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Chickpea-based Vegan Bologna: Nutritional Quality, Antioxidant Activity, and Consumer Acceptance

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Abstract

Driven by increasing concerns regarding personal health, environmental sustainability, and animal welfare, plant-based nutrition is rapidly gaining global traction. Consequently, vegan meat analogues - particularly those replacing processed meat products - have become the focus of rigorous scientific investigation. This study describes the formulation and characterization of two chickpea-based vegan bologna analogues: a plain version (CBVB1) and a variant incorporated with beetroot powder as a natural colorant (CBVB2). The products were evaluated for total polyphenol content (Folin-Ciocalteu method), antioxidant potential (DPPH assay), proximate composition, and sensory attributes (5-point hedonic scale). Results indicated that both formulations contained substantial total polyphenols, with CBVB2 exhibiting the highest concentration. Both products demonstrated superior antioxidant capacity, maintaining significant DPPH radical scavenging activity even at high dilutions (1:100 and 1:1000), with the strongest antiradical performance observed in CBVB2. Proximate analysis revealed negligible nutritional and energetic differences between the two variants. Compared to conventional meat-based bologna, these chickpea analogues were cholesterol-free, lower in lipids and proteins, and reduced in caloric density, while being significantly enriched with dietary fiber. Sensory evaluation showed that the beetroot-enhanced variant was the most preferred by panelists. While the plain version received a "satisfactory" rating for color, all other organoleptic characteristics for both formulations were highly rated, suggesting that chickpea-based bologna is a viable and health-promoting meat alternative. .

Keywords: *plant-based meat analogues, chickpea-based pariser, beetroot powder fortification, antioxidant activity, nutritional profile.*

1. Introduction

In the context of growing concerns regarding health, sustainability, and ethics, plant-based diets are increasingly gaining ground. Consumers are seeking alternatives to animal products that offer not only nutritional benefits but also appealing sensory properties and a positive impact on health [1].

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While meat provides essential nutrients, high intake is often linked to health complications stemming from elevated levels of cholesterol and saturated fats [2, 3]. Conversely, plant-based diets have been identified as a cost-effective strategy for lowering the risk of hypertension, diabetes, cardiovascular disease, and overall mortality [4-6].

Meat analogues are successfully transitioning from niche markets into the mainstream. This rise in popularity is driven by a significant shift in consumer preference toward plant-based alternatives, which are increasingly perceived as superior options for both personal health and environmental sustainability [1]. Meat analogues - alternatively known as meat substitutes, mock meat, or faux meat - are plant-derived products engineered to replicate the aesthetic, flavor profile, and fibrous consistency of traditional meat [7, 8]. By utilizing diverse protein sources such as legumes, cereals, fungi, and microalgae, manufacturers can replace animal proteins to create a broad array of meat-free staples, including sausages, nuggets, and burger patties [9, 10]. Plant-based meat substitutes are increasingly recognized as healthier protein alternatives to animal products, offering nutritional benefits that support a reduction in overall meat consumption [11, 12]. These meat analogs provide essential amino acids while remaining cholesterol-free and low in saturated fats [1].

Chickpeas (*Cicer arietinum*), *Fabaceae* family, are highly nutritious and versatile legumes widely utilized in global cuisines. Originally native to the Middle East, they have become a staple ingredient across various cultures due to their exceptional nutritional value and culinary adaptability. Nutritionally, chickpeas serve as an excellent source of plant-based protein, making them vital for vegetarian and vegan diets. Furthermore, they are rich in dietary fiber, vitamins (notably B6 and folate), minerals such as iron, magnesium, and zinc, and antioxidants. The fiber content supports digestive health and blood sugar regulation, while the proteins are essential for the growth and repair of bodily tissues [13-15]. *Cicer arietinum* may be utilized in several forms, including fresh, dried, canned, or as flour. Prominent culinary applications include hummus (a puree of chickpeas, tahini, olive oil, lemon, and garlic) and falafel (fried patties consisting of spiced ground chickpeas). Furthermore, they are commonly incorporated into soups, stews, salads, and curries to enhance both consistency and nutritional density [16]. Chickpeas are widely recognized for their therapeutic potential, offering protective effects against chronic conditions such as cardiovascular disease, cancer, and type 2 diabetes [17]. Beyond disease prevention, they support cognitive function, weight regulation, and gastrointestinal health [18]. These multifaceted benefits have led to the extensive integration of chickpeas into cereal, bakery, and meat products to enhance their nutritional profile and physicochemical properties - specifically improving foaming, gelling, and emulsifying capacities [19]. Furthermore, chickpea proteins serve as effective microencapsulation matrices, stabilizing sensitive nutrients like folate and carotenoids [20, 21]. Practical applications in gluten-free noodles, muffins, and sausages demonstrate that chickpea flour not only lowers the glycemic index and starch digestibility but also optimizes texture and consumer acceptability [1]. Consequently, the chickpea is a versatile functional ingredient capable of significantly elevating the health-promoting qualities of diverse food systems [22].

