Defatted Jatropha curcas Flour as a Novel Functional Ingredient for Enhancing the Technological and Sensory Quality of Pizza Dough

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Abstract

Wheat-based baked products remain dietary staples due to their affordability, versatility, and desirable technological properties. Expanding their nutritional value through the use of underutilized crops aligns with current food system priorities. This study examined the incorporation of defatted *Jatropha curcas* flour obtained from an edible, non-toxic ecotype into wheat flour blends to determine substitution levels compatible with acceptable dough functionality and product quality. Five formulations (100/0, 95/5, 90/10, 85/15, and 80/20% wheat/*J. curcas*) were evaluated using standard alveograph and farinograph methods to assess dough strength, tenacity, extensibility, water absorption, and mixing behavior. Substitutions below 15% retained viscoelastic characteristics comparable to wheat flour, although gluten dilution reduced deformation energy while increasing tenacity (P/L from 0.84 to 2.59) and decreasing extensibility (92.01 to 36.04 mm). Water absorption increased moderately (46.45–54.07%), with development times ranging from 2.50 to 3.53 min, reflecting higher hydration requirements associated with the protein- and fiber-rich *J. curcas* fraction. Sensory evaluation revealed high consumer acceptance, particularly at 10–15% substitution, supporting its applicability in low volume baked products such as pizza bases. Protein content increased from 11.52% in the control to 16% at 20% substitution. These findings demonstrate that defatted *Jatropha curcas* flour is a promising ingredient for enhancing the nutritional value of wheat-based foods, with substitution levels up to 15% achieving an optimal balance between improved composition and functional performance.

1 Introduction

Pizza and other wheat-based baked products remain among the most consumed foods worldwide, not only for their sensory appeal but also for their cultural relevance and versatility as convenient meals in modern diets [1]. In Mexico, pizza consumption has increased substantially over the past decade, placing the country as the second-largest consumer globally, surpassed only by the United States [2]. Although pizza is traditionally perceived as a complete meal providing carbohydrates, proteins, lipids, and micronutrients current consumer demands and public-health priorities have accelerated interest in nutritionally enhanced formulations [3, 4]. This is particularly relevant in regions seeking to increase dietary protein quality while diversifying the use of local underutilized crops.

Among such crops, Jatropha curcas L. (locally known as *piñón mexicano*) has gained attention for its high-quality protein content, adaptability to marginal soils, and potential contribution to food and nutrition security. Edible ecotypes of *J. curcas* contain 25–30% protein in whole seed, which may increase up to 60% in defatted meal, offering a valuable plant-based protein source. Previous studies report in vitro protein digestibility values of 78–88%, depending on thermal treatment and processing conditions [5, 6], positioning this species as a promising ingredient for food fortification.

The reformulation of staple foods using nutrient dense flours requires an understanding of their rheological, physicochemical, and sensory impacts. In wheat based matrices, gluten governs dough viscoelasticity, gas-holding capacity, and final product texture. Thus, rheological evaluation using instruments such as the alveograph and farinograph provides essential insights for predicting dough performance and optimizing processing variables [7, 8]. Incorporating alternative flours into these systems may improve nutritional value but can also alter hydration properties, gluten network development, and dough strength factors that influence product acceptability.

Integrating *J. curcas* flour into pizza dough formulations presents an opportunity to increase protein density and promote the use of non-traditional, locally relevant crops. However, wheat-based formulations remain unsuitable for individuals with celiac disease or gluten-related disorders, highlighting the need to characterize new blends not only nutritionally but also structurally and sensorially [9, 10].

This study evaluates the effects of replacing wheat flour with *Jatropha curcas* flour in pizza dough, focusing on its rheological performance, physicochemical characteristics, and sensory attributes, with the aim of identifying its potential as a viable ingredient for developing more nutritious and innovative baked products.

