ranged from 5.0 to 15.2%. It was also categorized as low methoxyl pectin (DE of 22.1-51.8%).

***Premna microphylla* Turcz**

A member of the Verbenaceae family, Premna microphylla Turcz is commonly found in mountainous areas and is referred to locally as "*Dou Fu Chai*" (Lu

Table 1: Some Natural sources of low methoxyl pectin

Sl. No.	Natural Sources of LM Pectin	MeO%			DE%			Reference
1	Sunflower	4.50-4.70			17.7-19.4			Ma *et al.* 2020; Bekheit *et al.* 2008
2	Jackfruit	Peel	Core	rags	Peel	Core	rags	Islam *et al.* 2023
		3.41	3.10	1.87	43.30	38.46	—	
		3.43	2.98	3.624-3.912	34.29	36.31	37.851-39.662	Ahmmed *et al.* 2017; Shinde *et al.* 2024
3	Plum	5.32-6.8			42.48- 54.9			Khan and Nandkishor, 2019
4	Pomelo	6.62			40.1			Liew *et al.* 2018; Yu *et al.* 2024
		2.8- 5.3			39.2- 40.5			Norziah *et al.* 2000
5	Kaffir Lime	2.42-3.78			11.86			Shaha *et al.* 2013
6	Banana	3.096			45.56			Chodijah *et al.* 2019; Kukwa *et al.* 2017
7	Pistachio Nut	—			7.31- 19.02			Chaharbaghi *et al.* 2017
8	Watermelon	2.56- 4.86			29.56- 44.41			Abidin *et al.* 2020
9	Okra	—			39.5-43.6			Xu *et al.* 2020
10	Carrot	—			5.0- 15.2 and 22.1- 51.8			Jafari *et al.* 2016
11	Cocoa	5.08			24			Hennessey-Ramos *et al.* 2021; Sarah *et al.* 2018; Vriesman *et al.* 2012; Pinkaew *et al.* 2024
		6.51			40.3			
12	Durian Rind	3.46%			18.99			Jong *et al.* 2023; Firdaus *et al.* 2018
13	Pineapple	2.4- 5.6			—			Ukiwe and Alinnor
14	Fig	—			32.41-39.42			Gharibzahedi *et al.* 2019
15	Orange	6.43			—			Hundie, 2020
16	Sour Orange	—			17- 30.5			Hosseini *et al.* 2016
17	Lemon	5.4			20.07			Alfa and Abilasha, 2016
18	Sugar Palm	—			Ripened 21.7- 35.4			Rungrodnimitchai, 2011
		—			Young 29.3- 45.0			
19	Apple	8.16			50.98			Fertonani *et al.* 2009
		3.7			33.44			Virk and Sogi, 2004
20	*Citrus Limetta*	5.45			45.62			Panwar *et al.* 2022
		4.460			2.98			Kanmani *et al.* 2014
21	*Citrus sinensis*	5.27-6.2			38.46-58.62			Devi *et al.* 2014
		5.37-5.64			75.58-77.56			Kamal *et al.* 2021
		6.840			3.50			Kanmani *et al.* 2014
22	*Citrus limon*	2.348			1.50			Kanmani *et al.* 2014
		3.97			27.38			Sikder and Ahmed, 2019
		2.86			21.96			

Table 2: Other Physical characterization of LM pectin

Sl. No.	Crop		Yield (%)	Equivalent Weight (g/mol)	Intrinsic Viscosity (dL/g)	Reference
1	Sunflower		6.57	—	—	Ma *et al.* 2020
2	Jackfruit	Peel	25.35	0.476	—	Islam *et al.* 2023; Shinde *et al.* 2024 Ahmmed *et al.* 2017; Sontakke *et al.* 2024
		Core	35.13	0.454	—	
		Rags	28.21	0.555	2.464 – 2.856	
		Peel	14	0.475	2.173	
		Core	10.9	0.460	—	
3	Plum		10.67 to 13.26	625- 1020	—	Khan and Nandkishor, 2019
4	Pomelo		12.6- 20.8	391.2-738.3	—	Norziah *et al.*
			19.6	—	—	Liew *et al.* 2018
5	Kaffir Lime		41.20-61.80	658.1- 735.4	—	Shaha *et al.* 2013
6	Banana		22.57	862.07		Pagarra *et al.* 2019
6	Pistachio Nut		23.42	—	—	Chaharbaghi *et al.* 2017
7	Watermelon		9.87- 10.60	356.43- 479.88	—	Abidin *et al.* 2020; Susanti, 2021
8	Carrot		16.0	—	—	Jafari *et al.* 2016
9	Cocoa		3.7-10.6	—	—	Vriesman *et al.* 2012 Hennessey-Ramos *et al.* 2021
			10.20	0.833	—	Sarah *et al.* 2018; Pinkaew *et al.* 2024
10	Durian Rind		6.02 to 10.96	3860.7	1.487	Jong *et al.* 2023; Firdaus *et al.* 2018; Nguyen *et al.* 2024
11	Fig		6.05-11.71	—		Gharibzahedi *et al.* 2019
12	Orange		26.74	—	—	Hundie, 2020
13	Sour Orange		2 to 17.6	—	—	Hosseini *et al.* 2016
14	Lemon		13.8-44.2	510	—	Alfa and Abilasha, 2016
15	Sugar Palm		Young 3.8-8.1	—	—	Rungrodnimitchai, 2011
			Ripened 9.8-16.7	—	—	
16	Apple		20.07	588.23	—	Fertonani *et al.* 2009; Virk and Sogi, 2004; Naqash *et al.* 2021
			—	652.48	—	
17	*Citrus sinensis*		17.4-76.0	312.5-833.33	—	Devi *et al.* 2014; Kamal *et al.* 2021; Kanmani *et al.* 2014; Ayele *et al.* 2024
			12.4-21.28	1765.19-1899.33	—	
			29.41	594.86	—	
18	*Citrus Limetta*		32.42	386.45	—	Kanmani *et al.* 2014
19	*Citrus limon*		36.71	253.70	—	Kanmani *et al.* 2014; Ahmed and Sikder, 2019; Salam *et al.* 2012
			5.71	298	—	
			12.73	301	—	

