

International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(9): 1177-1185
www.biochemjournal.com
Received: 12-06-2026
Accepted: 16-07-2026

Dr. Kailas Yewale
Department of Food
Processing Technology, College
of FPT & BE, Anand
Agricultural University,
Anand, Gujarat, India

Dr. Samit Dutta
College of Food Processing
Technology & Bioenergy,
Anand Agricultural
University, Anand, Gujarat,
India

Optimization of Enzyme-Assisted Papaya Juice Extraction Using Response Surface Methodology

Kailas Yewale and Samit Dutta

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i9So.9978>

Abstract

The effect of pectinase enzyme concentration, incubation time, and incubation temperature on extract yield, TSS, ascorbic acid, and viscosity of papaya fruit (*Carica Papaya* L.) juice was studied. Extraction of papaya juice was carried out using pectinase enzyme at three levels of concentration, incubation time, and temperature ranging from 0.2-1.2%, 50-120 min, and 35-60 °C, respectively. The papaya juice samples were analyzed for extract yield, viscosity, total soluble solids, and ascorbic acid using response surface methodology with the help of Design Expert 13 software. The optimum conditions for pectinase enzyme treatment for papaya fruit juice were found to be 1.2% enzyme concentration, 46.68 °C incubation temperature, and 79.16 min of incubation time. The result showed a significant increase in extract yield $90.18 \pm 0.37\%$ due to the degradation of the pectic substances, and was able to release the intracellular juice, whereas TSS ($12.484 \pm 0.12^\circ\text{Brix}$) increased by a small amount. The reduction in viscosity (1.11 ± 0.02 cP), indicating the ability of pectinase to break down highly organized polysaccharides, thus enhancing juice flowability and filtration attributes, was observed to be significant, while ascorbic acid decreased by a small amount. The results of these findings indicate that enzyme-assisted extraction is a good technology for papaya juice processing to obtain high-quality papaya juice.

Keywords: Pectinase, extraction yield, viscosity, incubation time, ascorbic acid

Introduction

Papaya (*Carica papaya* L.) originates from tropical regions of the Americas but has since spread widely and is now cultivated in Asia, Africa, and other parts of the world. (Farina *et al.*, 2020⁵). Papayas are kept for only 7 to 14 days after harvest. They are perishable, which makes it difficult to transport to far-off locations during peak season and earn a reasonable price for farmers. To prevent quality deterioration and increase shelf life, several researchers have developed post-harvest preservation methods that preserve high sensory and nutritional attributes. The fruit's shelf life has been increased through the investigation and use of several preservation techniques (Marpudi *et al.*, 2011) ^[10].

Nutritionally, the seedless type was superior, with increased levels of crude protein (0.76%), fat (0.13%), ash (0.47%), fiber (1.19%), reducing sugars (8.94%), total sugars (10.91%), vitamin C (55.84 mg/100 g), and β -carotene (1.07 $\mu\text{g}/100$ g). The seeded variety, however, contained marginally more moisture (92.69%) along with higher total soluble solids (12.07 °Brix) and pH (5.65). Mineral composition was almost identical in both cultivars, with calcium (16.59-16.63 mg/100 g), phosphorus (12.57-12.61 mg/100 g), sodium (5.52-5.58 mg/100 g), potassium (68.41-68.47 mg/100 g), and iron (0.48-0.50 mg/100 g) showing only minor differences Prabha and Modgil (2018) ^[13].

Papaya is a fruit with multiple therapeutic benefits, including antioxidant, antimicrobial, anticancer, and hepatoprotective properties. It contains several bioactive components that strengthen the immune system and act as natural antioxidants. The pulp of papaya has long been used in traditional medicine for healing wounds and treating burns, while the ripe fruit helps prevent conditions such as dysentery, various skin diseases, psoriasis, and ringworm. Papain, an enzyme present in papaya, aids in the digestion of proteins and supports a healthy digestive system. It is a nutritionally rich tropical fruit containing vitamins A, C, and E, essential minerals, and enzymes like papain and chymopapain. Every part of the plant—including the fruit, leaves, seeds, roots, and latex—holds medicinal importance and is used in both traditional and modern healthcare (Saeed, 2014) ^[17].

Corresponding Author:
Dr. Kailas Yewale
Department of Food
Processing Technology, College
of FPT & BE, Anand
Agricultural University,
Anand, Gujarat, India

The use of enzymes has become an integral part of fruit juice processing, where they contribute to higher extraction efficiency and better product quality by disrupting structural components of the fruit cell wall. Among the most important are pectinases, cellulases, and amylases, which hydrolyse pectin and cellulose, thereby facilitating greater juice recovery and improved clarity. The performance of enzymatic treatment is strongly influenced by variables such as enzyme formulation, dosage, incubation conditions, and the specific characteristics of the fruit, highlighting the importance of optimizing protocols for each raw material. When appropriately applied, enzyme-assisted processing not only increases juice yield and reduces cloudiness but also lowers viscosity and elevates soluble solids, underscoring its role as a valuable approach for improving both the efficiency and quality of juice production (Pui and Saleena, 2023) [14].

Pectinases play an essential role in modern fruit processing, where they are primarily employed to improve the recovery and clarity of juices. Enzyme-based processing is a competitive strategy for the fruit juice industry as it is a cost-effective and sustainable solution. (Jayani *et al.*, 2005; Kashyap *et al.*, 2001) [7, 8]. There is limited research done on the enzymatic extraction of papaya fruit. Also, a comprehensive study on the effects of enzymatic concentration, incubation time, and incubation temperature has not been reported in the literature. The optimization of process parameters for enzyme-treated juice of papaya was investigated. The overall goal of this study is to improve the yield with low viscosity and stability of bioactive compounds.