2 Material and Methods

2.1 Kernel and flour

The plant material used in this study consisted exclusively of kernels (seeds without hulls) from an edible, non-toxic ecotype of *J. curcas*. The kernels were obtained from cultivated plants grown in the community of Pueblillo, municipality of Papantla, Veracruz, Mexico (approximately 20.3710° N, –97.3157° W). The material was supplied by local producers who maintain small scale agricultural plots dedicated to the cultivation of J. curcas edible. No wild populations were used, and no additional plant parts beyond the kernels were collected.

Defatted *Jatropha curcas* flour was obtained from seeds of a non-toxic, edible ecotype (phorbol esters not detected) produced in Pueblillo, Veracruz, Mexico. The seeds were dehulled, milled, and passed through an 80-mesh sieve to standardize particle size. The flour was then defatted with hexane in a Soxhlet extractor at 68°C for 16 h to remove lipids. The wheat flour used was a commercial product (San Antonio, Extrafina; Tres Estrellas™).

2.2 Fortified Flour Formulation

Wheat and *Jatropha curcas* flours were blended at four substitution levels for the pizza dough bases. The control (P-T) contained 100% wheat flour. Experimental formulations were P-5 (95% wheat/5% J. curcas*), P-10 (90%/10%), P-15 (85%/15%), and P-20 (80%/20%), expressed on a flour basis (w/w).

2.3 Proximate Chemical Analysis

Protein, lipid, ash, moisture, and fiber were quantified in triplicate according to the AOAC [11]. Official Methods in whole and defatted *Jatropha curcas* flours, wheat flour, and the pizza dough bases prepared with the formulations described above.

2.4 Rheological Properties (Viscoelasticity and Mixing)

2.4.1 Alveograph: Tests were conducted by kneading 50 g of refined wheat flour for 8 min; added water was adjusted to the flour's moisture content as determined by AACC Method 54-30A [12]. The evaluated parameters were dough tenacity (P, mm), extensibility (L, mm), and deformation energy (W, $\times 10^{-4}$ J), where W corresponds to the area under the curve and reflects flour strength/protein quality. Alveograms were obtained at the Wheat Laboratory, Centro Experimental Valle de México (CEVAMEX), INIFAP.

2.4.2 Farinograph: This test quantified dough resistance to mixing. Based on the flour's moisture and protein contents and using CEVAMEX (INIFAP) reference tables, the appropriate flour mass was weighed and placed in the farinograph bowl. Water was then added during mixing to center the torque curve at 500 Brabender Units (U.B.), as specified by AACC Method 54-40A [13].The reported parameters were development time, water absorption, stability, and mixing tolerance index (MTI).

2.5 Product Preparation

2.5.1 Pizza Dough Base

A total of 500 g of dough (wheat/*Jatropha curcas* flour blend) was prepared. Yeast (15 g) was dissolved in 150 mL of warm water (30°C), and mixing commenced while gradually adding the remaining water together with salt (2 g) and olive oil (12 mL). The dough was transferred to a greased tray and fermented for 30 min. It was then degassed and kneaded briefly to expel trapped air and improve softness, followed by a second 30-min fermentation. The dough was sheeted into a 35-cm round with a 2-cm rim and prebaked at 180°C for 10 min.

2.6 Sensory Evaluation

A panel of 100 untrained consumer judges, 50 from the student and staff population of Colegio de Postgraduados, Campus Tabasco, and 50 from Universidad Popular de la Chontalpa participated in this study. A hedonic test was conducted using a seven-point scale with five coded samples, allowing judges to rate their degree of liking or disliking, following Anzaldúa [14]. The test was performed 10 min after preparing the pizza dough base.

2.7 Statistical Analysis

Data were analyzed using SAS V.9.0. [15] under a completely randomized design, and mean comparisons were performed using Tukey's test ($p = 0.05$).