The primary objective of this research was to develop and characterize two novel chickpea-based vegan bologna analogues: a control formulation (CBVB1) and a variant enriched with beetroot powder as a natural colorant (CBVB2). The study aimed to quantify their bioactive potential - specifically total polyphenol content (Folin-Ciocalteu) and antioxidant activity (DPPH) - as well as to evaluate their nutritional profile through proximate analysis. Furthermore, sensory attributes were assessed via a 5-point hedonic scale to determine consumer acceptability.

2. Materials and method

2.1. Chickpea-based vegan bologna analogues preparation

Raw materials sourced from the Romanian market were utilized to develop chickpea-based vegan bologna analogues, adhering to the formulations presented in Table 1.

All ingredients for CBVB1 and CBVB2 were weighed based on the predefined recipes. The chickpea flour was mixed with water and salt and boiled for 5–6 minutes until thickened. Spices (and beetroot powder for the CBVB2 variant) were then integrated into the hot mixture via vertical mixing until homogenized. Following the addition of oil, the composition was poured into pre-oiled cylindrical molds. Subsequent to cooling, the products were refrigerated at 4°C for a minimum of 3 hours before further analysis or packaging.

Table 1. Recipes for chickpea-based vegan bologna analogues

Bologna analogue assortment / Ingredient (%)	CBVB1	CBVB2
Chickpea flour	20	20
Water	67	66
Garlic powder	0.3	0.3
Black pepper	0.3	0.3
Dried thyme	0.3	0.3
Sweet paprika	0.3	0.3
Soy sauce	0.8	0.8
Olive oil	10	10
Salt	1	1
Beet root powder	-	1

The resulting chickpea-based vegan bologna analogues are presented in Figure 1.

CBVB1 CBVB2

Figure 1 – Chickpea-based vegan bologna analogues

2.2. Assessment of total polyphenol content, antiradical activity, proximate composition and sensory analysis

The total phenolic content (TPC) of both raw materials and finished products was quantified using the Folin-Ciocalteu reagent, while the antioxidant potential was evaluated via DPPH free-radical scavenging activity (RSA) according to the spectrophotometric method described by Dumbrava *et al.* (2022) [23]. Furthermore, a sensory characterization of the chickpea-based vegan bologna analogues was conducted employing a 5-point hedonic scale. Determinations proximate composition, and sensory attributes strictly adhered to the analytical protocols established by Dumbrava *et al.* (2020) [24].

2.3. Statistical and Correlation Analysis

Experimental data for TPC, RSA, and proximate composition were statistically processed using Microsoft Excel 2010. Results are expressed as the arithmetic mean ± standard deviation of at least three independent replicates. The relationship between TPC and RSA was evaluated by calculating both Pearson's correlation coefficient (r) to assess linear dependence and Spearman's rank correlation coefficient (ρ) to determine monotonic associations, thereby accounting for potential non-linear saturation kinetics at higher antioxidant concentrations [25, 26]. Computational analyses and statistical significance testing were executed in Python (v. 3.10).

3. Results and discussion

3.1. Total polyphenol content

The total phenolic content (TPC) of the raw materials and the formulated vegan analogues is summarized in Table 2.

Dried thyme exhibited the highest phenolic density, followed by black pepper with 645.11 ± 3.78 mg GAE/100g and garlic powder with 511.23 ± 4.05 mg GAE/100g. Additionally, ingredients used to enhance the sensory profile, such as beetroot powder.

