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Performance evaluation of CAET developed pectin extraction unit for jackfruit (*Artocarpus heterophyllus*) peel waste

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Abstract
Pectin is an extremely acidic complex polysaccharide extracted from plant materials. Very little work has been done on experimental study for extraction of pectin from Jackfruit peel waste. Therefore, it is need to optimize the process parameters and to identify the best treatment for the production of Pectin from peel waste. Present study investigated for Performance evaluation of pectin extraction unit from Jackfruit peel waste at different temperatures (70, 80 and 90 °C), Extraction period (1, 1.5 and 2 h) and pH (1.8, 2 and 2.2). Optimum values of process parameters for the extraction of pectin for Jackfruit peel waste was found at Extraction temperature 80 °C, Extraction period 1.5 h and pH 2. Highest pectin yield for jackfruit peel were 15.67% (dwb) and 3.05% (FWB). Cost of production for 1 kg of pectin extracted from Jackfruit peel waste was Rs.1982 /- with Benefit Cost ratio 1.4.

Keywords: Jackfruit, peel waste, pectin extraction unit

1. Introduction

In the world, in recent years, the impact of fruit waste is one of the biggest problems increasing the global environmental burden. For example, the proportion of rejected materials in most fruit processing industries is usually very high and depending on the location and method of harvest (e.g. mango 30–50%, banana 20%, pomegranate 40–50% and citrus 30–50%) (Laufenberg *et al*. 2003, Parfitt *et al*. 2010) [11, 15]. The food industry produces about 45 percent of all industrial organic pollution (Akerberg and Zacchi 2000) [2]. These organic wastes are rich in Pectin (Anuradha *et al*. 1999) [5]. Maharashtra is second major producer of fruits with production of about 10.82 MT (Anonymous, 2021-22) [3]. Konkan is termed as a fruit basket. Mango, coconut, sapota, etc., are the major fruit crops occupying nearly 94% area (Bhattacharyya *et al*. 2021) [7].

India is assumed to be the motherland of jackfruit (*Artocarpus heterophyllus*) (Nandu Lal *et al*. 2020) [14]. The jackfruit production in Maharashtra is 7200 metric tonnes from 320 ha area (Anonymous, 2021) [3]. The coastal warm and humid climate of the Konkan region is enthusiastic for jackfruit cultivation (Gawankar *et al*. 2021) [9]. It is a fruit crop widely distributed in India and India is the second largest producer of jackfruit with a production of 1.4 million tonnes. According to the Food and Agriculture Organization of the United Nations, 75% of fruits produced in India are wasted because fruits can easily spoil if not eaten or stored within a few days. Jackfruit is popular for making vegetables, papad, pickles, as an ingredient of ice cream, candies, and other desserts, and in many culinary preparations. But during these processing large amount of peel waste is discarded from industries which can be used for further processing (Moorthy *et al*. 2016) [13].

Pectin is a polysaccharide found in cell walls and middle lamellae of higher plants and it has long been used for its gel formation, thickening and stabilizing properties in a wide range of applications from food to the cosmetic industries. Pectin is a soluble dietary fiber and polymer of galacturonic acid, with an acidic polysaccharide. Part of an acid is present as methyl ester. Pectin is a hydrocolloid and keeps a large amount of water and creates thickening and gelling properties (Kumar V., 2018) [10]. The value of the worldwide pectin market, which was estimated at USD 1.63 billion in 2022, increased by 7.95% CAGR from 2023 to 2032. By 2032, the market is anticipated to grow to $3.50 billion USD. During the projection period, North America is anticipated to grow the fastest (Anonymous, 2023) [4]. The worldwide annual consumption of pectin is approximately 45,000 tonnes, occupying the global market value of at least 400 million Euros (Savary *et al*. 2003) [17].