3 Results and Discussion

3.1 Proximate Chemical Analysis

When assessing the proximate composition, statistically significant differences were observed between wheat flour and *Jatropha curcas* flour (Table 1). Wheat flour showed higher moisture than *J. curcas* flour. The protein content of wheat flour (9.85%) falls within the 9–11% range reported by Sweta et al. [10] and Maghaydah et al. [16]. Whole J. *curcas* flour contains 24.5% protein, which increases to 55.01% after defatting, values consistent with Martínez et al. [17] i.e., approximately 5.6-fold higher than wheat. This elevated protein level motivates the use of *J. curcas* flour for food fortification, including pizza bases. For comparison, Singh and Lal [18] developed a pizza base enriched with whole wheat, kodo millet, buckwheat, and brown rice flours; its protein content ranged from 7.13% to 9.50%, higher than a conventional refined wheat base yet still below levels achievable with *J. curcas* fortification.

Table 1
Chemical Composition of the Flours

Types of flours	Moisture (%)	Ash (%)	Protein (%)	Lipids (%)
Wheat flour	11.05 ± 0.03[a]		9.85 ± 0.01[a]	1.05 ± 0.01[a]
Whole flour *J.c.*	5.5 ± 0.15[c]	4.29 ± 0.07[a]	24.5 ± 0.06[c]	53.52 ± 0.05[c]
Defatted flour *J.c.*	6.4 ± 0.10[d]	10.4 ± 0.05[b]	55.01 ± 0.06[d]	1.44 ± 0.01[a]

J. c: *Jatropha curcas.* Means with the same letter in each column are not statistically different (Tukey, 0.05).

Table 1. **Chemical Composition of the Flours**

3.2 Viscoelastic Properties (Alveograph)

The addition of *Jatropha curcas* flour altered all viscoelastic properties of the wheat dough (Table 2). The control wheat flour exhibited medium-strong gluten strength (W = 290 × 10^{-4} J) and tended toward a strong, balanced profile, as indicated by its P (77 mm) and L (92 mm) values, which are consistent with the Mexican wheat classification [19]. The P/L (tenacity-to-extensibility) ratio was comparable to values reported for soft wheats used in cookies, tortillas, artisanal bread, and pizza dough, ranging from 0.06 to 0.8 (Peña et al., 2008). These results suggest that the commercial wheat flour used in this study may be suboptimal for high-volume breadmaking but offers intermediate quality for low-volume products such as pizza dough.

Table 2. Viscoelastic Properties of Wheat Dough Fortified with *J. curcas* Flour

Treatment	W x 10^{-4} J	P (mm)	L (mm)	P/L
HT-T	290±0.78^{a}	77.01±00^{a}	92.01±0.58^{a}	0.84±0.01^{a}
HT-5	210±0.96^{b}	78.01±0.96^{b}	90.13±0.58^{b}	0.85±0.01^{b}
HT-10	195±0.96^{c}	80.03±0.82^{c}	70.01±0.96^{c}	1.14±0.01^{c}
HT-15	122±0.92^{d}	88.03±0.58^{d}	48.00±0.96^{d}	1.83±0.03^{d}
HT-20	89.50±0.58^{e}	93.47±58^{e}	36.04±0.50^{e}	2.59±0.03^{e}

W = Strength, P = Tenacity, L = Extensibility, P/L = Tenacity/Extensibility Index.
Means with the same letter in each column are not statistically different (Tukey, 0.05).

Replacing wheat flour with *Jatropha curcas* flour reduced gluten strength (W, $\times 10^{-4}$ J) but increased dough tenacity (P) and the tenacity-to-extensibility ratio (P/L), while decreasing extensibility (L) (Table 2; Fig. 1). Specifically, W decreased by 80, 95, 168, and 200 $\times 10^{-4}$ J with 5%, 10%, 15%, and 20% *J. curcas* addition, respectively; P increased by 1.00, 3.02, 11.02, and 16.44 mm; L decreased by 1.88, 22.00, 44.01, and 55.97 mm; and P/L raised by 0.01, 0.30, 0.99, and 1.75 relative to the control.