Table 2. TPC of raw materials and finished products

Sample	Total polyphenols content (mg GAE/100g)
Chickpea flour	61.08 ± 1.02
Garlic powder	511.23 ± 4.05
Black pepper	645.11 ± 3.78
Dried thyme	1108.71 ± 9.56
Sweet paprika	218.72 ± 2.26
Soy sauce	141.15 ± 1.88
Olive oil	138.34 ± 1.29
Beetroot powder	338.64 ± 2.86
CBVB1	28.14 ± 0.44
CBVB2	30.47 ± 0.51

(338.64 ± 2.86 mg GAE/100g) and sweet paprika (218.72 ± 2.26 mg GAE/100g), demonstrated a significant antioxidant contribution, which may positively influence the oxidative stability of the final matrix. The results of the current study align well with literature values for both key bioactive ingredients. Specifically, the TPC for dried thyme falls within the 1950–4020 mg/100 g range documented by Karadeniz et al. (2026) [27], while the beetroot powder content is consistent with the 147 to 373 mg GAE/100 g DW reported by Bárta et al. (2021) [28] for various cultivars.

Regarding the liquid and fatty ingredients, soy sauce and olive oil displayed intermediate and very close phenolic concentrations, with values of 141.15 ± 1.88 mg GAE/100g and 138.34 ± 1.29 mg

GAE/100g, respectively.

Chickpea flour, despite constituting the main structural and protein matrix of the product, showed a modest phenolic content of 61.08 mg GAE/100g. The TPC levels obtained in this study were notably higher than those described by Gupta *et al.* (2017) [29], who documented values from 4.70 ± 0.10 to 35.40 ± 0.20 mg GAE/100 g in an evaluation of 40 chickpea genotypes.

The analysis of total polyphenol content (TPC) in the final products revealed values of 28.14 ± 0.44 mg GAE/100g for the control formulation CBVB1 and 30.47 ± 0.51 mg GAE/100g for the CBVB2 variant. The substantially lower polyphenol levels in the bologna analogues compared to the individual spices are primarily attributed to the matrix dilution effect, given that water (66–67%) and chickpea flour (20%) constitute the vast majority of the total mass, whereas high-TPC spices are incorporated at low levels (0.3% each).

Comparing the two formulations directly reflects the impact of the recipe modification, with sample CBVB2 showing an increase in polyphenol content of 8.28% relative to CBVB1. This difference is solely attributed to the replacement of 1% water with beetroot powder in the CBVB2 formulation, while all other ingredients remained identical. Given the high intrinsic phenolic content of beetroot powder (338.64 mg GAE/100g), its incorporation serves a dual purpose: enhancing the visual color properties of the bologna analogue and acting as an effective bioactive fortifier that increases the overall antioxidant density of the final plant-based product.

3.2. Radical scavenging activity

Table 3 provides the RSA results, which was experimentally measured for the elderberry jam samples following a 1:100 dilution.

RSA evaluated at a standardized 1:100 dilution for individual raw materials, revealed a broad spectrum of antioxidant potentials. Spices and dried plant powders exhibited exceptional RSA values, consistently exceeding the 80% threshold. The highest inhibition capacity was recorded for dried thyme (93.35 ± 0.44%), closely followed by black pepper (90.42 ± 0.40%), garlic powder (88.14 ± 0.38%), and beetroot powder (86.62 ± 0.33%).

This potent antiradical capability correlates directly with the high density of phenolic compounds present in these matrices. In contrast, sweet paprika displayed moderate activity (44.81 ± 0.24%), while the liquid ingredients - soy sauce (25.61 ± 0.22%) and olive oil (21.42 ± 0.16%) - demonstrated lower scavenging capacities at this dilution level.

Table 3. DPPH Radical Scavenging Activity (RSA)

Sample	Dilution	RSA (%)
Chickpea flour	1:100	15.11 ± 0.19
Garlic powder	1:100	88.14 ± 0.38
Black pepper	1:100	90.42 ± 0.40
Dried thyme	1:100	93.35 ± 0.44
Sweet paprika	1:100	44.81 ± 0.24
Soy sauce	1:100	25.61 ± 0.22
Olive oil	1:100	21.42 ± 0.16
Beetroot powder	1:100	86.62 ± 0.33
CBVB1	1:10	91.86 ± 0.48
	1:100	61,33 ± 0.24
	1:1000	28.14 ± 0.12
CBVB2	1:10	96.04 ± 0.50
	1:100	64.82 ± 0.29
	1:1000	30.16 ± 0.11

Chickpea flour, serving as the main structural base, exhibited the lowest RSA value (15.11 ± 0.19%), confirming that native legumes possess limited baseline antioxidant activity prior to fermentation or thermal processing.