Materials and Methods

Collection of Papaya Fruits

The raw material, i.e., papaya fruits (*Carica Papaya* L.) used in the present research, were uniform, firm, mature, ripened, and of the Red Lady variety. These fruits were procured from the Department of Horticulture, AAU, Anand, Gujarat.

Pectinase Enzyme

Pectinase enzyme with enzyme activity ≥ 800 IU was obtained from Sigma-Aldrich Co., 3050 Spruce Street, St. Louis, MO 63103, USA.

Packaging Materials

Polyethylene terephthalate (PET) bottles having a capacity of 100 mL were purchased from M/s Axar Blow Plast, GIDC, Anand, Gujarat.

Estimation of juice yield

The ratio of clarified juice to the papaya fruit pulp percentage is defined as the clarified juice yield (%).

$$\text{Juice Yield (\%)} = \frac{\text{Clarified juice}}{\text{Pulp}} \times 100$$

Total soluble solids (TSS)

TSS of papaya fruit pulp, extracted juice, and beverage was measured using an Atago RX-7000x refractometer.

Viscosity

The Brookfield viscometer was used to test the juice's viscosity in cP at 60 rpm (25°C) using needle number 63 of the DV-11 Plus Pro model.

Ascorbic acid

Ascorbic acid of the samples was determined using the 2,6-dichlorophenolindophenol method by titration (Ranganna, 2007) [15].

Enzyme-assisted extraction of papaya fruit juice

Optimal Randomized Design under the Response Surface category of the program Design Expert (version 13) was used to optimize the levels of pectinase enzyme concentration, incubation temperature, and incubation duration in papaya fruit juice extraction. Incubation time (A), incubation temperature (B), and enzyme concentration (C) were the independent variables. The dependent responses studied were yield, TSS, ascorbic acid, and viscosity. To maximize papaya fruit juice extraction, the mean value of the collected data was statistically examined. The levels of each independent variable based on preliminary trials are presented in Table 1, and the whole experimental design for the optimization of papaya fruit juice is presented in Table 2.

The process flowchart for the production of clarified juice from papaya fruit pulp is presented in Figure 1, and the process includes the addition of enzyme, mixing, incubation, centrifugation, and filtration. Clarification parameters were selected as per review (Rashima *et al* 2022; Vishal *et al.*, 2015) [16, 20].

Results and Discussion

The Response Surface Methodology (RSM) with Central Composite Design (CCD) was used to optimize the enzyme-assisted extraction process of papaya juice with three independent variables: extraction time (50-120 min), extraction temperature (35-60 °C), enzyme concentration (0.2-1.2%). Twenty experimental runs were conducted to examine the combined effect of these processing variables on juice yield, viscosity, TSS, and ascorbic acid (AA), and the optimization was done.

Effect of independent parameters on juice yield

The results of this experiment showed that the juice yields ranged from 81.13% to 90.31% (Table 2) under different extraction conditions. The optimum condition (90.31%) was found to be 79.16 min extraction time, 46.68°C, and 1.2% enzyme concentration, while the minimum condition (81.13%) was 50 min extraction time, 60°C, and 0.2% enzyme concentration. The higher juice yield with increasing enzyme concentration may be due to the increased degradation of pectic substances and degradation of cell wall polysaccharides by pectinase, which results in more juice being released from the cells. However, there was no additional increase in yield with extraction time at higher temperatures, suggesting some enzyme inactivation or degradation of cell wall components.

The developed model was highly significant, as shown by the F value and p value of the model, which were 127.05 and < 0.0001 , respectively, showing that the developed model was able to explain the relationship between the independent variables and juice yield (Table 4). The large model F-value indicates that the chance of getting such a high value through random error is very small, thus supporting the reliability of the regression model to predict juice yield. The data were presented using the three-dimensional response surface plot (Fig. 2). The curved response surface supports the significant BC interaction in

the ANOVA and illustrates the strong interaction between these two variables.

The result of the response surface indicated a gradual rise in the juice yield with enzyme concentration ranging from 0.2% to about 1.0-1.2%. The improved yield is said to be owing to an increased extent of degradation of pectin and other structural polysaccharides by pectinase, resulting in the juice trapped in plant tissues being released (Fig 2). Likewise, higher extraction temperatures (from 35°C to approximately 47-50°C) resulted in increased juice yield as a consequence of increased enzyme activity and increased cell wall permeability.

The results of the present study are similar to those reported in the literature for enzyme-assisted extraction of fruit juices. Kumar and Singh (2019) [9] reported the extraction yield of papaya juice using pectinase treatment, which yielded optimum extraction conditions of 55°C, 86 min of extraction time, and 0.87% of enzyme concentration, obtaining yields of about 78.8%. Ghorband and Joshi (2023) [6] also optimized the extraction yield of dragon fruit juice using pectinase enzyme concentration of 0.01 to 0.1%, incubation time of 150 min, and incubation temperature of 45 °C. Extraction yield was significantly increased ($p < 0.05$) by 16.71%. Rai *et al.* (2004) [17] optimized pectinase-assisted extraction of mosambi juice and reported a maximum juice yield at 32-49°C at 0.0004-0.0014% (w/v) enzyme concentration, which is close to the optimum temperature of 46.68°C in the present study at 1.2% enzyme concentration, at which 90.31% juice yield was obtained for the recovery of tropical fruit juices.