The processing of pectin typically incorporated extraction with purification, concentration, and drying. Pectin extraction is a multiple-stage physical and chemical process in which the hydrolysis and extraction of pectin macromolecules from plant tissue and their solubilization take place under the supremacy of different factors, mainly temperature, pH and time (Ahmmed *et al*. 2017) [1]. The peel waste is ultimately thrown into municipal waste collection centers from where it is collected by the area municipalities to be further thrown into the landfills and dumps. Unattended waste lying around attracts flies, rats, and other creatures that in turn spread diseases. Normally it is the wet waste that putrefy and emancipate a bad odor. This leads to unhygienic conditions and thereby to a rise in the health problems (Suryawanshi *et al*. 2013) [19].

The fruits processing produces mainly two types of wastes, a solid waste of peel/skin and seeds, and a liquid waste of juice and wash water. In some fruits the repudiated portion can be very high (eg. mango 30-50%, banana 20%, pineapple 40-50% and orange 30-50%). Therefore, there is often a serious waste disposal and scrapping problems. There are a number of probabilities for use of some types of solid fruit wastes. One of the main problems in using fruit wastes is to ensure that the waste has an equitable microbiological quality. Only waste produced during the same day should therefore be used it is injudicious to store-up wastes. The possible products obtained from fruit waste are can dried peel, oils, pectin, reformed fruit pieces, enzymes and wine/vinegar (Christy *et al*. 2014) [8].

Peel waste of citrus, mango, banana, pineapple, jackfruit have a potential to give pectin after some processing. The global pectin market is estimated at USD 1.0 billion in 2019 and it is projected to grow up to USD 1.5 billion by 2025. In Foreign rate of pectin per Kg is about 800 to 1500 Rs but in India it's around 3500 to 3600 Rs due to less production in India (Anonymous 2023) [4]. In Konkan region higher amount of mango peel and stone waste is generated. Jackfruit peel waste, banana peel waste, pineapple peel waste is also generated in good amount. If small fruit processor uses the fruit peel waste after processing to extract value added product such as pectin, then they can earn some money from the waste material generated in their plant. The peel waste is major solid waste since solid waste poses serious environmental problems, the present study is focused on conversion of waste to wealth. The study also invokes the concept of "zero waste" through complete utilization of fruit waste for the extraction of pectin from the peel (Christy *et al*. 2014) [8].

2. Material and Methods

2.1 Collection and preparation of sample

Mature jackfruits were purchased from CRS, Wakawali and some of purchased from local market of Dapoli, Maharashtra. Pectin extraction unit developed by the Department of Agricultural Process Engineering, CAET, and Dapoli and used to extract pectin from Jackfruit peel powder.

2.2 Preparation of Jackfruit Peel Powder

The flow chart of preparation of jackfruit peel powder from fresh peels was shown in fig. 1. The prepared jackfruit peel powder will very fine and passing through 80 mesh screen.

Jackfruit fresh peels
↓
washing of Jackfruit peels with tape water
↓
Cutting in small pieces of Jackfruit peels
↓
Drying of Jackfruit peels at 65 °C for 8 hours
↓
Grinded in Pulverizer
↓
Sieving of Jackfruit peel powder through 80 mesh sieves
↓
Jackfruit peel powder

Fig 1: Process flow chart for preparation of Jackfruit peel powder

2.3 Extraction of Pectin

The method of extraction of pectin from jackfruit peel waste with acidified distilled water at different temperatures (T) as 70 °C, 80 °C and 90 °C for specific extraction period (P) as 1, 1.5 and 2 hours and specific pH (H) as 1.8, 2 and 2.2 was a very imperceptible procedure with separately designed equipment's for each step in extraction of pectin. And not possible on small scale at the waste utilization fruits processing industry level so it was decided that the extraction period (P), pH (H) and temperature (T) for pectin extraction should be maintained in single tank-1 of pectin extraction unit with the help of electric heater, stirrer and control panel. This method was also saved the cost of electricity charges and power consumption. The pectin yield (%) was determined by the ratio of dried peel powder immersed in tank – 1 to the pectin powder extracted from pectin extraction unit. Pectin yield varies for fruit to fruit. The quality characteristics such as output capacity (%), pectin yield (%), equivalent weight, methoxyl content (%), anhydrouronic acid content (%), degree of esterification (%) of extracted pectin were measured (Ranganna S. 1986) [16].