Regarding the final formulated products (CBVB1 and CBVB2), assessing antioxidant capacity across serial dilutions (1:10, 1:100, and 1:1000) demonstrated a clear, statistically significant dose-dependent response. At the most concentrated level (1:10), both Bologna analogues exhibited near-complete radical inhibition, reaching 91.86 ± 0.48% for CBVB1 and 96.04 ± 0.50% for CBVB2. Even at a moderate 1:100 dilution, the products retained substantial antioxidant activity (61.33% and 64.82%, respectively), substantially surpassing the value of pure chickpea flour (15.11%). This underscores the strong bioactive fortification effect conferred by incorporating functional spices (thyme, pepper, garlic, beetroot). At the highest dilution (1:1000), scavenging activity declined proportionally to approximately 28–30%.

Comparing the two formulations highlights the enhanced antiradical capacity of the CBVB2 variant over the control CBVB1 across all tested dilution levels. This superior antioxidant performance is directly attributed to the formulation adjustment, specifically replacing 1% water with beetroot powder. Rich in TPC, the incorporation of beetroot powder serves a dual functional role: acting as a natural colorant for the plant-based Bologna analogue and operating as an effective antioxidant agent capable of enhancing matrix stability against oxidative degradation.

3.3. Correlation between TPC and RSA

To assess the correlation between Total Polyphenol Content (TPC) and Radical Scavenging Activity (RSA) (Figure 2), data corresponding to the standard 1:100 dilution (common across all 10 samples) was used.

At the 1:100 dilution, the data analysis reveals a statistically significant, moderate-to-strong positive correlation between TPC and RSA, characterized by a Pearson coefficient of r = 0.6978 (p = 0.0249), a by the linear regression equation RSA (%) = 0.0619 x TPC + 39.21. At the 1:100 dilution, the data analysis reveals a statistically significant, moderate-to-strong positive correlation between TPC and RSA, characterized by a Pearson coefficient of r = 0.6978 (p = 0.0249), a Spearman rank coefficient of ρ = 0.7091 (p = 0.0217), and a coefficient of determination R^2 = 0.4869, modeled by the linear regression equation RSA (%) = 0.0619 x TPC + 39.21. Notably, when evaluating the individual raw plant ingredients alone, this linear relationship becomes considerably stronger (r = 0.8154, p = 0.0136), whereas the formulated samples CBVB1 and CBVB2 act as interesting outliers; despite possessing lower TPC values (28.14$ and 30.47 mg GAE/100g), they maintain remarkably high antioxidant activities (61.33 % and 64.82 %), strongly suggesting the presence of non-phenolic antioxidant compounds or synergistic interactions among the combined components. ***Proximate composition and energy value of chickpea – based bologna analogues*** The proximate composition and energy content of the chickpea-based bologna analogues are detailed in Table 4.