The decrease in dough strength may stem from a reduced capacity of the gluten network to retain gas during biological fermentation [20]. This reduction is primarily attributable to gluten dilution i.e., the effective gliadin-to-glutenin balance of the wheat matrix is altered when non-gluten *Jatropha curcas* flour is added together with competition for water and potential physical interference with gluten development [21]. Such dilution of gluten proteins [22] weakens dough strength; however, the resulting rheology is advantageous for low-volume products such as pizza.

The increase in tenacity (Figs. 1d and 1e) and the decrease in extensibility (Figs. 1b and 1c) are consistent with dilution and perturbation of the gluten network upon addition of non-gluten flour. In wheat dough, gliadins primarily confer extensibility, whereas glutenins contribute to strength/elasticity; thus, a lower effective gliadin contribution and reduced water availability lead to lower L and higher P [3–20].

Based on these findings, adding *Jatropha curcas* flour at levels below 15% is recommended, as higher concentrations impair dough sheeting and shaping, yielding a denser crumb and firmer texture. Substitutions above 15% may be feasible when using strong (high-gluten) wheat flour, so that blending with *J. curcas* does not compromise gluten strength and extensibility.

Figure 1 Alveograms corresponding to: (a) the control made with 100% wheat flour, (b) wheat flour with 5% *J. curcas* flour, (c) wheat flour with 10% *J. curcas* flour, (d) wheat flour with 15% *J. curcas* flour, and (e) wheat flour with 20% *J. curcas* flour.

3.3 Farinograms

Substituting *Jatropha curcas* flour modified the dough's physical properties and overall mixing profile (Table 3). Water absorption increased by up to 7.6% at 20% *J. curcas* addition. Although the base wheat flour already exhibited high hydration capacity, it raised further with the incorporation of the protein and fiber-rich *J. curcas* fraction, which binds water through hydrophilic sites [22]. A comparable trend has been reported for blends with purple yam *(Dioscorea alata*) flour, attributed to the abundance of hydroxyl groups in its starch structure [23].

Table 3
Farinographic Characteristics

Parameters	WA (%)	ODT (min)	DW (UB)	MTI (UB)	S (min)
HT-T	46.45 ± 0.25^{a}	2.50 ± 0.06^{a}	190.17 ± 0.06^{a}	220 ± 0.58^{a}	6.5 ± 0.06^{d}
HT-5	50.43 ± 0.58^{b}	2.50 ± 0.06^{a}	170.30 ± 0.10^{b}	180 ± 0.58^{b}	6.0 ± 0.00^{c}
HT-10	50.80 ± 0.00^{b}	2.63 ± 0.10^{a}	160.17 ± 0.12^{c}	170.67 ± 0.58^{c}	4.5 ± 0.06^{a}
HT-15	50.90 ± 0.06^{b}	3.00 ± 0.10^{b}	143.67 ± 0.89^{d}	158.33 ± 0.58^{d}	5.3 ± 0.03^{b}
HT-20	54.07 ± 0.12^{c}	3.53 ± 0.06^{b}	130.17 ± 0.06^{e}	140.83 ± 0.76^{e}	4.4 ± 0.06^{a}

WA = Water Absorption; ODT = Optimal Development Time; MTI = Mixing Tolerance Index (Brabender Units); DW = Degree of Weakening; S = Stability. Means with the same letter in each column are not significantly different (Tukey, 0.05).

Table 3. **Farinographic Characteristics**

Optimal development time (ODT) and dough stability (DS) are critical in breadmaking. Adding 20% *Jatropha curcas* flour increased ODT by 1.03 min relative to the control, likely due to gluten dilution: the non-gluten fraction slows the arrangement and alignment of glutenin and gliadin, delaying gluten development and peak strength [23]. For strong-gluten flours, development times typically range from 5–10 min, whereas for soft wheats (used for cookies and related products) they span 3–5 min [24], a range that encompasses the 15% and 20% *J. curcas* blends.