Pectin Yield (%)

Pectin yield extracted from Jackfruit peel can be calculated by using the equation given below (in the form of dry basis):

$$\text{Pectin Yield \%}\left(\frac{w}{w}\right) = \frac{\text{Weight of pectin extracted (g)}}{\text{weight of peel powder used for extraction(g)}} \times 100 \quad \ldots(1)$$

2.4 Extraction of pectin from Jackfruit peels

The extraction of pectin from jackfruit peel waste was carried out as shown in figure 2 The 1 kg peel powder which was dried at 65 °C for 8 hours taken for the extraction of pectin in CAET developed pectin extraction unit. The mixture of dried jackfruit peel powder + acidified (With 0.1 N H_2SO_4) distilled water added to extraction tank-1. Turn on the agitator which had rpm 180 rev/min and heater with 189.9 KW power. After setting the desired temperature (i.e. 70, 80, 90 °C). Calculated the time required to attain the desired temperature. After attaining desired temperature, calculated time required to complete previously selected extraction period (i.e. 1h, 1.5h, and 2h), then take off heated mixture from tank-1 to the tank-2. In tank-2 the mixture was filtered through 3 muslin cloth sieves and cooled to room temperature. Calculated the cooling time. After cooling, take out the filtrate from tank-2 and measuring it. After measuring the filtrate, adding ethanol (99.9% pure) to the filtrate which was double of filtrate (i.e. if filtrate was 7 litre then 14 litre ethanol should be added into it) to form jelly precipitate in the filtrate + ethanol solution. That jelly precipitate collected and put into hot air oven to dry at 50 °C for 16 h. dried jelly precipitate grinded from to get fine jackfruit peel pectin powder and was passes through 50 mesh sieves. And packed in transparent container with lid (Waghmode *et al*. 2022) [20].

Jackfruit peel powder
↓
Adding 10 litre distilled water in heating tank + 0.1N sulphuric acid + heating at 70, 80, 90 °C
↓
Adding 1kg peel powder heating at 70, 80 and 90 °C for 1, 1.5, 2, hrs
↓
Filtration
↓
Cooling to room temperature
↓
Added ethanol 1:2 (filtrate to ethanol)
↓
Separate precipitate
↓
Drying pectin precipitate at temperature 50 °C for 16 hrs in hot air oven
↓
Grinding in pulverizer
↓
Sieving pectin with 50 mesh sieves
↓
Pectin powder (0.297 mm)

Fig 2: Process flow chart of pectin extraction from jackfruit peel

2.5 Effect of process parameters on quality characteristics of extracted pectin

Response Surface Methodology (RSM) was used to find the effect of Extraction temperature, Extraction period and pH of extracted pectin. RSM was applied to the experimental data using a commercial statistical package, (Design Expert version 13 Stat ease, Minneapolis, USA) for the generation of response surface plots and optimization of process variables. Box-Behnken experimental Design (BBD) was used for designing the experiments of extraction of pectin from jackfruit peel waste. Using three process parameters (Extraction temperature, Extraction period and pH) with three levels. The levels of the process parameters were based on the results of preliminary studies. Non-linear regression equations were developed between the coded values of the independent variables (*viz*., P1, P2, and P3) and the dependent variables. A second order polynomial equation of the following form was assumed to relate the response Y and the factors, such as:

$$Y = \beta_0 + \sum_{j=1}^{k} \beta_i P_j + \sum_{j=1}^{k} \beta_{jj} P_j^2 + \sum_{j=1}^{k} \beta_{ii} P_i^2 + \sum_{j=2}^{k} \beta_{ij} P_i P_j + \epsilon \ \ldots (2)$$

Where,
Y = Predicted response
β_0 = A constant
β_i = Linear coefficient
β_{ii} = Squared coefficient
β_{ij} = Interaction coefficient
P_i and P_j = The independent variables and ϵ = noise or error.