Effect of independent parameters on viscosity

The viscosity of juices ranged from 1.16 to 1.67 cP. Among the optimized conditions, the lowest viscosity (1.16 cP) was obtained, and the highest viscosity (1.67 cP) was obtained at 50 min and 60°C with 0.2% enzyme concentration (Table 2). The decrease in viscosity with increasing concentration of the enzyme is evidence of good pectin hydrolysis, which led to a decrease in the molecular weight of polysaccharides and an increase in flow characteristics. In commercial juice processing, it is highly desirable to have less viscous juices, because it is easier to filter, pump, fill, and package less viscous juices.

The ANOVA test results (Table 5) showed that the developed quadratic model was highly significant, with an F-value of 62.50 and a p-value < 0.0001 , which means that the developed regression model explains the relationship between process variables and juice viscosity. The high model F-value and low probability value indicate that the changes in viscosity that were observed were mainly due to the selected processing variables and not to random experimental error. Of the linear terms, the most significant was enzyme concentration (C) with the highest F-value of 129.11 at a p-value of < 0.0001 . This was followed by extraction temperature (B) with an F-value of 64.78 ($p < 0.0001$) and extraction time (A) with an F-value of 52.13 ($p < 0.0001$). The juice viscosity was found to depend greatly on the extraction time (50-120 min) and temperature (35-60°C) when the enzyme concentration was kept constant at 0.7% (Fig. 3). The response surface is clearly curved, suggesting that both variables are significant for the viscosity. The figure indicates that the viscosity gradually decreased with the increase of extraction time from 50 to about 85-95 min, which was enough to allow pectinase to

break down the pectin molecules into smaller, soluble fragments that had less resistance to flow. In the same way, the higher temperature of the extraction (35°C to about 47-50°C) led to a significant decrease in viscosity because of increased enzyme activity and increased degradation of pectic substances.

Ghorband and Joshi (2023) [6] also observed a decrease in viscosity of dragon fruit juice when treated with pectinase enzyme at concentrations from 38 to 380 IU. Pectinase (50°C) treated mosambi juice showed a decrease in viscosity from 2.45 cP to 1.67 cP, as compared to 1.16 cP reported by Rai *et al.* (2004) [17] for pectinase-treated mosambi juice at 32-49°C. They noted that the best treatment temperature was between 45-50°C, which agrees with the present study. Abdullah *et al.* (2007) [1] also found a reduction in viscosity of carambola juice upon treatment with 0.1% enzyme.

Effect of independent parameters on Total Soluble Solids (TSS) of papaya juice

The total soluble solids (TSS) is one of the important quality parameters that is directly related to sweetness, flavor, and acceptability of fruit juice and is an indication of the amount of soluble sugar, organic acid, and other dissolved solids present in the juice. TSS ranged from 11.60 to 12.95 °Bx. The ANOVA results shown in Table 6 revealed that the built quadratic regression model was highly significant (F value is 31.85 with p value < 0.0001), which indicates that the model used was able to explain the variation in TSS with the different extraction conditions. The response surface indicated that the extraction temperature of pectinase had a positive effect on the amount of TSS, with the reaction temperature ranging from 35°C to about 47-50°C, which led to the degradation of pectic substances and increased release of soluble sugars and other soluble solids from papaya tissues. Extracting for 50 minutes and then 80-90 minutes also resulted in higher TSS, as more enzymes act and mass transfer is enhanced for the longer extraction time.

But beyond the optimum region, further increases in extraction temperature or extraction time gave little additional increase or decrease in TSS (Fig 4). Enzymatic activity for pectinase will be partially inhibited at temperatures above 50 to 55°C, and maximum soluble solids extraction occurs in less than 90 to 100 minutes, after which little additional hydrolysis can be achieved due to the amount of substrate already broken down. Veer *et al.* (2026) [21] observed that when pectinase enzyme treatment was given to dragon fruit juice at independent factors: enzyme concentration (0.1 to 0.5%), incubation temperature (35 to 55°C), and incubation time (100 to 140 min), TSS was found to increase, and the optimum TSS was 11.01°Bx. Ghorband and Joshi *et al.* (2023) [6] also indicated an increase in soluble solids content in dragon fruit juice by pectinase treatment; TSS (Total soluble solids) of dragon fruit juice increased from 11.42 to 12.14°Bx.

Effect of independent parameters on ascorbic acid of papaya juice

Ascorbic acid is one of the more notable nutritional quality indicator components of fruit juice due to its antioxidant property and susceptibility to degradation during processing. Ascorbic acid content ranged from 56.01 to 57.01 mg /100g. (Table 3). ANOVAs presented in Table 7 showed that the developed quadratic regression model was highly significant with an F-value of 42.12 and a p-value of < 0.0001 , which

indicates that the model was able to account for the differences in ascorbic acid content with respect to the different extraction conditions. The shape of the response surface is smooth and domed, suggesting that the extraction process has an optimum level at moderate conditions for maximum ascorbic acid retention. As seen in the figure, with the increase in the extraction time from 50 to around 80-90 minutes, there was a corresponding rise in the ascorbic acid concentration. Enzymatic degradation of the cell wall during this time resulted in increased release of vitamin C into the juice, yet there was little degradation. The contour plot (Fig 5) showed the shape of the contours to be elliptical, consistent with the quadratic effect found in the ANOVA for extraction time and temperature. The maximum predicted ascorbic acid content (56.8-57.0 mg/100 g) was obtained around 85-90 minutes of extraction time and 47-50°C, while the minimum content (56.0 mg/100 g) was achieved by the shortest extraction time at either very low or very high temperatures. The results of the present study were similar to those reported in some studies on

enzyme-assisted extraction and vitamin C retention in fruit juice.