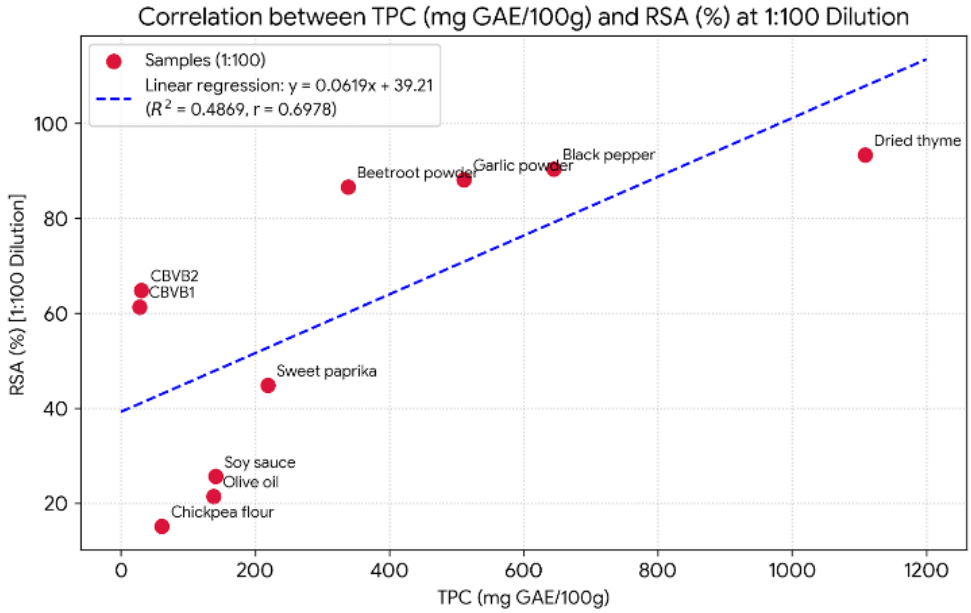

Figure 2 – Correlation between TPC and RSA

Table 4. Proximate composition and energy value of chickpea – based bologna analogues

Parameters	CBVB1	CBVB2
Moisture (g/100g)	61.33±1.85	60.80±1.80
Total fat (g/100g)	14.33±0.26	14.33±0.24
- Saturated fat	1.60±005	1.60±0.04
Total carbohydrates (g/100g)	14.27	14.80
- Sugars (g/100g)	3.27±0.08	3.67±0.12
- Dietary fiber (g/100g)	3.40±0.11	3.40±0.09
Protein (g/100g)	6.67±0.18	6.67±0.15
Energy value (kcal/100g)	212.73	214.85

The proximate composition and caloric value of the formulated chickpea-based bologna analogues (CBVB1 and CBVB2) revealed high nutritional consistency between the two variants. Moisture constituted the primary component, accounting for 61.33 ± 1.85 g/100g in CBVB1 and 60.80 ± 1.80 g/100g in CBVB2. These high moisture levels align with typical commercial emulsion-type bologna products, indicating that chickpea proteins and starches effectively retained water to mimic the juiciness and elastic matrix of conventional meat products [30].

Regarding the lipid profile, both formulated analogues contained 14.33 g/100g of total fat, with saturated fatty acids (SFA) accounting for only 1.60

g/100g. Furthermore, as plant-based formulations, both analogues are inherently cholesterol-free. In contrast, traditional commercial pork and beef bologna sausages typically exhibit significantly higher total fat contents (~23.0–25.0 g/100g), elevated levels of saturated fats (~7.00–9.30 g/100g), and substantial cholesterol concentrations (~60–83 mg/100g). Consequently, the chickpea-based analogues achieved a ~77–82% reduction in saturated fatty acids compared to conventional meat counterparts, aligning with nutritional guidelines aimed at reducing cardiovascular risk factors [31-33].

The protein content remained completely stable across both formulations at 6.67 g/100g, providing a viable plant-based amino acid source. Notably, unlike traditional meat products which naturally lack dietary fiber, both analogues provided 3.40 g/100g of dietary fiber. According to European Regulation (EC) No 1924/2006 on nutrition claims [34], achieving a fiber content above 3 g per 100 g officially qualifies these formulations for the nutritional claim "Source of fiber," adding functional value to the final product.

Total carbohydrates showed a minor variation between the two formulations, measuring 14.27 g/100g in CBVB1 and 14.80 g/100g in CBVB2. This slight increase was primarily driven by the sugar fraction, which rose from 3.27 ± 0.08 g/100g to 3.67 ± 0.12 g/100g, respectively. Consequently, the calculated energy value reflected this marginal difference in carbohydrate content, increasing slightly from 212.73 kcal/100g in CBVB1 to 214.85 kcal/100g in CBVB2. Overall, these findings demonstrate that minor recipe adjustments between CBVB1 and CBVB2 preserved the core structural and macronutrient matrix, maintaining a balanced and highly competitive nutritional profile compared to conventional processed meats.

3.4. Sensory analysis

The sensory profile of the chickpea-based bologna analogues (CBVB1 and CBVB2), as evaluated by a panel of 20 non-trained consumers using a hedonic scale ranging from 4.2 to 4.8, is depicted in Figure 3. Overall, both formulations received high acceptance scores across all sensory attributes, consistently scoring above 4.4 points. However, CBVB2 demonstrated superior sensory appreciation compared to CBVB1 in almost all evaluated parameters, indicating that the slight formulation adjustments in CBVB2 positively enhanced consumer perception.