Table 3: Other Chemical characterization of LM pectin

Sl. No.	Crop		GalA (%)	Moisture (%)	AUA (%)	Ash (%)	Reference
1	Sunflower		82	5.35-6.15	—	3.80-4.18	Ma *et al.* 2020; Bekheit *et al.* 2008
2	Jackfruit	Peel	65.53-68.65	7.758 – 8.456	44.79	1.55	Islam *et al.* 2023; Shinde *et al.* 2024; Saurabh *et al.* 2023
		Core	—	—	45.76	0.90	
		Rags	57.562- 62.267	8.518-9.694	40.48	1.30	
		Peel	42.140-45.347	9.82	56.78	8.82	Ahmmed *et al.* 2017; Sontakke *et al.* 2024
		Core	—	9.10	53.62	7.89	
3	Plum		61.4 to 79.2	—	69.88- 74.97	0.452- 0.917	Khan and Nandkishor, 2019
4	Pomelo		56.34	—	39.9-74.9	2.5-16.1	Norziah *et al.* 2000; Yu *et al.* 2024; Liew *et al.* 2018
			76.62	—	2.96		
5	Banana		77.44	8.33	56.32	3.060	Chodijah *et al.* 2019; Kukwa *et al.* 2017; Pagarra *et al.* 2019
6	Pistachio Nut		65	—	—	—	Chaharbaghi *et al.* 2017
7	Watermelon		47.268	11.03	47.72- 55.24	1.47- 1.82	Abidin *et al.* 2020; Susanti, 2021
8	Okra		62.67- 68.77	—	—	—	Xu *et al.* 2020
9	Carrot		75.5	—	—	—	Jafari *et al.* 2016
10	Cocoa		52.06	8.27	32.71	16.9	Hennessey-Ramos *et al.* 2021; Sarah *et al.* 2018; Pinkaew *et al.* 2024
			58.08	5.4	29.7	5	
11	Durian Rind		96.78	6.61	49.88 to 77.35	4.57	Jong *et al.* 2023; Firdaus *et al.* 2018; Nguyen *et al.* 2024
12	Fig		76.85	—	—	—	Gharibzahedi *et al.* 2019
13	Orange		—	—	68.25	—	Hundie, 2020
14	Sour Orange		57-83	8.81	—	1.89	Hosseini *et al.* 2016; Hosseini *et al.* 2019
15	Lemon		—	—	65.4	6.66	Alfa and Abilasha, 2016
16	Sugar Palm		Young 43.3-70.0 Ripened 34.3-74.3	—	—	—	Rungrodnimitchai, 2011
17	Apple		41.26	—	91.84	—	Fertonani *et al.* 2009; Virk and Sogi, 2004; Naqash *et al.* 2021
			—	—	62.82	1.44	
18	*Citrus sinensis*		—	10.64	51.04-91.52	3.5-7.5	Devi *et al.* 2014; Kamal *et al.* 2021; Kanmani *et al.* 2014; Ayele *et al.* 2024
			—	9.81	40.36- 41.30	1.42	
			—	—	68.74	1.35	
19	*Citrus limetta*		—	—	42.80	—	Kanmani *et al.* 2014
20	*Citrus limon*		—	12.2	39.48	3.3	Kanmani *et al.* 2014; Sikder and Ahmed, 2019; Salam *et al.* 2012
			—	—	82.12	4.15	
			—	—	74	4.02	