Nguyen *et al.* (2018) ^[11] treated mulberry juice with Pectinex Ultra SP-L and observed an increase in ascorbic acid, which was found to be 35.5 mg/100 mL for different incubation times from 60 to 240 min. Sin *et al.* (2006) ^[19] evaluated enzyme-assisted extraction of tropical fruit juices and found that the optimum temperature range for vitamin C retention was between 45 and 50°C; however, temperatures above 55°C resulted in significant vitamin C losses due to thermal oxidation. The maximum ascorbic acid (57.01 mg/100 g) was also seen in the present study around 46.68°C, which also indicated that moderate temperature is the key factor to preserve vitamin C during enzymatic processing. Dhuique-Mayer *et al.* (2007) ^[4] investigated the effect of process conditions on vitamin C retention in citrus fruits and found that vitamin C retention was the highest at below 50°C processing temperature due to a greater rate of oxidation with an increase in temperature.

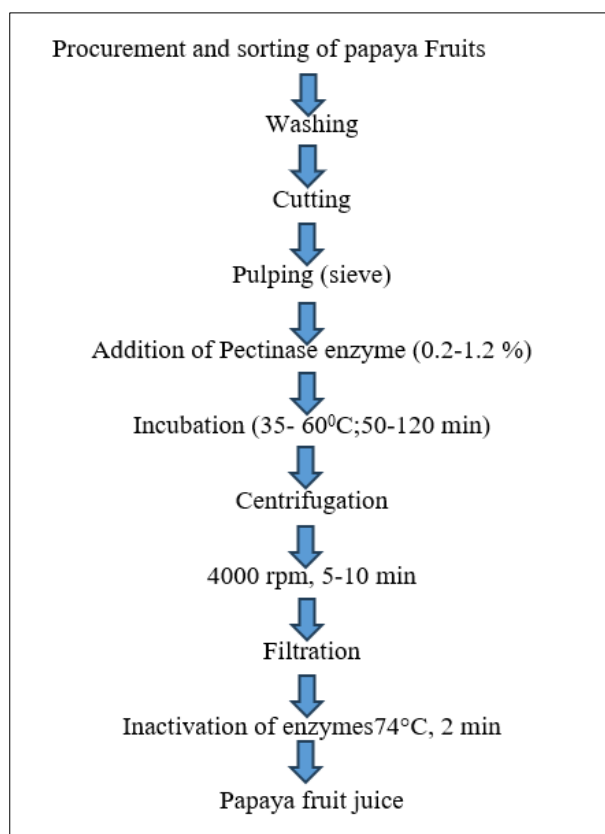


Fig 1: Flow chart for production of juice from papaya fruit pulp

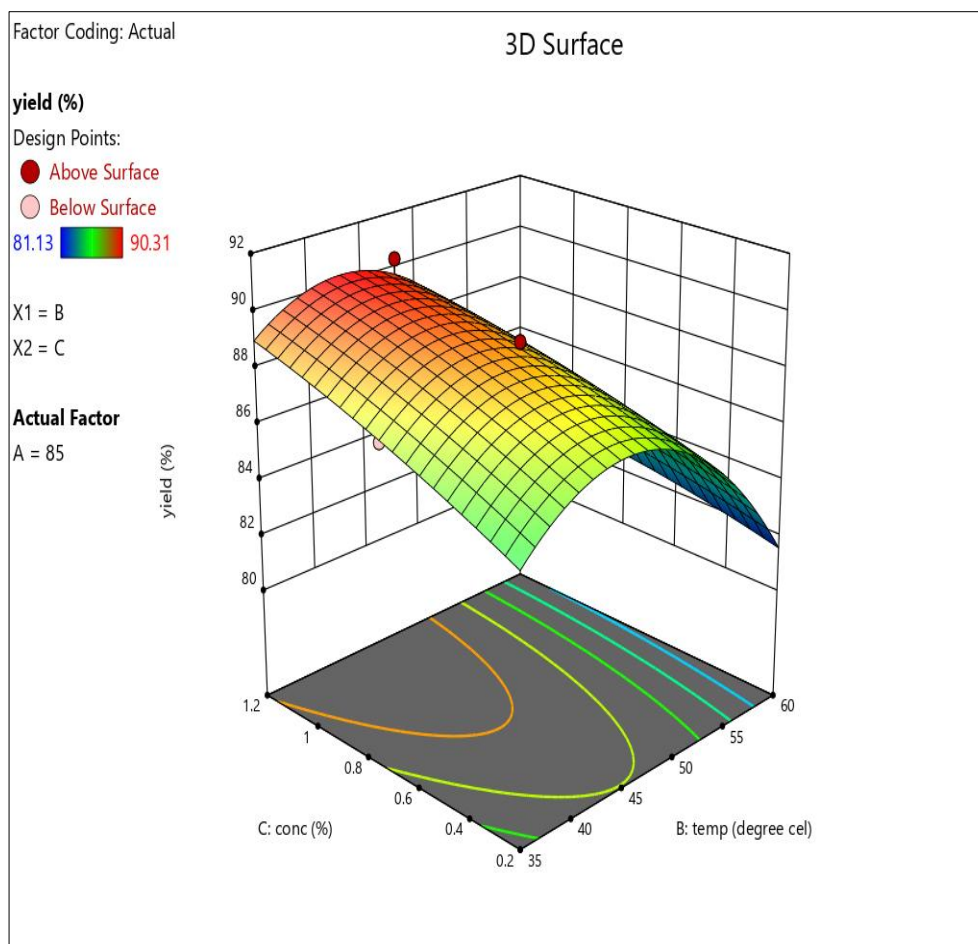


Fig 2: Surface plot for the effect of enzyme treatment on extract yield content of papaya juice