Stability an indicator of flour mixing tolerance, decreased by 2.1 min with 20% *Jatropha curcas* addition relative to wheat flour alone, placing the blend in Group 3 (weak/low-strength gluten) according to Peña et al. [24]. A similar trend has been reported for wheat–rice flour blends [25]. At 20% substitution, the degree of weakening (DW) decreased by 60 BU and the mixing tolerance index (MTI) by 79.2 BU compared with the control, findings that align with the increased dough tenacity observed in the alveograph test.

3.4 Proximate Chemical of Pizza

3.4.1 Analysis of Pizza

Substituting defatted *Jatropha curcas* flour altered the proximate composition (Table 4). At 20% *J. curcas* addition, moisture increased by 10.56%, protein by 4.48%, lipids by 2.30% and ash by 2.06%, whereas fiber decreased by 2.06%. The higher moisture is consistent with increased protein and its greater water-holding capacity [26]. Lipid content raised because defatted *J. curcas* flour still retains 1.44% lipids; notably, higher values (4.4%) are reported in Domino's™ pizza nutrition tables. Fiber declined from 4.56% to 3.04%. The elevated ash content aligns with the calcium, magnesium, and potassium present in *J. curcas* flour [6].

Table 4
Proximate Chemical Analysis of Pizza

Sample	Moisture (%)	Protein (%)	Lipids (%)	Ashes (%)	Fiber (%)
P-T	19.55 ± 0.06^{a}	11.52 ± 0.22^{a}	10.11 ± 0.11^{a}	1.04 ± 0.01^{a}	4.56 ± 0.06^{a}
P-5	28.49 ± 0.17^{b}	12.46 ± 0.39^{b}	10.45 ± 0.12^{a}	1.57 ± 0.01^{b}	4.33 ± 0.10^{b}
P-10	28.49 ± 0.38^{b}	13.83 ± 0.91^{c}	11.00 ± 0.33^{b}	$2.060.02 \pm {}^{c}$	3.93 ± 0.06^{c}
P-15	31.91 ± 0.19^{b}	15.28 ± 0.21^{d}	11.76 ± 0.19^{c}	2.69 ± 0.02^{d}	3.37 ± 0.03^{d}
P-20	30.11 ± 0.59^{b}	16.00 ± 0.40^{e}	12.41 ± 0.04^{d}	3.10 ± 0.01^{e}	3.04 ± 0.03^{e}
Means with the same letter in each column are not significantly different (Tukey, 0.05).					

Protein content reached 16.0% at 20% *Jatropha curcas* substitution, consistent with the increases reported by Maldonado et al. [27] when enriching wheat flour with 5–10% rice bran (*Oryza sativa*). This value is well above the 5.3% reported on the FUD™ pizza nutrition label, underscoring the potential of J. curcas flour as a high-protein fortifier, an observation also noted by Argüello et al. [5] and Arguello et al [28] in fortified cookies and tortillas made with edible *J. curcas* flour.

Table 4. **Proximate Chemical Analysis of Pizza**

3.5 Sensory Analysis

Consumer acceptance of pizzas supplemented with *Jatropha curcas* flour showed a predominantly positive trend, with most responses distributed within the upper categories of the hedonic scale (Fig. 2). Overall, 84% of panelists rated the formulations within the "like" range, whereas 16% provided scores within the "dislike" range, indicating a generally favorable perception of the product. Among the formulations evaluated, the 10% substitution level obtained the highest proportion of top-box ratings (9.6%), followed closely by the 5% and 15% substitutions (7.17% each). These results suggest that moderate incorporation levels may enhance consumer acceptance without negatively impacting sensory attributes.