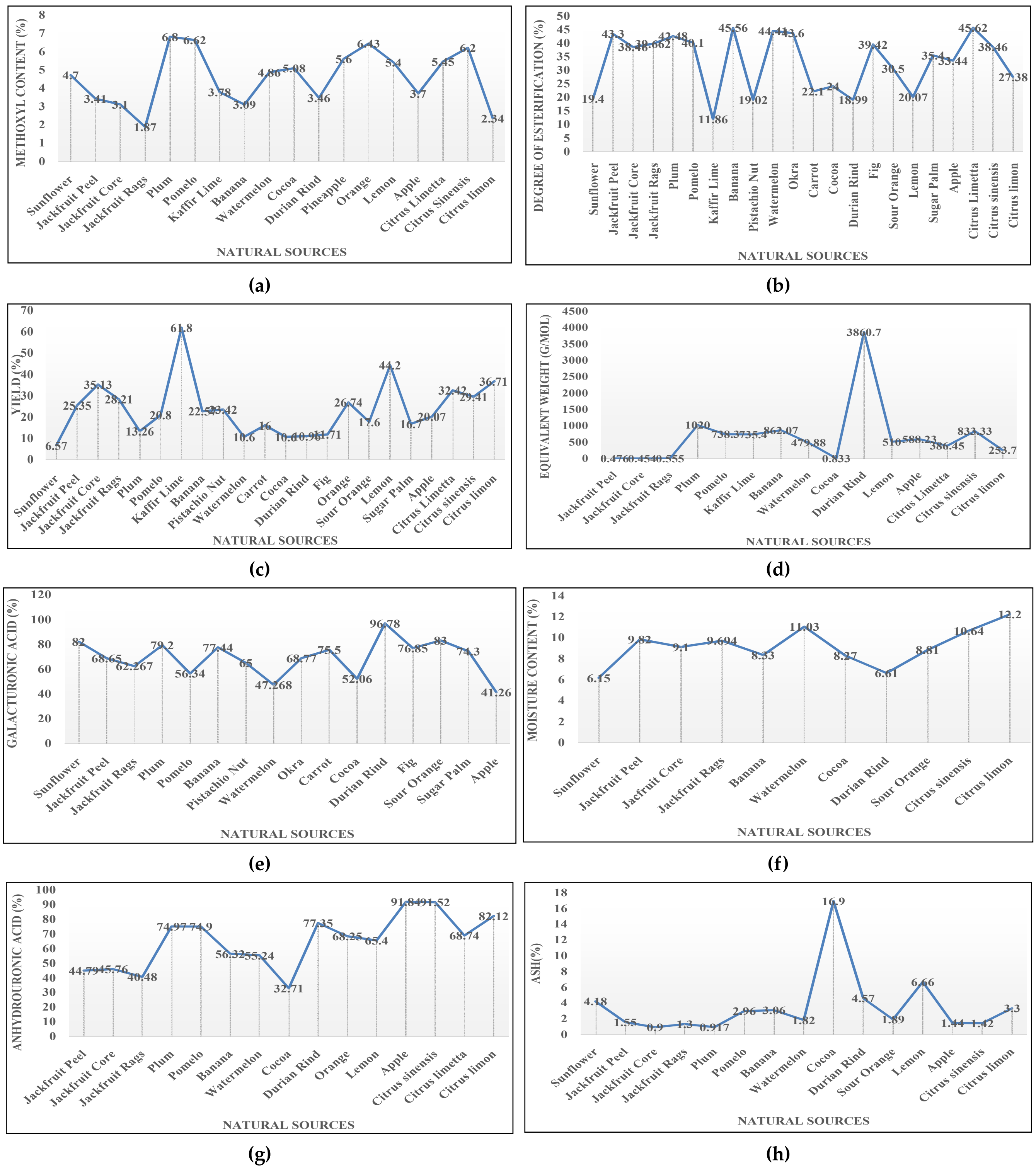

Fig. 1: Physico-Chemical Properties of Low Methoxyl Pectin from differe natural plant sources **(a)** Methoxyl Content, **(b)** Degree of Esterification, **(c)** Yield, **(d)** Equivalent Weight, **(e)** Galacturonic Acid, **(f)** Moisture Content, **(g)** Anhydrouronic Acid, **(h)** Ash

et al. 2019; Tang *et al.* 2018). Pan *et al.* (2019) state that the ammonium oxalate extraction pectin from *Premna microphylla* Turcz is a type of linear LMP (DE: 13.69%) that is rich in homogalacturonan and has a low branching degree, both of which enhance the pectin's gelling qualities.

APPLICATION OF LOW METHOXYL PECTIN IN FOOD INDUSTRY

Low-methoxyl and amidated pectin are used in savory applications (such as sauces and marinades), fruit preparations for yogurts, dessert gels and toppings, low-sugar goods, and reduced-sugar preserves. They are also utilized in high-sugar, low-acid preserves made with bananas, figs, and other sweets (Anonymous, 2009).

Customers who are watching their calorie intake and diabetics who require sugar-free products are driving up demand for jams and jellies with reduced or no sugar. These items contain LM pectin, which creates pectin-calcium gels. Low-sugar goods also contain other natural gums like carrageenan and agar. Although the inability to regulate the setting time of LM pectin gels may be a drawback, the advantages of LM pectins over these gums include their increased stability in acidic environments (Peschardt, 1956).

Conserves are goods that only contain fruit juice or fruit concentrate as a sweetener. Conserves have a soluble solid percentage of 55–62%. At the upper soluble level, a rapid-set HM pectin is used, while LM pectin is applied at the lower limit to provide the products with appropriate mouthfeel and body (Towel and Christensen, 1959).

Bakery jams and jellies with a greater range of relevant soluble solids and acidity can be made with LM pectin. When using LM pectin instead of HM pectin, more pectin must be added to the formulation in order to achieve the same level of firmness. Because of its flavor release qualities and texture, LM pectin is added to some retail brands of barbecue sauce. The ultimate consistency and texture of the product are determined by the amount of calcium and LM pectin in the formula (Hoefler, 1991).

Pectin is added to frozen foods to improve their shape, slow down the growth of crystals, and prevent syrup loss during thawing. Fruits used in ice creams can have their texture and quality enhanced by coatings containing LM pectins (Decker, 1953).

In stirred or Swiss-style yogurt, LM pectin is used to stop the fruit bits from floating and distributing unevenly. Stirred yogurt can be mixed with pectin and fruit concentrate after fermentation to achieve the necessary product viscosity (Basak and Ramaswamy, 1994; Ramaswamy and Basak, 1992).

In order to avoid whey separation and provide body, LM pectin with gelatin has been proposed for use in the production of a sour cream mix (National Dairy Products Inc., 1968).

When Ca^{2+} is added to the mixture, LMP can strengthen the firmness of Japonica rice noodles and be utilized as a thickening agent in acidic dairy products (Zidi *et al.* 2019; Nitta *et al.* 2018). Additionally, LMP gels can be used to glaze, retort, microwave, bake, sterilize, or pasteurize low-calorie jams and jellies (Li and Chang, 1997).

Anionic polysaccharides, such Ca^{2+} sensitive low-methoxyl pectin (LMP), may encourage hydrated pectin chains to interpenetrate into protein networks in set yogurt, resulting in the production of mixed gels in the yoghurt matrix (Wijaya *et al.* 2017).

Khubber *et al.* (2021) found that the yogurt without pectin had the lowest firmness, while the highest was the yogurt with LMP of concentration (1.0%). The low-fat set yogurt's rheology, sensory appeal, and physico-chemical quality all improved with the inclusion of LMP. Bacterial counts increased as LMP levels increased. This has increased acidity and antioxidant potential by aiding in the synthesis of metabolites. LMP has shown promise as a stabilizing element for low-fat set yogurt. Low methoxy pectin in milk at a concentration of 0.2% (w/w) was effectively utilized to enhance moisture retention and improve the texture of low-fat Mexican manchego cheese because calcium ion interaction with pectin can disrupt the compact para-casein matrix.

Low methoxyl pectin is becoming more and more in demand as a result of calorie-conscious consumers and the requirement for diabetics to eat sugar-free products. For these customers, a marmalade with amidated citrus pectin (low methoxyl pectin) and maltitol was created, with few variations in properties from commercial marmalade (Zhilinskaya *et al.* 2018).

The precise qualities and texture that are needed in the finished product determine the type and concentration of pectins that are utilized. For example, guava juice's cloud stability and ascorbic acid retention were positively influenced by low-methoxy pectin (LMP). It improved overall acceptability when mixed with gum Arabic while having no effect on viscosity (Mousa, 2020).