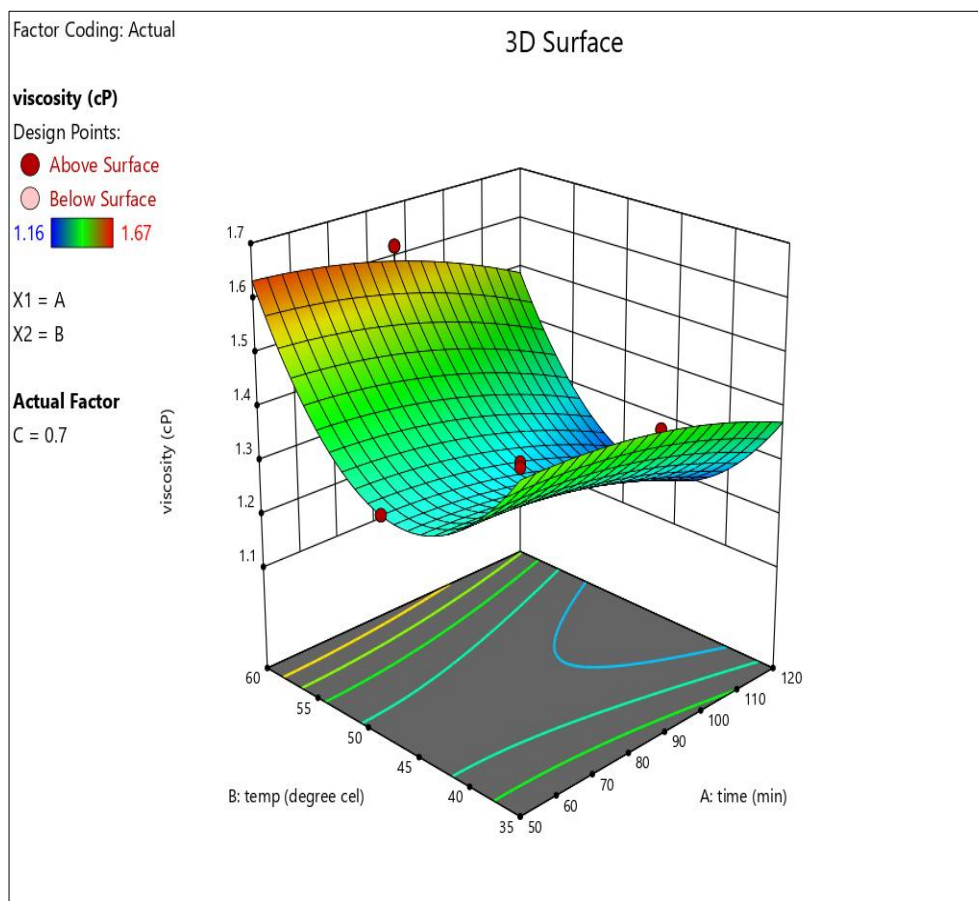


Fig 3: Surface plot for the effect of enzyme treatment on viscosity of papaya juice

