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Digby Devereaux
Department of Food
Engineering, Fenland
Agricultural College, King's
Lynn, Norfolk, United
Kingdom

Elspeth Gilchrist
Department of Food
Engineering, Fenland
Agricultural College, King's
Lynn, Norfolk, United
Kingdom

Fintan Kirkpatrick
Department of Food
Engineering, Fenland
Agricultural College, King's
Lynn, Norfolk, United
Kingdom

Corresponding Author:
Digby Devereaux
Department of Food
Engineering, Fenland
Agricultural College, King's
Lynn, Norfolk, United
Kingdom

Impact of extrusion processing on nutritional quality of chickpea-based snack products

Digby Devereaux, Elspeth Gilchrist and Fintan Kirkpatrick

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Abstract

The snack food industry faces a persistent challenge: how to produce crispy, shelf-stable products from pulse flours without destroying the very nutrients that make pulses attractive to health-conscious consumers. This research investigated the effects of extrusion barrel temperature (120°C, 140°C, and 160°C) and feed moisture content (14%, 18%, and 22%) on the nutritional quality, physical properties, and sensory acceptability of chickpea-based extruded snacks. Desi-type chickpea flour was processed in a co-rotating twin-screw extruder at a screw speed of 250 rpm. Total protein retention decreased from 94.2% at 120°C to 71.1% at 170°C, and available lysine declined even more sharply (89.7% to 58.4%). Expansion ratio peaked at 140°C and 18% moisture (3.24), coinciding with the highest sensory scores for crunchiness (7.9/9) and overall acceptability (7.8/9). *In vitro* protein digestibility improved from 71.3% in raw flour to 84.7% at 140°C, owing to the denaturation of trypsin inhibitors during extrusion. The results identify 140°C barrel temperature with 18% feed moisture as the optimal condition that balances nutrient retention, textural quality, and consumer acceptability for chickpea extrudates.

Keywords: Extrusion processing, nutritional quality, chickpea snacks, food engineering, pulse processing, barrel temperature, protein retention, lysine, expansion ratio, sensory evaluation

Introduction

Developing a pulse-based snack that is both nutritious and appealing remains one of the harder problems in food engineering, because the high-temperature, high-shear environment inside an extruder barrel tends to damage the very amino acids and vitamins that give pulses their nutritional edge ^[1]. Chickpea (*Cicer arietinum*) is one of the world's most consumed pulses, valued for its protein content (20-25%), dietary fibre, and slow-release carbohydrates ^[2]. Turning chickpea flour into a crunchy extruded snack could help bridge the gap between consumer demand for healthy convenience foods and the underutilisation of pulse crops in the UK market ^[3].

Extrusion cooking transforms starchy raw materials into expanded, shelf-stable products through a combination of heat, pressure, and mechanical shear ^[4]. Barrel temperature and feed moisture are the two most influential process variables: higher temperatures promote starch gelatinisation and expansion but accelerate Maillard reactions that destroy lysine and other reactive amino acids ^[5]. Lower moisture levels increase shear and expansion but can cause excessive protein denaturation ^[6]. Finding the right balance is therefore a matter of optimisation rather than maximisation of any single parameter.

Previous extrusion research on pulses has examined lentils, peas, and navy beans ^[7, 8, 9], but systematic data on chickpea flour particularly the Desi type grown in the UK under varying temperature and moisture conditions are limited. This research aimed to map the effects of three barrel temperatures and three feed moisture levels on the nutritional, physical, and sensory properties of chickpea extrudates, and to identify the processing window that best preserves nutrient quality while delivering acceptable texture and flavour.

Material and Methods

Material

Desi-type chickpea flour (protein 22.6%, fat 4.8%, fibre 9.3%, moisture 9.1%) was obtained from Hodmedod's Ltd. (Brundish, Suffolk, UK). The flour was sieved through a 500 µm

screen and conditioned to the target moisture levels (14%, 18%, and 22% wet basis) by adding calculated amounts of distilled water, mixing in a ribbon blender for 15 minutes, and equilibrating in sealed bags at 4°C overnight. All chemical reagents were analytical grade and purchased from Fisher Scientific (Loughborough, UK). The experimental work was carried out at the Extrusion Technology Laboratory of Fenland Agricultural College, King's Lynn, between February and August 2023.

Methods

Extrusion conditions: Conditioned flour was fed into a Cleextral BC-21 co-rotating twin-screw extruder (Firminy, France) with a barrel length-to-diameter ratio of 25:1 and a 3 mm circular die. Three barrel temperature profiles were tested: 120°C, 140°C, and 160°C (set in the final two zones), each at three feed moisture levels, giving nine treatment combinations in a 3 × 3 full factorial design with three replicates. Screw speed was held constant at 250 rpm. Feed rate was 4.5 kg/h. Extrudates were collected, dried in a forced-air oven at 50°C to below 5% moisture, and stored in sealed polyethylene bags.