Although LM pectin may be preferable with soluble solids exceeding 60% if a particularly soft, spreadable, or thixotropic texture is desired, LM pectin is employed in applications with soluble solids content below 60%. Relatively low-reactivity LM pectin can be used for applications involving more than 50% soluble solids. However, unless there are specific needs for a particularly soft and spreadable texture, for which a low-reactivity LM pectin is appropriate, medium-reactive LM pectin should be utilized at soluble solids below 50% or at higher filling temperatures. Perfect gels may initially be produced by reactive LM pectin when the soluble solids content is less than 25%. Because of its excellent thermal stability, HM medium rapid set pectin has been utilized traditionally. However, LM pectin would be a better choice because these gels have a tendency to synerise after being pumped or sheared at soluble solids below 60%. LM pectin will result in a pumpable, shearable, and heat-stable baked filling at soluble solids between 50% and 60%. LM pectin must be used if a heat-reversible jam is required. LM pectin is used as a thickening in sauces like fruit-based ripples and toppings when a thick, pumpable texture is preferred. When used in fruit preparations for yoghurt, LM pectin produces a soft, thixotropic gel that is both readily stirred into the yoghurt and solid enough to guarantee consistent fruit distribution even in big containers. Since neutral flavors work better with a pH range of 4.0 to 4.5, this range is required when making non-fruit-flavored pectin jellies with flavors like peppermint and toffee. Some varieties of amidated LM pectin can be used for this kind of application. LM pectin can be used as a gelling ingredient in cold-setting milk desserts. Small levels of LM pectin improve the firmness, texture, and creaminess of stirred and set yoghurt by interacting with milk proteins, having a strong water-binding ability, and being calcium reactive. The rheological characteristics of tomato ketchup can be altered by adding LM pectin, ranging from smooth and pourable to nearly spreadable. Excellent flavor release is also attained. The thickness of vegetable-based sauces, including salsa and chutney, can range from pourable to thick and nearly sliceable when amidated LM pectin is used either by itself or in conjunction with other hydrocolloids, like modified starch (Brejnholt, 2009).

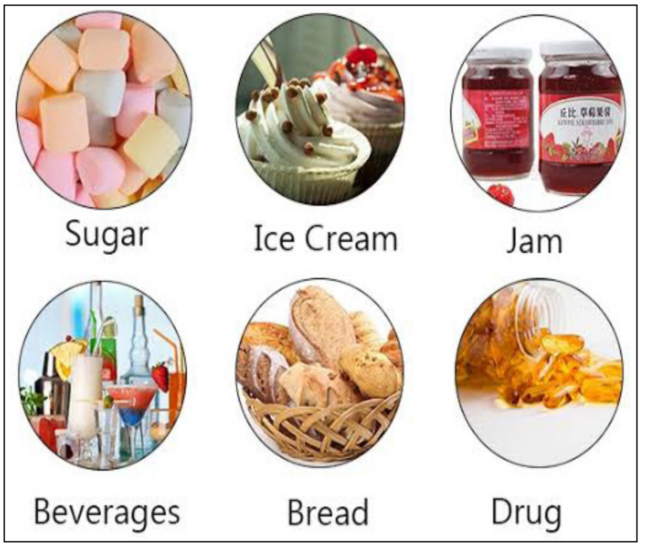

Fig. 2: Application of Low Methoxyl Pectin

Pharmaceutical Uses

In addition to being excellent for wound healing applications, LMP also gets along well with yogurt and may be utilized extensively as a probiotic delivery system. Li *et al.* 2019; Kocaaga *et al.* 2019).

LMP interacts with the intestinal epithelia more easily because it can readily pass through the mucin layer of the intestinal wall (Sriamornsak *et al.* 2010). Through direct interaction with the epithelium, LMP is discovered to increase the production of mucin in the small intestine (Hino *et al.* 2013). Limiting the development of acute pancreatitis into a severe form depends on the construction and function of the intestinal mucosal barrier, which may be positively influenced by LMP (Sun *et al.* 2017).

In the upper part of the gastrointestinal tract, low methoxyl pectin core could reduce the medication's impending preview (Rehmat *et al.* 2022). Low methoxy pectin's mucoadhesive properties, which include a propensity to stick to the mucin with the aid of hydrogen bonds, were found to be effective for the distribution of nasal medications (Klemetsrud *et al.* 2013). Sriamornsak & Nunthanid (1998) altered the drug release pattern from calcium pectinate gel beads by altering the DE of LM-pectin.

The current study's findings show that, when taken orally, LM pectin would be a more effective anti-inflammatory medication than HM pectin. Both systemic and local inflammation were observed to be inhibited by LM pectin (Popov *et al.* 2013).

Other Uses of LM Pectin

Low methoxyl pectin (DE _ 33%) demonstrated greater lipid antioxidant potential than the high methoxyl pectin (DE _ 58%); consequently, low methoxyl pectin can be effectively used as a natural substitute for synthetic antioxidants. The degree of esterification was significantly influenced by the oxidative stability of the emulsions (Celus *et al.* 2018).

Applications where conventional gelation conditions are inappropriate may benefit from the use of low methoxyl pectin (LMP). Formulators may investigate other calcium sources in these situations, such as milk protein or insoluble salts like calcium phosphate and calcium citrate (Assifaoui *et al.* 2024).

Low methoxy pectin's (LMP) capacity to gel at room temperature with the aid of divalent cations is essential for the creation of encapsulation matrix. Heat-sensitive compounds including vitamins, antioxidants, enzymes, proteins, and probiotics can be encapsulated with this property (Assifaoui *et al.* 2013; Cargnin *et al.* 2021; Dhalleine *et al.* 2011; Heumann *et al.* 2020; Huynh *et al.* 2017; Jantrawut *et al.* 2013).

CONCLUSION

From this review we concluded that to avoid long and costly process of extracting Low methoxyl pectin we can be extracted it from several natural sources like sunflower, passion fruit, mango, jackfruit, cashew apple, radish, banana, okra, cocoa, watermelon, etc. Low methoxyl pectin. Low methoxyl pectin is used in food industries like bekaries, milk industry, confectionery, sauses, etc. It is also used in pharmaceutical for curing several disease.

REFERENCES

Abidin, S.A.S.Z., Badarudin, N.S.A. and Ab Mutalib, S.R. 2020. Ultrasound-assisted extraction increases pectin yield from watermelon (*Citrullus lanatus*) Rind. In *2020 11th IEEE Control and System Graduate Research Colloquium (ICSGRC)*, pp. 291-294.

Adetunji, L.R., Adekunle, A., Orsat, V. and Raghavan, V. 2017. Advances in the pectin production process using novel extraction techniques: a review. *Food Hydrocoll.*, **62**: 239–250.

Ahmmed, R., Inam, A.K.M.S., Alim, M.A., Sobhan, M.M. and Haque, M.A. 2017. Extraction, characterization and utilization of pectin from jackfruit (*Artocarpus heterophyllus L.*) waste. *Journal of Environmental Science and Natural Resources*, **32**: 57-66.