To our knowledge, no peer reviewed studies have previously evaluated pizza formulations fortified with *Jatropha curcas* flour, which limits direct comparison. However, the positive acceptance observed aligns with reports on bakery and cereal based products fortified with alternative protein-rich flours, where partial substitution often improves flavor complexity or texture tolerance when maintained within moderate levels. This trend supports the potential of *Jatropha curcas* flour as a viable ingredient for developing nutritionally enhanced baked products.

Figure 2. Acceptability of pizzas with *Jatropha curcas* flour at different substitution levels.

4 Conclusions

Fortifying pizza bases with defatted *Jatropha curcas* flour increases protein content (up to 16.0% at 20% substitution) and raises moisture, lipids, and ash, with a slight reduction in fiber. Substitution reduces gluten strength (W), increases tenacity (P) and the P/L ratio, and decreases extensibility (L), consistent with gluten dilution and greater water demand. In farinograph tests, water absorption increases (+ 7.6%), optimal development time rises (1.03 min), and stability declines (2.1 min), alongside decreases in degree of weakening (60 BU) and mixing tolerance index (79.2 BU). Despite these shifts, performance remains suitable for low-volume products; sensory acceptance was high (84% in the “like” range), with peak top-box scores at 10% substitution. Overall, ≤ 15% *J. curcas* provides the best balance between nutritional improvement and processability, while higher levels may be feasible when using strong (high-gluten) wheat flours.

Declarations

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Conflicts of Interest: All authors declare that they have no conflicts of interest regarding the publication of this manuscript.

Ethics and Consent to Participate

Ethics statement

The sensory evaluation was conducted with healthy adult volunteers who provided informed consent prior to participation. The study protocol was reviewed and approved by the Research Ethics Committee of Colegio de Postgraduados in accordance with national guidelines and the Mexican standard NMX-F-605-NORMEX-2016 for sensory evaluation of foods. The committee determined that the study involved minimal risk and was conducted following all relevant guidelines and regulations. Clinical trial number: not applicable

Consent to participate

All participants were adults and provided freely given, informed consent prior to taking part in the sensory evaluation. Participation was voluntary, and all procedures were conducted in accordance with institutional guidelines and the Mexican standard NMX-F-605-NORMEX-2016 for sensory evaluation of foods.

Consent to publish

Informed consent to publish the anonymized results of the sensory evaluation was obtained from all adult participants.

Data Availability

The datasets generated and analyzed during the current study are included in this published article and its supplementary materials. Additional raw data are available from the corresponding author upon reasonable request.

Plant guidelines

The edible, non-toxic ecotype of *Jatropha curcas* used in this study was obtained from cultivated plants grown in Pueblillo, Veracruz, Mexico. No wild populations were collected. The collection and use of plant material complied with all applicable national regulations, including those of the Secretaría de Agricultura y Desarrollo Rural (SADER) and the Mexican environmental guidelines for non-protected plant species. The species is not listed under any national or international protection status; therefore, no additional permits or licenses were required for its use.

Statement for Permissions to Collect Plant Material

The edible, non-toxic ecotype of *Jatropha curcas* used in this study was obtained from cultivated plants grown in Pueblillo, Veracruz, Mexico. As the species is not listed under any national or international protection status and is commonly cultivated for agricultural use, no special permits or licenses were required for its collection. All procedures involving plant material complied with applicable Mexican agricultural and environmental regulations.

Name of the person who identified the plant/plant part

The edible, non-toxic ecotype of *Jatropha curcas* used in this study corresponds to the same plant material previously described by Martínez-Herrera and co-authors (2006), whose specimens were taxonomically identified by Dr. Victor Steinmann at the outset of the research on this edible ecotype. The kernels used in the present work were obtained from cultivated plants in Pueblillo, Papantla, Veracruz, Mexico, and originate from the same characterized material reported in those earlier publications; therefore, no additional taxonomic identification was required.