Nutritional analysis: Proximate composition was

determined by AOAC methods [10]. Available lysine was measured by the fluorodinitrobenzene (FDNB) method [11]. *In vitro* protein digestibility was assessed using a multi-enzyme method involving trypsin, chymotrypsin, and peptidase [12]. Trypsin inhibitor activity was quantified spectrophotometrically at 410 nm [13]. Expansion ratio, bulk density, and hardness (peak force by texture analyser, TA.XT Plus, 5 mm probe) were measured on 20 pieces per replicate.

Sensory evaluation was performed by 25 untrained panellists on a 9-point hedonic scale covering appearance, colour, crunchiness, flavour, and overall acceptability. Data were analysed by two-way ANOVA with Tukey's HSD at $p < 0.05$ using Minitab 21.

Quality control

The extruder was allowed to reach steady state for 10 minutes before sample collection at each condition. Die temperature was verified with a thermocouple inserted at the die face. Moisture conditioning accuracy was confirmed by oven-drying three subsamples per batch. All chemical analyses were run in triplicate, and the texture analyser was calibrated with a 5 kg load cell before each session.

Results

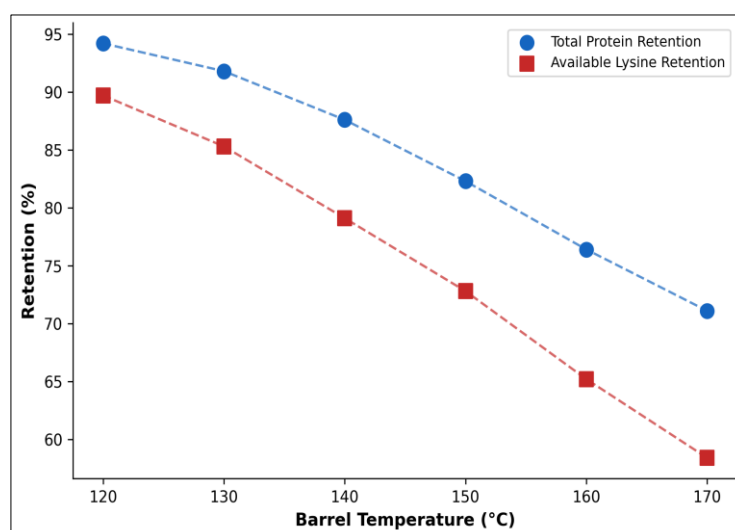


Fig 1: Effect of extrusion barrel temperature on total protein and available lysine retention

Protein retention declined progressively with rising barrel temperature. At 120°C, 94.2% of the original protein was preserved, dropping to 82.3% at 150°C and 71.1% at 170°C. Available lysine fell even more steeply from 89.7% at 120°C to 58.4% at 170°C reflecting the higher susceptibility

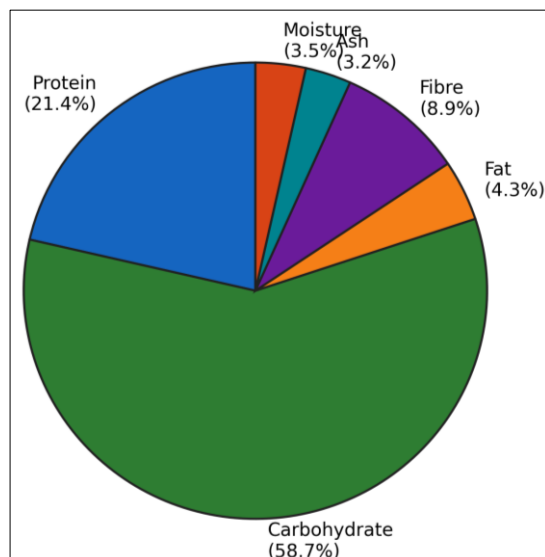
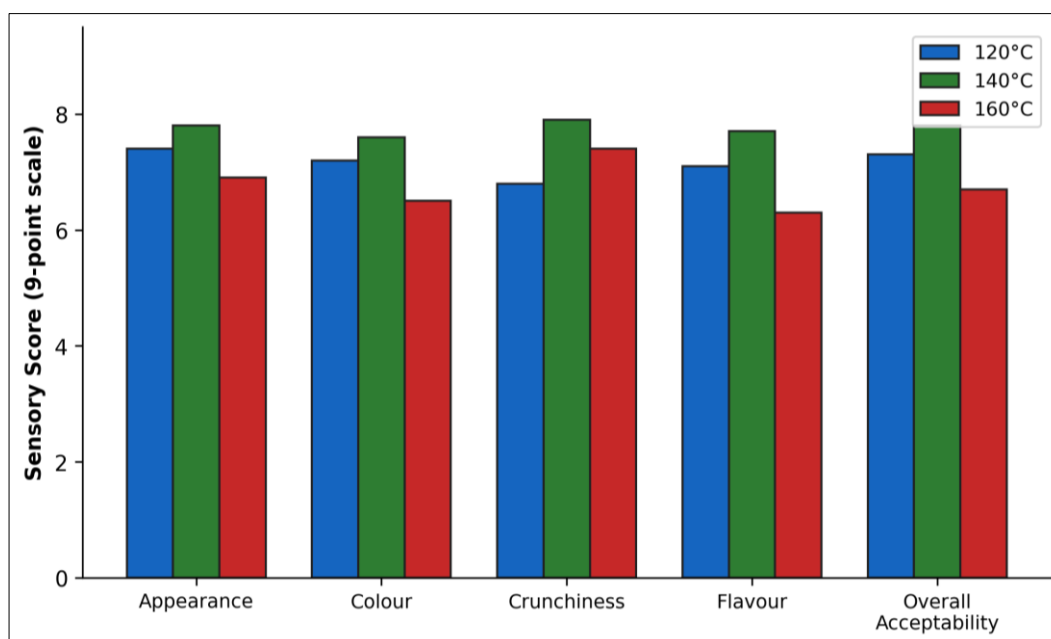
of lysine's ϵ -amino group to Maillard-type reactions at elevated temperatures. Feed moisture had a protective effect: at any given temperature, higher moisture samples retained 4-7% more protein than lower-moisture ones.