Regarding visual characteristics, CBVB2 achieved noticeably higher scores for both appearance in section (4.65 vs. 4.40) and color (4.75 vs. 4.45). The improved color and cross-sectional uniformity of CBVB2 likely contributed to a more appealing physical resemblance to traditional emulsified meat products. In terms of olfactory features, both formulations achieved an identical score for odor (4.50), suggesting that the base aroma profile remained unchanged between samples.

Taste and flavor evaluations further underlined the preference for CBVB2. While both variants yielded close results for taste, with CBVB2 slightly leading (4.55 vs. 4.50), the distinction was more pronounced in flavor perception, where CBVB2 reached 4.60 compared to 4.50 for CBVB1. Interestingly, both formulations achieved an identical, highly favorable score for texture (4.70), demonstrating that both matrixes successfully maintained an elastic and smooth mouthfeel characteristic of commercial bologna sausages. Driven by its enhanced visual appeal and flavor profile, CBVB2 achieved a higher overall acceptability score (4.75) than CBVB1 (4.50), establishing CBVB2 as the most promising formulation for consumer market adoption

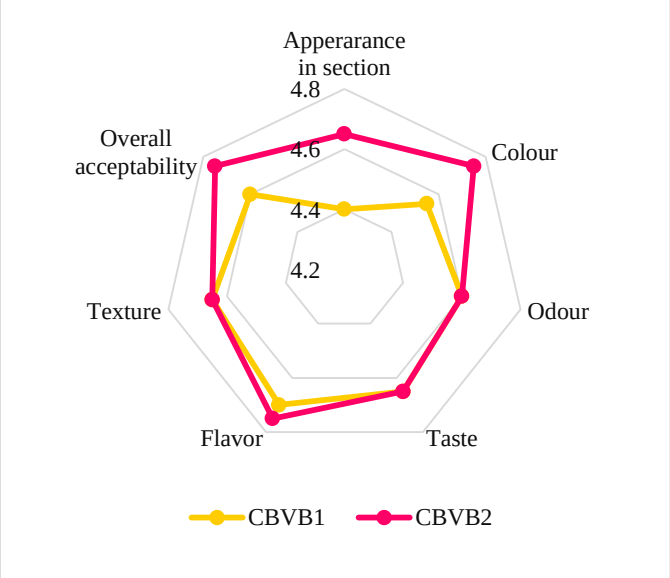

Figure 3. - The global values of the sensory evaluation of chickpea – based bologna analogues

4. Conclusion

This study successfully demonstrated the viability of developing chickpea-based vegan bologna analogues (CBVB1 and CBVB2) as functional, health-promoting alternatives to conventional meat products.

The integration of chickpea flour alongside selected herbs and spices established a robust structural and

bioactive matrix. Incorporation of 1% beetroot powder in the formulation (CBVB2) not only served as an effective natural colorant but also significantly enhanced the total polyphenol content by 8.28% compared to the control variant (CBVB1). Both formulations exhibited remarkable, dose-dependent radical scavenging capabilities (DPPH), maintaining high inhibition potential even under significant dilution levels, with CBVB2 consistently displaying superior antioxidant activity.

Nutritional characterization confirmed that both chickpea analogues possess a highly balanced proximate composition with low caloric density (~213–215 kcal/100g). Compared to traditional pork or beef bologna, these plant-based variants offer key health advantages: they are inherently cholesterol-free and feature a drastically reduced saturated fatty acid content (1.60 g/100g). Furthermore, with a dietary fiber content of 3.40 g/100g, both products officially fulfill the criteria for the European nutritional claim "Source of fiber".

Sensory evaluation revealed excellent consumer acceptability for both formulations, with scores consistently exceeding 4.4 out of 5. The beetroot-fortified variant (CBVB2) was particularly favored by the evaluation panel, achieving higher scores in visual appearance, color, flavor, and overall acceptability (4.75 vs. 4.50).

In conclusion, chickpea flour combined with beetroot powder provides a technically feasible and sensorially appealing foundation for producing clean-label, antioxidant-rich, and fiber-dense meat analogues. These findings support the broader adoption of chickpea-derived ingredients in the food industry to meet growing consumer demand for sustainable, plant-based nutrition

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