Herbarium Details

Voucher specimens of the edible ecotype of Jatropha curcas used in this study were previously deposited by Martínez-Herrera and co-authors (2006) in a public herbarium, where they were taxonomically identified by Dr. Victor Steinmann (Euphorbiaceae specialist). The reference voucher is deposited in the National Herbarium of Mexico (MEXU), Institute of Biology, National Autonomous University of Mexico, under the accession number MEXU-1103518. The plant material used in the present study corresponds to the same characterized and archived ecotype; therefore, no additional voucher deposition was required.

Authors' contributions

LCT was responsible for conceptualization, project administration, and research. JMH and GHS contributed to software development, validation, and writing—original draft preparation, as well as methodology and formal analysis. EAG handled visualization, supervision, resource management, and validation. ECM focused on research. OSS was involved in supervision, editing, and visualization, while APV and RICZ also contributed to supervision, editing, and visualization.

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Figures

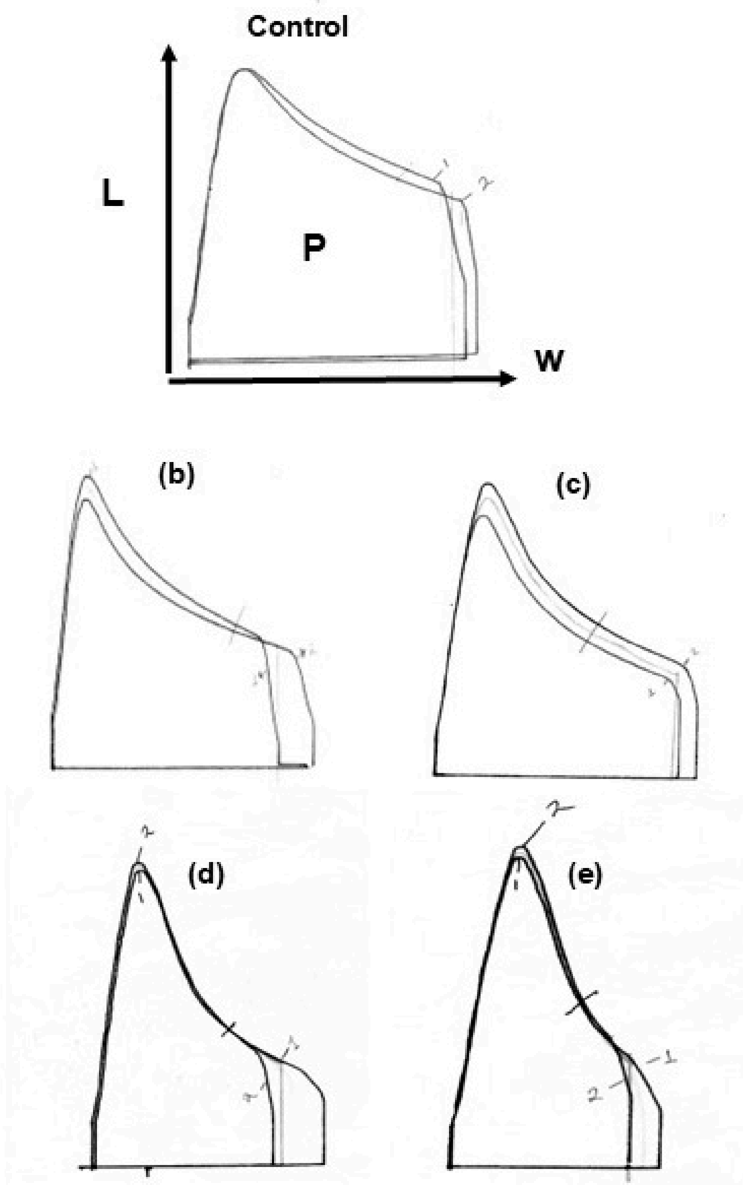

Figure 1

Alveograms corresponding to: (a) the control made with 100% wheat flour, (b) wheat flour with 5% *J. curcas* flour, (c) wheat flour with 10% *J. curcas* flour, (d) wheat flour with 15% *J. curcas* flour, and (e) wheat flour with 20% *J. curcas* flour.