3. Results and Discussion

From table 2, on the basis of quantitative parameters extracted pectin had acceptable limits of moisture content (%) and ash content (%). Extracted pectin from jackfruit peel waste was characterized as low methoxyl pectin. But due to lower than 65% value of anhydrouronic acid (%) further purification of pectin was needed.

Table 1: Box-Behnken Design (BBD) for% pectin yield (dwb and fwb) from jackfruit and mango peel waste.

Variables	**Range and levels of independent variables**				
	-1	0		1	
Temperature, °C	70	80		90	
pH	1.8	2		2.2	
Extraction period(h)	1	1.5		2	
Run order	**Independent variables**			**% yield of pectin from jackfruit peels**	
	Extraction Temperature, °C	**pH**	**Extraction period, h**	**dwb**	**fwb**
1	70	1	2	10.5	2.1
2	70	1.5	1.8	11.2	2.24
3	70	1.5	2.2	10	2
4	70	2	2	12.2	2.44
5	80	1	2.2	11.9	2.38
6	80	1	1.8	12.7	2.54
7	80	1.5	2	15.45	3.09
8	80	1.5	2	14.75	2.95
9	80	1.5	2	15.2	3.04
10	80	1.5	2	14.95	2.99
11	80	1.5	2	15.95	3.19
12	80	2	2.2	11.4	2.28
13	80	2	1.8	13.95	2.79
14	90	1	2	6.71	1.342
15	90	1.5	2.2	5.35	1.07
16	90	1.5	1.8	8.8	1.76
17	90	2	2	7.23	1.446

Table 2: Quantitative parameters of extracted pectin from jackfruit peel waste using pectin extraction unit

Parameters	**Content**
Moisture content (%)	9.72
Ash content (%)	8.7
Equivalent weight	465.29
Methoxyl content (%)	3.41
Anhydrouronic acid (%)	57.17
Degree of esterification (%)	33.83

3.1 Effect of process parameters on Pectin yield (PY) of pectin powder prepared from Jackfruit peel waste

In the experimental data, the second - order polynomial equation was used to fit. The relationship between the pectin yields of the pectin powder prepared from Jackfruit peel waste was obtained with process parameter. From Table 3, the model F value implies that the model for pectin yield is significant. The coefficients of linear terms of P_1, P_2, and P_3, and the quadratic term of P_1^2, P_2^2, P_3^2 and interaction term P_1P_2, P_2P_3, P_1P_3 were significant at 5% level of significance. The second - order polynomial equation describing the effect of the process variables on pectin yield was presented through equation 3.1.

$$PY (\%) = + 15.26 - 1.98P_1 + 0.3713P_2 - 1.00 P_3 - 0.2950P_1P_2 - 0.5625 P_1 P_3 - 0.4375 P_2 P_3 - 4.88 P_1^2 - 1.23 P_2^2 - 1.55 P_3^2 \quad (R^2=0.9898) \ldots\ldots (3)$$