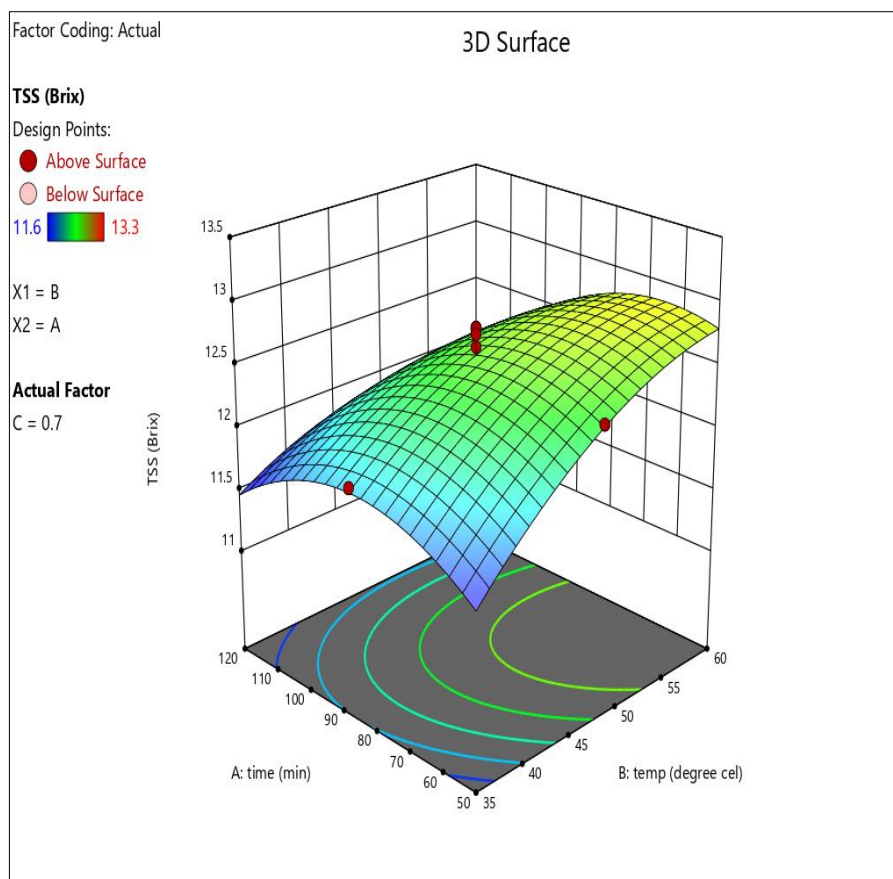


Fig 4: Surface plot for effect of enzyme treatment on total soluble solids on content of papaya juice

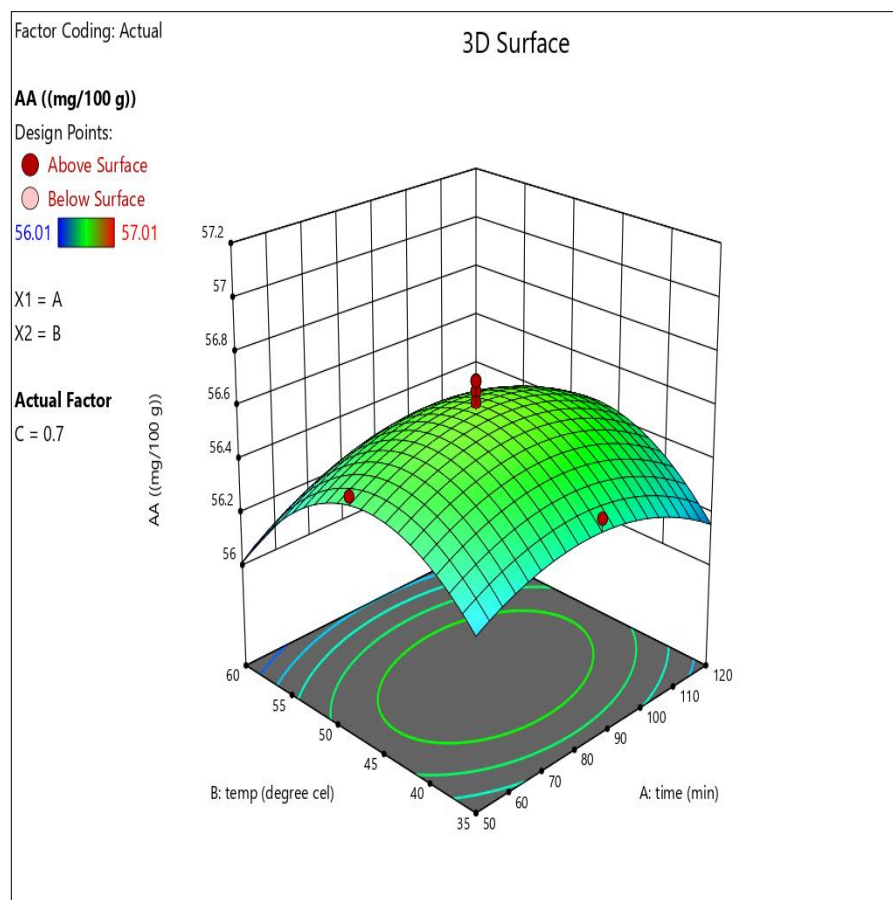


Fig 5: Surface plot for effect of enzyme treatment ascorbic acid of papaya juice

Table 1: Levels of each independent parameter for extraction of papaya fruit juice

Code	Particulars	Low	High
A	Enzyme concentration (%)	0.2	1.2
B	Incubation time (min)	50	120
C	Incubation temperature (°C)	35	60

Table 2: Experimental design parameters along with the responses of yield and viscosity

Run	Incubation time (A) (Min)	Incubation temp (B) (°C)	Enzyme concentration (C)b (%)	Yield (%)	Viscosity (cP)
1	85	60	0.7	82.98	1.62
2	120	47.5	0.7	89.31	1.22
3	120	60	0.2	81.45	1.56
4	85	47.5	0.7	88.93	1.3
5	85	47.5	0.2	86.87	1.36
6	85	35	0.7	87.36	1.46
7	85	47.5	0.7	88.54	1.29
8	85	47.5	0.7	88.58	1.25
9	85	47.5	1.2	90.31	1.16
10	50	35	0.2	84.36	1.53
11	120	60	1.2	82.87	1.33
12	85	47.5	0.7	88.96	1.23
13	120	35	0.2	85.91	1.44
14	50	35	1.2	88.27	1.36
15	50	60	0.2	81.13	1.67
16	50	47.5	0.7	87.84	1.31
17	120	35	1.2	88.96	1.23
18	50	60	1.2	82.36	1.52
19	85	47.5	0.7	88.36	1.27
20	85	47.5	0.7	88.39	1.26