Alba, K., Laws, A.P. and Kontogiorgos, V. 2015. Isolation and characterization of acetylated LM-pectins extracted from okra pods. *Food Hydrocolloids*, **43**: 726-735.

Alfa, E. and Abilasha, D. 2016. Extraction and characterization of pectin from lemon peel. International *Jouranal of Advance Science Research*, **1**(12): 12-15.

Anonymous. 2009. Non amidated low methoxyl pectin. *Technical evaluation report* pp. 1e11. USDA. CAS number: 9000-69-5, INS no. 440.

Assifaoui, A., Bouyer, F., Chambin, O. and Cayot, P. 2013. Silica-coated calcium pectinate beads for colonic drug delivery. *Acta Biomaterialia*, **9**(4): 6218–6225.

Assifaoui, A., Hayrapetyan, G., Gallery, C. and Agoda-Tandjawa, G. 2024. Exploring Techno-Functional Properties, Synergies, and Challenges of pectins: a review. *Carbohydrate Polymer Technologies and Applications*, pp.100496.

Axelos, M.A.V. and Thibault, J.F. 1991. The chemistry of low-methoxyl pectin gelation. Ch. 6. *In* R. H. Walter (Ed.), *The chemistry and technology of pectin,* pp. 109e118. San Diego, CA: Academic Press, Inc.

Ayele, A.T., Endalew, S.A. and Okpala, C.O.R. 2024. Physicochemical Properties of Ethiopian Orange (*Citrus sinensis*) Peels and Extracted Pectin by Varieties. *Polish Journal of Environmental Studies*.

Banerjee, J., Vijayaraghavan, R., Arora, A., MacFarlane, D.R. and Patti, A.F. 2016. Lemon juice based extraction of pectin from mango peels: waste to wealth by sustainable approaches. *ACS Sustainable Chemistry & Engineering*, **4**(11): 5915-5920.

Basak, S. and Ramaswamy, H.S. 1994. Simultaneous evaluation of shear rate and time dependency of stirred yogurt rheology as influenced by added pectin and strawberry concentrate, *J. Food Eng.,* **21**: 385.

Bekheit, A.A., Ali, F.A., Ali, M.H. and Galal, S.M. 2008. Extraction and Evaluation Of Pectin From Sunflower Head Residue Using Ultrasonic. *Journal of Food and Dairy Sciences*, **33**(1): 309-320.

Brejnholt, S.M. 2009. Pectin. *Food stabilisers, thickeners and gelling agents*, pp. 237-265.

Capel, F., Nicolai, T., Durand, D., Boulenguer, P. and Langendorff, V. 2006. Calcium and acid induced gelation of (amidated) low methoxyl pectin. *Food Hydrocolloids*, **20**(6): 901–907.

Cargnin, M. A., Gasparin, B.C., dos Santos Rosa, D. and Paulino, A.T. 2021. Performance of lactase encapsulated in pectin-based hydrogels during lactose hydrolysis reactions. *LWT, 150*, Article 111863.

Celus, M., Salvia-Trujillo, L., Kyomugasho, C., Maes, I., Van Loey, A.M., Grauwet, T. and Hendrickx, M.E. 2018. Structurally modified pectin for targeted lipid antioxidant capacity in linseed/sunflower oil-in-water emulsions. *Food Chem*., **241**: 86–96.

Chaharbaghi, E., Khodaiyan, F. and Hosseini, S.S. 2017. Optimization of pectin extraction from pistachio green hull as a new source. *Carbohydrate Polymers*, **173**: 107-113.

Chan, S.Y., Choo, W.S., Young, D.J. and Loh, X.J. 2017. Pectin as a rheology modifier: Origin, structure, commercial production and rheology. *Carbohydrate Polymers*, **161**: 118-139.

Chodijah, S., Husaini, A. and Zaman, M. 2019, February. Extraction of pectin from banana peels (*Musa paradiasica* fomatypica) for biodegradable plastic films. In *Journal of Physics: Conference Series* (Vol. 1167, No. 1, p. 012061). IOP Publishing.

Ciriminna, R., Fidalgo, A., Scurria, A., Ilharco, L.M. and Pagliaro, M. 2022. Pectin: New science and forthcoming applications of the most valued hydrocolloid. *Food Hydrocolloids,* **127**, Article 107483.

Colodel, C., Vriesmann, L.C., Teófilo, R.F. and de Oliveira Petkowicz, C.L. 2020. Optimization of acid-extraction of pectic fraction from grape (Vitis vinifera cv. Chardonnay) pomace, a Winery Waste. *International Journal of Biological Macromolecules*, **161**: 204-213.

Decker, C.W. 1953. *Can. Dairy Ice Cream J.,* **30**: 46, 1951; *Chem. Abstr.*, **47**: 227.

Devi, W.E., Kumar, R.S.K.B.A. and Mishra, A.A. 2014. Extraction of pectin from citrus fruit peel and its utilization in preparation of jelly. *International Journal of Engineering Research*, **3**(5).

Dhalleine, C., Assifaoui, A., Moulari, B., Pellequer, Y., Cayot, P., Lamprecht, A. and Chambin, O. 2011. Zinc-pectinate beads as an in vivo self-assembling system for pulsatile drug delivery. *International Journal of Pharmaceutics,* **414**(1): pp. 28–34.

Fertonani, H.C.R., Scabio, A., Carneiro, E.B.B., Schemim, M.H.C., Nogueira, A. and Wosiacki, G. 2009. Extraction model of low methoxyl pectin from apple pomace effects of acid concentration and time on the process and the product. *Brazilian Archives of Biology and Technology*, **52**: pp.177-185.

Firdaus, F.E., Redella, A. and Nursabila, S. 2018. The Effectiveness Biosorption of Durian (*Durio zibhetinus*) Rind Pectin on Handling Liquid Waste Containing Heavy Metal (Pb II). *In MATEC Web of Conferences* (Vol. 248, p. 04003). EDP Sciences.

Gharibzahedi, S.M.T., Smith, B. and Guo, Y. 2019. Pectin extraction from common fig skin by different methods: The physicochemical, rheological, functional, and structural evaluations. *International Journal of Biological Macromolecules*, **136**: 275-283.