Where,

P_1 = Extraction temperature in tank -1, P_2 = Extraction period, and P_3= pH

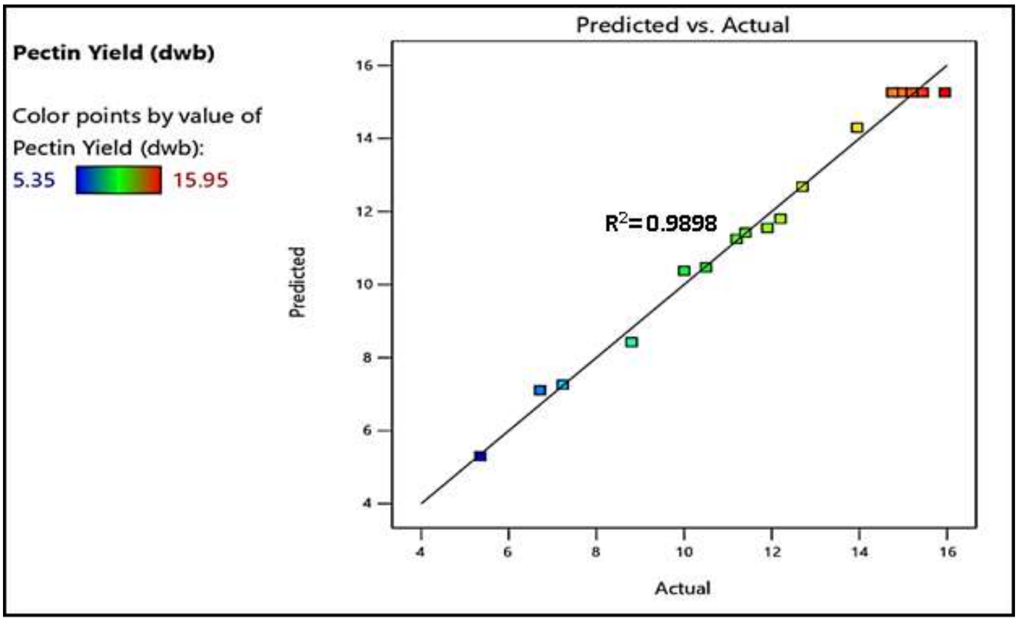

Fig 3: Predicted and experimental values of response for the extraction of pectin from jackfruit peel waste

The high value of the coefficient of correlation (R^2 = 0.9898) was obtained for the responses indicated that developed model for Pectin yield adequately explained 98.98% of the total variation. The positive coefficients in case of first order term of extraction period (P_2) indicated that increase in pectin yield with increase in this parameter while negative coefficients of Extraction temperature (P_2), and pH (P_3) and their quadratic terms suggested that excessive increase of these parameters resulted in decrease of pectin yield.

Table 3: Analysis of Variance (ANOVA) for process parameters showing the effect on pectin yield for jackfruit peel waste.

Source	Sum of Squares	df	Mean Square	F-value
Model	167.13	9	18.57	75.63*
(P_1): temperature	31.24	1	31.24	127.24*
(P_2): extraction time	1.10	1	1.10	4.49*
(P_3): pH	8.00	1	8.00	32.58*
P_1 P_2	0.3481	1	0.3481	1.42*
P_1 P_3	1.27	1	1.27	5.15*
P_2P_3	0.7656	1	0.7656	3.12*
P_1^2	100.07	1	100.07	407.51*
P_2^2	6.32	1	6.32	25.73*
P_3^2	10.08	1	10.08	41.06*
Residual	1.72	7	0.2456	
Lack of Fit	0.8469	3	0.2823	1.29^{NS}
Pure Error	0.8720	4	0.180	
Cor Total	168.85	16		
R^2	0.9898			
Adj.R^2	0.9767			
Pre.R^2	0.9117			
Adeq Precision	26.20			
Std. Dev	0.4955			
C.V%	4.25			

*Significant at 5% level, NS- Non significant

From magnitude of coefficient of linear term showed that temperature (P_1) was most prominent on pectin yield followed by pH (P_3) and extraction time (P_2). The comparative effect of each parameter on pectin yield of extracted pectin from jackfruit peel waste was observed by the F-values (75.63) in the ANOVA (Table 4). The lack of fit of F value was non-significant for the model obtained. Moreover, the predicted R^2 of 0.9117 was in reasonable agreement with the adjusted R^2 of 0.9767; i.e. the difference is less than 0.2. This revealed that the non-significant terms have not included in the model. Adeq. Precision measures the signal to noise ratio, a ratio greater than 4. Therefore, this model could be used to helm the design space.