Table 3: Experimental design parameters along with the responses of AA and TSS

Run	Time (A) (Min)	Temp (B) (°C)	Concentration (%)	TSS (°Bx)	Ascorbic acid (mg/100 g)
1	85	60	0.7	12.57	56.13
2	120	47.5	0.7	11.75	56.39
3	120	60	0.2	12.25	56.2
4	85	47.5	0.7	12.8	56.66
5	85	47.5	0.2	12.95	56.57
6	85	35	0.7	11.97	56.4
7	85	47.5	0.7	12.75	56.7
8	85	47.5	0.7	12.5	56.58
9	85	47.5	1.2	11.6	57.01
10	50	35	0.2	11.9	56.09
11	120	60	1.2	11.85	56.42
12	85	47.5	0.7	12.65	56.62
13	120	35	0.2	11.75	56.15
14	50	35	1.2	12.6	56.7
15	50	60	0.2	13.3	56.01
16	50	47.5	0.7	12.45	56.48
17	120	35	1.2	11.67	56.55
18	50	60	1.2	12.8	56.41
19	85	47.5	0.7	12.55	56.59
20	85	47.5	0.7	12.47	56.58

Table 4: ANOVA table for the effect of enzyme treatment on extraction yield of juice

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	162.15	9	18.02	127.05	< 0.0001	significant
A-Time	2.06	1	2.06	14.53	0.0034	
B-Temp	57.94	1	57.94	408.55	< 0.0001	
C-Conc	17.03	1	17.03	120.09	< 0.0001	
AB	0.2485	1	0.2485	1.75	0.2150	
AC	0.0561	1	0.0561	0.3957	0.5434	
BC	2.32	1	2.32	16.37	0.0023	
A ²	0.2386	1	0.2386	1.68	0.2237	
B ²	37.64	1	37.64	265.41	< 0.0001	
C ²	0.2149	1	0.2149	1.52	0.2465	

Residual	1.42	10	0.1418			
Lack of Fit	1.08	5	0.2156	3.17	0.1155	not significant
Pure Error	0.3399	5	0.0680			
Cor Total	163.57	19				

Table 5: ANOVA table for the effect of enzyme treatment on the viscosity of papaya juice

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	0.4015	9	0.0446	62.50	< 0.0001	significant
A-Time	0.0372	1	0.0372	52.13	< 0.0001	
B-Temp	0.0462	1	0.0462	64.78	< 0.0001	
C-Conc	0.0922	1	0.0922	129.11	< 0.0001	
AB	0.0008	1	0.0008	1.12	0.3147	
AC	0.0018	1	0.0018	2.52	0.1434	
BC	0.0000	1	0.0000	0.0000	1.0000	
A ²	0.0024	1	0.0024	3.36	0.0966	
B ²	0.1657	1	0.1657	232.11	< 0.0001	
C ²	0.0033	1	0.0033	4.60	0.0576	
Residual	0.0071	10	0.0007			
Lack of Fit	0.0038	5	0.0008	1.14	0.4441	not significant
Pure Error	0.0033	5	0.0007			
Cor Total	0.4087	19				

Table 6: Effect of enzyme treatment on total soluble solids (TSS) content of papaya juice

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	4.32	9	0.4795	31.85	< 0.0001	significant
A-Time	0.7728	1	0.7728	51.32	< 0.0001	
B-Temp	1.51	1	1.51	99.98	< 0.0001	
C-Conc.	0.2657	1	0.2657	17.64	0.0018	
AB	0.4608	1	0.4608	30.60	0.0003	
AC	0.0128	1	0.0128	0.8501	0.3782	
BC	0.0338	1	0.0338	2.24	0.1650	
A ²	0.5193	1	0.5193	34.49	0.0002	
B ²	0.1925	1	0.1925	12.78	0.0051	
C ²	0.1590	1	0.1590	10.56	0.0087	
Residual	0.1506	10	0.0151			
Lack of Fit	0.0586	5	0.0117	0.6367	0.6838	not significant
Pure Error	0.0920	5	0.0184			
Cor Total	4.47	19				

Table 7: ANOVA table for the effect of enzyme treatment on ascorbic acid (AA) content of papaya juice

Source	Sum of Squares	df	Mean Square	F-value	p-value	
Model	1.14	9	0.1271	42.12	< 0.0001	significant
A-Time	0.0000	1	0.0000	0.0133	0.9106	
B-Temp	0.0518	1	0.0518	17.18	0.0020	
C-Conc	0.4285	1	0.4285	142.00	< 0.0001	
AB	0.0105	1	0.0105	3.48	0.0915	
AC	0.0190	1	0.0190	6.30	0.0309	
BC	0.0190	1	0.0190	6.30	0.0309	
A ²	0.0716	1	0.0716	23.73	0.0007	
B ²	0.3020	1	0.3020	100.06	< 0.0001	
C ²	0.1031	1	0.1031	34.17	0.0002	
Residual	0.0302	10	0.0030			
Lack of Fit	0.0181	5	0.0036	1.50	0.3343	not significant
Pure Error	0.0121	5	0.0024			
Cor Total	1.17	19				

Table 8: Responses for optimized papaya fruit juice by enzymatic treatment

Parameters	Mean $\pm$ SD
Yield (%)	90.18 $\pm$ 0.37
TSS ($^{\circ}$ Bx)	12.484 $\pm$ 0.12
Ascorbic acid (mg/100 ml)	56.904 $\pm$ 0.59
Viscosity (cP)	1.112 $\pm$ 0.02

Conclusion

The results above showed that using an enzyme at 1.2% concentration, 79.16 minutes of incubation time, and 46.68 °C of incubation temperature can increase the extractability and quality of papaya fruit juice. Fruit juice processing has thus been made possible by the use of enzymes. Fruit juice is clarified by pectinase treatment, which also makes the product made from it more valuable to consumers. Increasing yield and TSS while lowering the extracted juice's viscosity and sugar content are also advantageous, which eventually lowers the overall cost of juice manufacturing.