Gilsenan, P.M., Richardson, R.K. and Morris, E.R. 2000. Thermally reversible acidinduced gelation of low-methoxy pectin. *Carbohydrate Polymers,* **41**(4): 339–349.

Hennessey-Ramos, L., Murillo-Arango, W., Vasco-Correa, J. and Paz Astudillo, I.C. 2021. Enzymatic extraction and characterization of pectin from cocoa pod husks (*Theobroma cacao* L.) using Celluclast® 1.5 L. *Molecules*, **26**(5): 1473.

Hercules Incorporated. 1999. Food gum products description: General description of pectin. (online - http://www.herc.com/foodgums/index.htm)

Heumann, A., Assifaoui, A., Da Silva Barreira, D., Thomas, C., Briandet, R., Laurent, J., Beney, L., Lapaquette, P., Guzzo, J. and Rieu, A. 2020. Intestinal release of biofilm-like microcolonies encased in calcium-pectinate beads increases probiotic properties of *Lacticaseibacillus paracasei*. *Npj Biofilms and Microbiomes,* **6**(1): 44.

Hino, S., Sonoyama, K., Bito, H., Kawagishi, H. *et al.* 2013. Low methoxyl pectin stimulates small intestinal mucin secretion irrespective of goblet cell proliferation and is characterized by jejunum Muco upregulation in rats. *J. Nutr*. **143**: 34–40.

Hoefler, A. C., Other pectin food products, in *The Chemistry and Technology of Pectin,* Walter, R.H. 1991. *Ed., Academic Press,* San Diego, 51

Hosseini, S.S., Khodaiyan, F. and Yarmand, M.S. 2016. Aqueous extraction of pectin from sour orange peel and its preliminary physicochemical properties. *International Journal of Biological Macromolecules*, **82**: 920-926.

Hosseini, S.S., Khodaiyan, F., Kazemi, M. and Najari, Z. 2019. Optimization and characterization of pectin extracted from sour orange peel by ultrasound assisted method. *International Journal of Biological Macromolecules*, **125**: 621-629.

Hotchkiss, A.T., Jr., Savary, B.J., Cameron, R.G., Chau, H.K., Brouillette, J., Luzio, G.A. *et al.* 2002. Enzymatic modification of pectin to increase its calcium sensitivity while preserving its molecular weight. *Journal of Agricultural and Food Chemistry,* **50**(10): 2931e2937.

Hundie, K.B. 2020. Ultrasound-assisted optimization of pectin extraction from orange peel using response surface methodology (RSM) and artificial neural network (ANN). *International Journal of Applied Science and Engineering*, **8**(2): 69-87.

Huynh, U.T.D., Assifaoui, A. and Chambin, O. 2017. Pellets based on polyuronates: Relationship between gelation and release properties. *Journal of Food Engineering,* **199**: 27–35.

Islam, M.R., Biswas, M.M.H., Esham, M.K.H., Roy, P. and Hasan, S.K. 2023. Jackfruit (*Artocarpus heterophyllus*) by-products a novel source of pectin: Studies on physicochemical characterization and its application in soup formulation as a thickener. *Food Chemistry Advances*, **2**: 100273.

Jafari, F., Khodaiyan, F., Kiani, H. and Hosseini, S.S. 2017. Pectin from carrot pomace: Optimization of extraction and physicochemical properties. *Carbohydrate Polymers*, **157**: pp.1315-1322.

Jantrawut, P., Assifaoui, A. and Chambin, O. 2013. Influence of low methoxyl pectin gel textures and *in vitro* release of rutin from calcium pectinate beads. *Carbohydrate Polymers,* **97**(2): 335–342.

Jong, S.H., Abdullah, N. and Muhammad, N. 2023. Optimization of low-methoxyl pectin extraction from durian rinds and its physicochemical characterization. *Carbohydrate Polymer Technologies and Applications*, **5**: 100263.

Kamal, M.M., Kumar, J., Mamun, M.A.H., Ahmed, M.N.U., Shishir, M.R.I. and Mondal, S.C. 2021. Extraction and characterization of pectin from *Citrus sinensis* peel. *Journal of Biosystems Engineering*, **46**: 16-25.

Kanmani, P., Dhivya, E., Aravind, J. and Kumaresan, K. 2014. Extraction and analysis of pectin from citrus peels: augmenting the yield from citrus limon using statistical experimental design. *Iranica Journal of Energy & Environment*, **5**(3).

Khan, M. and Nandkishor. 2019. Optimization of extraction condition and characterization of low methoxy pectin from wild plum. *Journal of Packaging Technology and Research*, **3**(3): 215-221.

Khubber, S., Chaturvedi, K., Thakur, N., Sharma, N. and Yadav, S.K. 2021. Low-methoxyl pectin stabilizes low-fat set yoghurt and improves their physicochemical properties, rheology, microstructure and sensory liking. *Food Hydrocolloids*, **111**: 106240.

Kim, W.J., Susulskiu, F. and Rees, S.C.K. 1978. Chemical and gelation characteristics of ammoniademethylated sunflower pectins, *J. Food Sci.,* **43**: 1436,

Klemetsrud, T., Jonassen, H., Hiorth, M., Kjoniksen, A., Smistad, G. 2013. Studies on pectin-coated liposomes and their interaction with mucin. *Colloids Surf. B: Biointerfaces*, **103**: 158−165.

Kocaaga, B. Kurkcuoglu, O., Tatlier, M., Batirel, S., Guner, F.S. 2019. Low-methoxyl pectin−zeolite hydrogels controlling drug release promote *in vitro* wound healing. *J. Appl. Polym. Sci*., **136**: 47640.

Koubala, B.B., Kansci, G., Mbome, L.I., Crépeau, M. J., Thibault, J.F. and Ralet, M.C. 2008. Effect of Extraction Conditions on Some Physicochemical Characteristics of Pectins from "Améliorée" and "Mango" Mango Peels. *Food Hydrocolloids,* **22**: 1345–1351.

Kukwa, R., Kukwa, D. and Onah, J. 2017. Stabilization of locally produced orange Juice using extracted pectin from banana peels. *Journal of Environmental Science, Toxicology and Food Technology*, **11**(7): 6-10.

Levigne, S., Ralet, M.C. and Thibault, J.F. 2002.Characterisation of Pectins Extracted from Fresh Sugar Beet under Different Conditions using an Experimental Design. *Carbohydrate Polymers,* **49**: 145-153.