It was observed through Fig 4 that, pectin yield of jackfruit peel waste increased with increase in extraction temperature (P_1) up to 80 °C, extraction period (P_2) up to 1.5 h and pH (P_3) at 2, respectively, further pectin yield of jackfruit peel powder decreased at higher levels of these process parameters due to increment up to 80 ℃ temperature helped in breakdown of cell wall and allow protopectin to be hydrolyzed by acids Sundarraj *et al.* (2017) [18], but after 80 ℃ increase in temperature degrade the pectin molecules. Ahmmed *et al.* (2017) [1]. Pectin is thermoreversible type complex polysaccharide that melt upon heating up to 80 °C with safe and unbreakable chemical structure but beyond the 80 °C up to 90 °C the chemical bond broken and damaged (Leong C.M. *et al.* 2016) [12]. This had direct impact on pectin yield produced from peel waste in pectin extraction unit. Increase in the extraction period increases the heating time of peel powder so that it started to degrade after 1.5 h this may rashly impact on chemical bond of pectin extracted from jackfruit peel waste. It was clearly observed through Fig 3.2 that, at optimum level resulting possible development of specific condition inside the tank -1, so that maximum amount of pectin extracted. But, further increase in extraction temperature, extraction period and pH may degrade the pectin. The amidation of pectin enabled it to withstand more calcium variation and be more thermo reversible (Belkheiri *et al.*, 2021) [21].

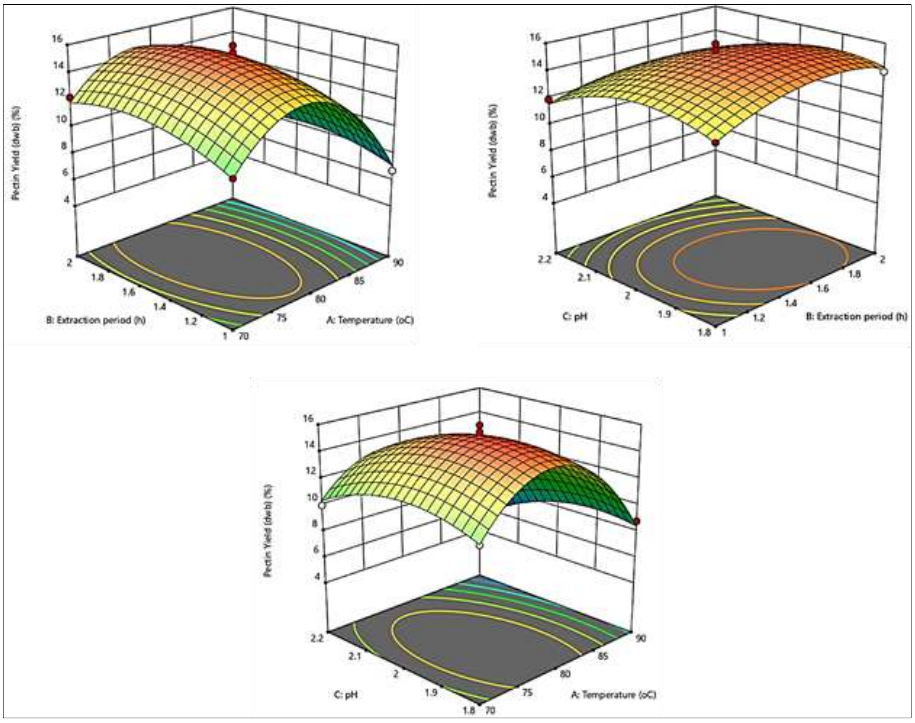

Fig 4: Effect of Extraction temperature vs. extraction period, pH vs. Extraction period and pH vs. Extraction Temperature on pectin yield (dwb) of pectin extracted from CAET developed pectin extraction unit at constant pH

3.2 Optimization and validation of process parameter for pectin yield form jackfruit peel waste

The optimization of process parameters was done using *Design Expert (version 13)* software was necessary to obtain better quality of pectin yield. It done for extracted pectin was performed on the basis of its characteristics such as the good quality extraction should have maximum pectin yield. The constraints given in Table 4 were used to find out the range of optimum values of process variables.