Acknowledgments

The authors acknowledge the Department of Food Processing Technology, College of Food Processing Technology & Bioenergy, Anand Agricultural University, Anand, Gujarat, for providing the facilities required to conduct this study.

Conflict of interest

The authors declare that they have no conflict of interest.

References

1. Abdullah AGL, Sulaiman NM, Aroua MK, Megat Mohd Noor MJ. Response surface optimization of conditions for clarification of carambola fruit juice using a commercial enzyme. *J Food Eng.* 2007;81(1):65-71.
2. Al-Habian A, Harikumar PE, Stocker CJ, Langlands K, Selway JL. Histochemical and immunohistochemical evaluation of mouse skin histology: comparison of fixation with neutral buffered formalin and alcoholic formalin. *J Histotechnol.* 2014;37(4):115-124.
3. Aho M, Irshad B, Ackerman SJ, Lewis M, Leddy R, Pope T, *et al.* Correlation of sonographic features of invasive ductal mammary carcinoma with age, tumor grade, and hormone-receptor status. *J Clin Ultrasound.* 2013;41(1):10-17. doi:10.1002/jcu.21990
4. Dhuique-Mayer C, Tbatou M, Carail M, Caris-Veyrat C, Dornier M, Amiot MJ. Thermal degradation of antioxidant micronutrients in citrus juice: kinetics and newly formed compounds. *J Agric Food Chem.* 2007;55(10):4209-4216.
5. Farina V, Tinebra I, Perrone A, Sortino G, Palazzolo E, Mannino G, *et al.* Physicochemical, nutraceutical, and sensory traits of six papaya (*Carica papaya* L.) cultivars grown in greenhouse conditions in the Mediterranean climate. *Agronomy.* 2020;10(4):501.
6. Ghorband AS, Joshi BH. Effect of enzyme treatment on yield, TSS, ascorbic acid and viscosity of dragon fruit juice. *Pharma Innov J.* 2023;12(11):2327-2331.
7. Jayani RS, Saxena S, Gupta R. Microbial pectinolytic enzymes: a review. *Process Biochem.* 2005;40(9):2931-2944.
8. Kashyap DR, Vohra PK, Chopra S, Tewari R. Applications of pectinases in the commercial sector: a review. *Bioresour Technol.* 2001;77(3):215-227. doi:10.1016/S0960-8524(00)00118-8
9. Kumar R, Singh AK. Effect of multi-enzyme (pectinase, cellulase and hemicellulase) treatment on clarification of papaya (*Carica papaya*) fruit juice. *Int J Recent Technol Eng.* 2019;8:12708-12721.
10. Marpudi SL, Abirami LSS, Srividya N. Enhancement of storage life and quality maintenance of papaya fruits using *Aloe vera*-based antimicrobial coating. *Indian J Biotechnol.* 2011;10(1):83-89.
11. Nguyen CL, Nguyen HV. The quality of mulberry juice as affected by enzyme treatments. *Beverages.* 2018;4(2):41.
12. Poling J, Kelly L, Chan C, Fisman D, Ulanova M. Hospital admission for community-acquired pneumonia in a First Nations population. *Can J Rural Med.* 2014;19(4):135-141.
13. Prabha A, Modgil R. Comparative nutritional quality evaluation of different cultivars of papaya. *Asian J Dairy Food Res.* 2018;37(2):158-161.
14. Pui LP, Saleena LAK. Enzyme-aided treatment of fruit juice: a review. *Food Process Technol.* 2023;10(1):1-10. doi:10.21603/2074-9414-2023-1-2413
15. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products. 2nd ed. New Delhi: Tata McGraw-Hill; 2007.
16. Rashima RS, Ong WL, Aina Nadiah Z, Maizura M. Effects of acidified blanching water and pectinase enzyme pretreatments on physicochemical properties and antioxidant capacity of *Carica papaya* juice. *J Food Sci.* 2022;87(4):1684-1695. doi:10.1111/1750-3841.16097
17. Rai P, Majumdar GC, Dasgupta S, De S. Optimizing pectinase usage in pretreatment of mosambi juice for clarification by response surface methodology. *J Food Eng.* 2004;64(3):397-403.
18. Saeed F, Arshad MU, Pasha I, Naz R, Batool R, Khan AA, *et al.* Nutritional and phyto-therapeutic potential of papaya (*Carica papaya* Linn.): an overview. *Int J Food Prop.* 2014;17(7):1637-1653. doi:10.1080/10942912.2012.709210
19. Sin HN, Yusof S, Hamid NSA, Rahman RA. Optimization of enzymatic clarification of sapodilla juice using response surface methodology. *J Food Eng.* 2006;73(4):313-319.
20. Vishal BV, Chauhan AS, Rekha MN, Negi PS. Quality evaluation of enzyme liquefied papaya juice concentrate (PJC) stored at various temperatures. *J Food Nutr Sci.* 2015;3(3):90-97. doi:10.11648/j.jfns.20150303.12
21. Veer SJ, Pawase PA, Khalid S, Dattatraya RH, Bashir O, Abdi G. Pectinase-assisted extraction of red dragon fruit (*Hylocereus polyrhizus*) juice: process optimization and quality assessment. *Food Chem Adv.* 2026;101244.