Li, G.J. and Chang, K.C. 1997. Viscosity and gelling characteristics of sunflower pectin as affected by chemical and physical factors. *J. Agric. Food Chem.,* **45**: 4785−4789.

Liew, S.Q., Teoh, W.H., Tan, C.K., Yusoff, R. and Ngoh, G.C. 2018. Subcritical water extraction of low methoxyl pectin from pomelo (*Citrus grandis* (L.) Osbeck) peels. *International journal of biological macromolecules*, **116**: 128-135.

Lofgren, C., Guillotin, S., Evenbratt, H., Schols, H., & Hermansson, A. M. 2005. Effects of calcium, pH, and blockiness on kinetic rheological behavior and microstructure of HM pectin gels. *Biomacromolecules*, **6**(2): pp. 646–652.

Lootens, D., Capel, F., Durand, D., Nicolai, T., Boulenguer, P. and Langendorff, V. 2003. Influence of pH, Ca concentration, temperature and amidation on the gelation of low methoxyl pectin. *Food Hydrocolloids*, **17**(3): 237–244.

Lu, J.K., Li, J.J., Jin, R.C., Li, S.F., Yi, J.J. and Huang, J.Y. 2019. Extraction and characterization of pectin from *Premna* *microphylla* Turcz leaves. *International Journal of Biological Macromolecules,* **131**: 323–328.

Ma, X., Jing, J., Wang, J., Xu, J. and Hu, Z. 2020. Extraction of low methoxyl pectin from fresh sunflower heads by subcritical water extraction. *ACS Omega*, **5**(25): 15095-15104.

Marenda, F.R.B., Mattioda, F., Demiate, I.M., de Francisco, A., de Oliveira Petkowicz, C.L., Canteri, M.H.G. and de Mello Castanho Amboni, R.D. 2019. Advances in studies using vegetable wastes to obtain pectic substances: A review. *Journal of Polymers and the Environment*, **27**: 549-560.

Mousa, R.M.A. 2020. Simultaneous development of cloud stability and antioxidant preservation in cloudy guava juice using hydrocolloid combinations. *International Food Research Journal,* **27**: 762–774.

Mugampoza, D., Gafuma, S., Kyosaba, P. and Namakajjo, R. 2020. Characterization of pectin from pulp and peel of Ugandan cooking bananas at different stages of ripening. *Journal of Food Research*, **9**(5): 67-77.

Naqash, F., Masoodi, F.A., Gani, A., Nazir, S. and Jhan, F. 2021. Pectin recovery from apple pomace: physico-chemical and functional variation based on methyl-esterification. *International Journal of Food Science & Technology*, **56**(9): 4669-4679.

National Dairy Products Inc., British Patent 1,124,238, 1968.

Nguyen, P.A.T., Nguyen, T.T.T. and Nguyen, D.K.V. 2024. Pectin from Durian peel (*Durio zibethinus* Murr.)-a novel reducing and stabilizing agent: physicochemical properties, green synthesis of silver nanoparticles and antimicrobial properties. *Carbohydrate Polymer Technologies and Applications*, pp. 100623.

Ni, Y., Yates, K.M. and Zarzycki, R., Nanotherapeutics Inc, 2010. *High molecular weight, low methoxyl pectins, and their production and uses*. U.S. Patent 7,691,986.

Nitta, Y., Yoshimura, Y., Ganeko, N., Ito, H., Okushima, N., Kitagawa, M., Nishinari, K. 2018. Utilization of Ca2+-induced setting of alginate or low methoxyl pectin for noodle production from Japonica rice. *LWT*, **97**: 362–369.

Norziah, M.H., Fang, E.O. and Abd Karim, A. 2000. Extraction and characterisation of pectin from pomelo fruit peels. In *Gums and Stabilisers for the Food Industry*, **10**: 27-36. Woodhead Publishing.

Pagarra, H., Purnamasari, A.B. and Rahman, R.A. 2019. Optimization of pectin extraction from kepok banana peels (*Musa paradisiaca*) using surface response methodology. In *Journal of Physics: Conference Series* (Vol. 1317, No. 1, p. 012100). IOP Publishing.

Pan, M.K., Zhou, F.F., Liu, Y. and Wang, J.H. 2021. Na+-induced gelation of a low-methoxyl pectin extracted from Premna microphylla Turcz. *Food Hydrocolloids*, **110**: 106153.

Peschardt, W.J.S. Canadian Patent, 520, 983, 1956.

Pinkaew, T., Inthachat, W., Khemthong, C., Kemsawasd, V., On-Nom, N. and Temviriyanukul, P. 2024. High Pectin Recovery from Cocoa Husks Using an Autoclave Approach: An Analysis of Its Physicochemical, Structural, and Genotoxicity Properties. *Foods*, **13**(5): 669.

Plaza, M. and Turner, C. 2015. Pressurized hot water extraction of bioactives. *Trends Anal. Chem.,* **71**: 39–54.

Ramaswany, H.S. and Basak, S. 1992. Pectin and raspberry concentrate effects on the rheology of stirred commercial yogurt, *J. Food Sci.,* **57**: 357.

Rehmat, S., Rizvi, N.B., Khan, S.U., Ghaffar, A., Islam, A., Khan, R.U., Mehmood, A., Butt, H. and Rizwan, M. 2022. Novel stimuli-responsive pectin-PVP-functionalized clay based smart hydrogels for drug delivery and controlled release application. *Frontiers in Materials*, **9**: 823545.

Renard, C.M. and Thibault, J.F. 1996. Degradation of pectins in alkaline conditions: kinetics of demethylation. *Carbohydrate Research*, **286**: 139-150.

Rungrodnimitchai, S. 2011. Novel source of pectin from young sugar palm by microwave assisted extraction. *Procedia Food Science*, **1**: 1553-1559.

Sarah, M., Hanum, F., Rizky, M. and Hisham, M.F. 2018, February. Microwave-assisted extraction of pectin from cocoa peel. In *IOP Conference Series: Earth and Environmental Science* (Vol. 122, p. 012079). IOP Publishing.

Shaha, R.K., Punichelvana, Y.N.A. and Afandi, A. 2013. Optimized extraction condition and characterization of pectin from kaffir lime (*Citrus hystrix*). *Research Journal of Agriculture and Forestry Sciences ISSN, 2320*, p.6063.