Table 4: Constraints of process parameters of pectin extracted from Pectin extraction unit for jackfruit peel waste

Independent variable	Goal	Lower limit	Upper limit
Extraction temperature (°C)	in range	70	90
Extraction period (h)	in range	1	2
pH	in range	1.8	2.2
Pectin yield (fwb) (%)	Maximum	5.35	15.95
Pectin yield (dwb) (%)	Maximum	1.07	3.19

3.3 Numerical optimization

The result of numerical optimization shows the different solution were selected at maximum desirability.

The optimum values of process variables obtained by numerical optimization as follows

Temperature (°C)	:	82.14
Extraction time (h)	:	1.59
pH	:	1.92

The optimum values of process variables obtained by numerical optimization as follows

Pectin yield (fwb) (%)	:	15.95
Pectin yield (dwb) (%)	:	3.19

3.4 Validation of model

The predicted optimum values of responses *viz.*, pectin yield (fwb & dwb) were verified by preparing the extracted pectin using the combination at optimum condition of process variables *i.e.* 80 °C extraction temperature of tank-1 (P_1), 1.5 h of extraction period (P_2) and 2 pH of Acidified distilled water in tank-1 (P_3). Table 5 shows the predicted and experimental values of pectin yield (dwb) (%) and pectin yield (fwb) (%).

Table 5: Predicted and experimental values of response for the extraction of pectin from CAET developed pectin extraction unit for jackfruit peel waste

Responses	Predicted values	Experimental values	CV (%)
Pectin yield (dwb) (%)	15.95	15.67	0.28
Pectin yield (fwb) (%)	3.19	3.05	0.14

From Table 5, it was demonstrated that experimental values and predicted values were very close. The values predicted by equation of pectin yield (%) (Eq.3.1) was 15.95%.

Plate 1: Jackfruit peel pectin powder

Plate 2: Jelly prepared by using Jackfruit peel pectin

4. Conclusion
The pectin yield (dwb and fwb) was obtained for 17 experiments which were selected by Box Behnken Design expert software version 13 given in table 5. It was clear that the highest pectin yield (dwb) was 15.95% obtained, according to designed trials the best result of pectin yield found at 80 °C extraction temperature, 1.5 h extraction period and 2 pH. The lowest pectin yield (dwb) was 5.35% obtained at 90 °C extraction temperature, 1.5 h extraction period and 2.2 pH. It could be concluded from the discussion that model developed for the pectin yield was adequate. The grade of extracted pectin from jackfruit peel waste was found to be 45.