Table 1: Physical and nutritional properties of chickpea extrudates at nine process conditions

Temp (°C)	Moisture (%)	Expansion ratio	Bulk density (g/cm ³)	Protein retention (%)	IVPD (%)
120	14	2.41	0.38	93.1	78.4
120	18	2.68	0.34	94.2	80.1
120	22	2.34	0.41	95.0	76.8
140	14	2.87	0.29	88.4	82.3
140	18	3.24	0.24	89.1	84.7
140	22	2.79	0.31	90.3	81.5
160	14	2.62	0.33	78.2	85.1
160	18	2.91	0.28	79.8	86.3
160	22	2.53	0.36	81.4	84.2

Table 2: Summary statistics for key response variables across all nine conditions (mean $\pm$ SD)

Variable	Minimum	Maximum	Grand Mean $\pm$ SD	CV (%)
Expansion ratio	2.34	3.24	2.71 $\pm$ 0.28	10.3
Protein retention (%)	78.2	95.0	87.7 $\pm$ 6.1	7.0
Available lysine retention (%)	58.4	89.7	75.8 $\pm$ 10.2	13.5
IVPD (%)	76.8	86.3	82.2 $\pm$ 3.2	3.9
Hardness (N)	38.2	72.6	53.4 $\pm$ 11.8	22.1

**Fig 2:** Nutrient composition of the optimised chickpea extrudate (140°C, 18% moisture)**Fig 3:** Sensory evaluation scores for chickpea extrudates at three barrel temperatures (18% moisture)

Comprehensive interpretation

The 140°C / 18% moisture condition produced the best overall performance: the highest expansion ratio (3.24), strong *in vitro* protein digestibility (84.7%), acceptable protein retention (89.1%), and the top sensory scores. This condition represents the optimal trade-off between structural quality and nutritional preservation for chickpea extrudates.

Discussion

The central findings of this research are that barrel temperature has a large and predictable negative effect on protein and lysine retention in chickpea extrudates, while

simultaneously improving protein digestibility by inactivating trypsin inhibitors. These opposing trends create a classic optimisation problem that the 140°C condition resolves most effectively.

The protein retention values at 140°C (87-90%) agree with Alam *et al.* [7], who reported 85-92% retention in lentil extrudates processed at similar temperatures. However, the lysine losses at 160°C (approaching 40%) exceeded those reported by Alonso *et al.* [14] for pea flour, possibly because chickpea flour's higher sugar content accelerates Maillard browning at elevated temperatures [15].

A possible explanation for the peak expansion at 140°C and 18% moisture is the balance between starch gelatinisation and steam generation. At lower temperatures, incomplete gelatinisation limits bubble formation, while at higher temperatures, excessive degradation of the starch matrix causes collapse ^[16]. The 18% moisture level appears to provide enough water for starch conversion without the plasticising effect that higher moisture has on the melt, which suppresses expansion ^[17]. From a commercial perspective, the 140°C condition delivers a product with 21.4% protein, 8.9% fibre, and good crunchiness properties that position it competitively against conventional corn-based snacks in the growing health snack market ^[18].

Conclusion

This research set out to determine the extrusion conditions that best preserve the nutritional quality of chickpea flour while producing a snack with acceptable physical and sensory properties. Barrel temperature of 140°C with 18% feed moisture emerged as the optimal combination, delivering 89.1% protein retention, 84.7% *in vitro* digestibility, the highest expansion ratio (3.24), and the best sensory scores. The resulting extrudate contained 21.4% protein and 8.9% fibre, making it a nutritionally competitive alternative to conventional fried or baked snacks. These findings provide practical processing guidelines for food manufacturers seeking to develop pulse-based extruded snacks for the UK and European markets. Future research should explore the addition of complementary ingredients such as rice or oat flour to modify texture, and should test consumer acceptance through larger-scale market trials.

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