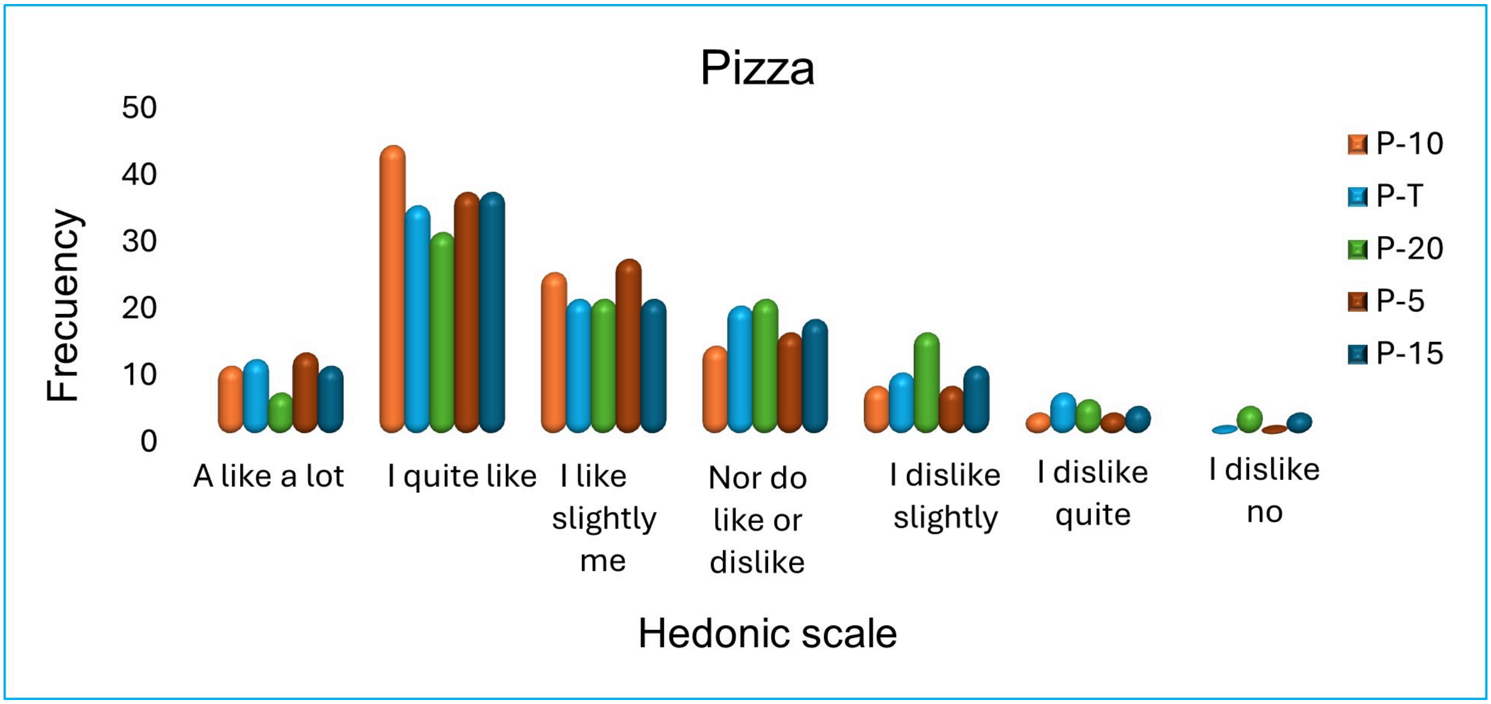

Figure 2

Acceptability of pizzas with *Jatropha curcas* flour at different substitution levels.

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