5. References

1. Ahmmed R, Inam AS, Alim MA, Sobhan MM, Haque MA. Extraction, Characterization and Utilization of Pectin from Jackfruit (*Artocarpus heterophyllus* L.) Waste. Bangladesh Journal of Environmental Science. 2017;32:57-66.
2. Akerberg, Zachhi. An economic evaluation of the fermentative production of lactic acid from wheat flour. Bioresource technology. 2000;75(2):119-126.
3. Anonymous, State Level. Department of Agriculture, Farmers Welfare, Mo a, FW. GoI (agricoop.nic.in) National Horticulture Board. (State wise fruit production-Jackfruit and Mango); c2021. https://agricoop.nic.in/sites/default/files/2021
4. Anonymous. Market research report, Report ID- TBI-13413. Pectin Market Size by Type (Low Methoxyl Pectin, High Methoxyl Pectin, Growth, Trends, and Forecast 2023 to 2032; c2023. https://www.thebrainyinsights.com/report/pectin-market-13413
5. Anuradha R, Suresh AK, Venkatesh KV. Simultaneous saccharification and fermentation of starch to lactic acid. Process Biochemistry. 1999;35:367-375.
6. Anissa B, Forouharb A, Ursu AV, Dubessay P, Pierre G, Delattre C, *et al*. Extraction, characterization and applications of pectins from plant by products. Applied Science. 2021;11:6596.
7. Bhattacharyya T, Handalkar PM, Haldavanekar PC, Burondkar MM, Salvi BR, Chakurkar ED, *et al*. Impact of Climate Change on Horticulture in Konkan, Maharashtra: Activities and Strategies. Indian Journal of Fertilizers. 2021;17(3):258-273.
8. Christy JS, Suganya K, Kiruba JJ, Madhumitha SP, Suja SK, Kalavani GJ, *et al*. Extraction of pectin from fruit waste: An effective method of municipal solid waste management. International Journal of Advanced Research. 2014;2(2):936-944.
9. Gawankar MS, Haldankar PM, Haldavanekar PC, Salvi BR, Burondkar MM, Pawar CD, *et al*. Effect of Potting Media on Seed Germination and Seedling Vigour of Jackfruit (*Artocarpus heterophyllus* Lam.) under the Konkan Region of Coastal Maharashtra. Journal Indian Society- Coastal Agriculture. 2021;39(1):61-65.
10. Kumar V, Sharma V, Singh L. Pectin from Fruit Peels and its Uses as Pharmaceutical and Food Grade: A Descriptive Review. European Journal of Biomedical and Pharmaceutical Sciences. 2018;5(5):185-199.
11. Laufenberg GB, Kunz, Nystroem M. Transformation of vegetable waste into value added products: (A) the upgrading concept; (B) Practical implementations. Bioresource Technology. 2003;87(2):167-198.
12. Leong CM, Noranizan MA, Kharidah M, Choo WS. Physicochemical properties of pectin extracted from jackfruit and chempedak fruit rinds using various acids. International Food Research Journal. 2016;23(3):973-978.
13. Moorthy IG, Maran JP, Ilakya S, Anitha SL, Sabarima SP, Priya B, *et al*. Ultrasound assisted extraction of pectin from waste *Artocarpus heterophyllus* fruit peel. Ultrasonics Sonochemistry. 2016;34:525-530.
14. Nandu Lal AM, Prince MV, Sreeja R. Studies on Characterization of Combined Pulsed Electric Field and Microwave Extracted Pectin from Jack Fruit Rind and Core. International Journal of Current Microbiology and Applied Sciences. 2020;9(03):2371-2380.
15. Parfitt JM, Barthel, Macnaughton S. Food waste within food supply chains: Quantification and potential for change to 2050. Philosophical Transactions of the Royal Society of London B: Biological Sciences. 2010;365(1554):3065-3081.
16. Ranganna S. Handbook of Analysis of Quality Control for Fruit and Vegetable Products, Tata McGraw- Hill Publ. Co., New Delhi, India; c1986.
17. Savary BJ, Hotchkiss AT, Fishman ML, Cameron RG, Shatters R. Development of a Valencia orange pectin methyl esterase for generating novel pectin products. In Voragen, H.S and Visser, R. (Eds). Advances in Pectin and Pectinase Research. Kluwer Academic Publishers, The Netherland. 2003;3:45-361.
18. Sundarraj AA, Ranganathan TV. Physicochemical characterization of Jackfruit (*Artocarpus integer*) Peel. Research Journal of Pharmaceutical, Biological and Chemical Sciences. 2017;8(3):2285-2295.
19. Suryawanshi PC, Jain KA, Bhardwaj S, Chaudhari AB, Yeole TY. Solid and Liquid Wastes: Avenues of Collection and Disposal, International Research Journal of Environmental Science. 2013;2(3):74-77.
20. Waghmode KG, Sawant AA, Khandetod YP, Pathak SV, Sawant PS, Kalse SB, *et al*. Design and development of pectin extraction unit for jackfruit waste. The Pharma Innovation Journal SP. 2022;11(11):573-576.
21. Belkheiri A, Forouhar A, Ursu AV, Dubessay P, Pierre G, Delattre C, *et al*. Extraction, characterization, and applications of pectins from plant by-products. Applied Sciences. 2021;11(14):6596.