Shinde, G.B. Swami, S.B., Zambre, S.S., Vankatesh, K.V., Pardeshi, I.L. and Patange, S.B. 2024. Effect of maturity levels and blanching temperature on extraction of pectin from jackfruit rags and study its properties. *International Journal of Advanced Biochemistry Research,* **8**(10): 827-829.

Sikder, M.B.H. and Ahmed, S. 2019. Extraction, characterization and application of three varieties of *Citrus limon* L. pectin in jelly product. *Food and Applied Bioscience Journal*, **7**(1): 31-50.

Sommano, S.R., Ounamornmas, P., Nisoa, M., Sriwattana, S., Page, P. and Colelli, G. 2018. Characterisation and physiochemical properties of mango peel pectin extracted by conventional and phase control microwave-assisted extractions. *International Food Research Journal*, **25**(6): 2657-2665.

Sontakke, P.B., Swami, S.B., Zambare, S., Pardeshi, I.L. and Vankatesha, K.V. 2024. *Pectin extraction from Jackfruit waste by Acid extraction method.*

Saurabh, V., Vathsala, V., Yadav, S.K., Sharma, N., Varghese, E., Saini, V., Singh, S.P., Dutta, A. and Kaur, C. 2023. Extraction and characterization of ultrasound assisted extraction: improved functional quality of pectin from jackfruit (*Artocarpus heterophyllus* Lam.) peel waste. *Journal of Food Measurement and Characterization*, **17**(6): 6503-6521.

Sriamornsak, P., Wattanakorn, N., Takeuchi, H. 2010. Study on the muco adhesion mechanism of pectin by atomic force microscopy and mucin-particle method. *Carbohydrate Polymers*, **79**: 54–59.

Str€om, A., Ribelles, P., Lundin, L., Norton, I.T., Morris, E.R. and Williams, M.A.K. 2007. Influence of pectin fine structure on the mechanical properties of calcium-pectin and acid-pectin gels. *Biomacromolecules,* **8**(9): 2668e2674.

Sun, Y., He, Y., Wang, F., Zhang, H., de Vos, P. and Sun, J. 2017. Low-methoxyl lemon pectin attenuates inflammatory responses and improves intestinal barrier integrity in caerulein-induced experimental acute pancreatitis. *Molecular Nutrition & Food Research*, **61**(4): p.1600885.

Sundar Raj, A.A., Rubila, S., Jayabalan, R. and Ranganathan, T.V. 2012. A review on pectin: Chemistry due to general properties of pectin and its pharmaceutical uses. *Open Access Scientific Reports*, **1**(12): 1-4.

Susanti, S. 2021. Comparing the chemical characteristics of pectin isolated from various Indonesian fruit peels.

Tang, G.Q., Lin, X.J., Li, J.N., Li, R., Wang, D. and Ji, S.G. 2018. Pharmacognostical studies of *Premna microphylla*. *Revista Brasileira de Farmacognosia,* **28**: 520–526.

Tang, L., Li, M., Zhao, G. and Ye, F. 2024. Characterization of a low-methoxyl pectin extracted from red radish (*Raphanus sativus* L.) pomace and its gelation induced by NaCl. *International Journal of Biological Macromolecules*, **254**: p.127869.

Thakur, B.R. *et al.* 1997. Chemistry and uses of pectin – A review. *Critical Reviews in Food Science and Nutrition,* **37**: 47-73.

Towel, G.A. and Christensen, O. 1959. Pectin, in *Industrial Gums—Polysaccharides and their Derivatives,* Whistler, R. L. and BeMiller, J. N., Eds., Academic Press, New York, 377.

Ukiwe, L.N. and Alinnor, J.I. 2011. Extraction of pectin from pineapple (*Ananas comosus*) peel using inorganic/organic acids and aluminum chloride. *Fresh Produce*, **5**(1): 80-83.

Van Buren, J.P. 1991. Function of pectin in plant tissue structure and firmness. *In* R. H. Walter (Ed.), The chemistry and technology of pectin (pp. 1e22). San Diego: Academic Press.

Virk, B.S. and Sogi, D.S. 2004. Extraction and characterization of pectin from apple (*Malus pumila*. Cv Amri) peel waste. *International Journal of Food Properties*, **7**(3): 693-703.

Vriesmann, L.C., Teófilo, R.F. and de Oliveira Petkowicz, C.L. 2012. Extraction and characterization of pectin from cacao pod husks (*Theobroma cacao* L.) with citric acid. *LWT*, **49**(1): 108-116.

Wijaya, W., Van der Meeren, P. and Patel, A.R. 2017. Cold-set gelation of whey protein isolate and low-methoxyl pectin at low pH. *Food Hydrocolloids,* **65**: 35–45.

Xu, K., Martinez, M.M., Yang, B. and Guo, M. 2020. Fine structure, physicochemical and antioxidant properties of LM-pectins from okra pods dried under different techniques. *Carbohydrate Polymers*, **241**: 116272.

Yapo, B.M. and Koffi, K.L. 2006. Yellow passion fruit rind a potential source of low-methoxyl pectin. *Journal of Agricultural and Food Chemistry*, **54**(7): 2738-2744.

Yapo, B.M. and Koffi, K.L. 2013. Extraction and characterization of highly gelling low methoxy pectin from cashew apple pomace. *Foods*, **3**(1): 1-12.

Yu, Y., Lu, P., Yang, Y., Ji, H., Zhou, H., Chen, S., Qiu, Y. and Chen, H. 2024. Differences in physicochemical properties of pectin extracted from pomelo peel with different extraction techniques. *Scientific Reports*, **14**(1): 9182.

Zhilinskaya, N.V., Sarkisyan, V.A., Vorobieva, V.M., Vorobieva, I.S., Kochetkova, A.A., Smirnova, E.A. and Glazkova, I.V. 2018. Development of a marmalade for patients with type 2 diabetes: Sensory characteristics and acceptability. *Food Sci. Technol. Int.*, **24**: 617–626.

Zidi, D., Gharsallaoui, A., Dupas-Farrugia, C., Attia, H. and Ayadi, M.A. 2019. Physicochemical and rheological changes of acidified camel milk added with commercial low methoxyl-pectin. *Int. J. Biol. Macromol.,* **128**: 347–353.