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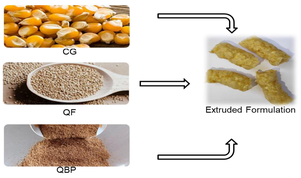
Optimization of an Extruded Formulation to Enhance Protein Content in Corn Grits-Based Products Using Quinoa and Its By-products

PROBLEMA

Extruded cereals are widely consumed around the world due to their convenience and ability to incorporate essential nutrients. However, achieving an optimal balance of macronutrients, particularly protein, remains a significant challenge in their formulation [1]. This study introduces a novel approach by incorporating quinoa by-products into maize-based extruded formulations to enhance protein content, as no previous research has explored this combination.



OBJETIVO GENERAL

To develop and optimize a high-protein extruded cereal through the incorporation of quinoa flour and quinoa agro-industrial by-products into corn grits-based formulations, promoting the valorization of food processing residues while maintaining desirable physicochemical characteristics.

PROPUESTA

- The CG, QF and QBP were obtained from some factories located in Chimborazo, Ecuador.
- The proximate composition of QF, CG, and QBP was determined using standard AOAC methods.

Table 1: Proximate composition of QF, CG, and QBP.

	QF	CG	QBP
Protein	12.99	7.73	42.76
Moisture	9.77	12.04	4.14
Fat	7.25	4.34	25.96
Ash	2.65	1.33	7.62
Crude fiber	1.93	7.05	3.49
Carbohydrates	65.41	74.56	19.49

- Extrusion was performed using a lab-scale Brabender® single-screw extruder operating at 220 RPM. The barrel temperatures were set at 90°C, 140°C, and 160°C across different sections of the extruder. A 4 mm diameter die was used. The extruded cereals were then packed in hermetically sealed aluminum bags and stored at room temperature.
- The expansion ratio (ER) was calculated as the ratio of extrudate diameter to die diameter.
- Bulk density (BD) was measured as the ratio of sample weight to the volume displaced in a graduated cylinder.
- The mechanical properties of the extrudates were assessed using a BROOKFIELD®. A 4 mm diameter probe penetrated the sample to a deformation of 4-7 mm, depending on the extrudate diameter, at a loading speed of 60 mm/min and a preload of 0.98 N.
- All statistical analyses were performed using Minitab 2019.

RESULTADOS

Effect of product formulation on PC.- The protein content (PC) in the different formulations of the extruded snacks ranged from 7.94 - 15.44 % (Table 2). Formulation 4 exhibited the highest PC, whereas Formulation 3 recorded the lowest. The increase in PC was primarily influenced by the QBP content, followed by QF, as these components contribute the most protein.

Table 2: Physicochemical properties of extrudates

Formula	CG (%)	QF (%)	QBP (%)	PC (%)	ER	BD (g cm^{-3})	Hardness (N)
1	60	20	20	15.32	2.5	0.129	44.86
2	50	40	10	11.42	1.9	0.37	24.88
3	60	40	0	7.94	2.85	0.086	14.94
4	50	30	20	15.44	1	0.38	45.42
5	55	32.5	12.5	14.2	2.4	0.275	35.48
6	57.5	26.25	16.25	13.92	1.4	0.228	40.91
7	52.5	36.25	11.25	13.59	1.9	0.32	30.43
8	57.5	36.25	6.25	10.5	2.25	0.183	20.15
9	52.5	31.25	16.25	14.39	2.34	0.33	41.29

- The highest PC values were observed in formulations with the highest QBP content, as illustrated by the elevated region in the surface plot (Figure 1).
- The ER values ranged from 1.0 to 2.95 across all formulations and the response surface (Figure 2) visually illustrates this, showing that ER increases with higher CG content.

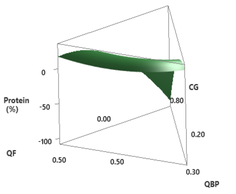


Figure 1. Response surface plot for protein content.

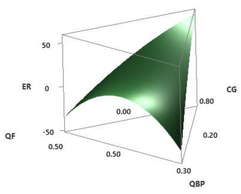


Figure 2. Response surface plot for expansion ratio.

- Figures 3 confirm the inverse relationship between CG concentration and BD, opposite to the trend observed for ER [4].
- As CG levels increase in the mixture, BD decreases. a higher proportion of QBP in the formulation increases the hardness of the extrudate, while a higher proportion of CG and QF decreases the hardness (Figure 4).

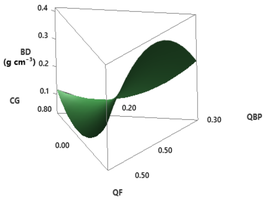


Figure 3. Response surface plot for bulk density..

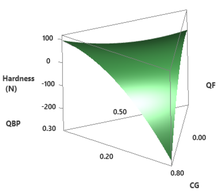


Figure 4. Response surface plot for hardness.

Table 3: Mixture obtained after simultaneous response optimization.

Composition			Parameter				
CG (%)	QF (%)	QBP (%)	PC (%)	ER	BD (g cm^{-3})	Hardness (N)	Composite desirability
57.2	34.3	8.5	10.83	3.04	0.193	22.31	0.746

CONCLUSIONES

- The optimal formulation, consisting of 57.2 % CG, 34.3 % QF, and 8.5 % QBP, resulted in a final product with a protein content of 10.83 %, an ER of 3.04, a BD of 0.193 g/cm3, and a hardness of 22.31 N.
- Given the promising role of QBP in enhancing protein content, further research should explore its detailed composition, particularly the presence of fermentable sugars and potential prebiotic compounds such as XOS, which could contribute to gut health benefits.