

Optimization of Protein Content of Pretreated Green Pea (*Pisum sativum L.*)

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ABSTRACT

The demand for new sources of food protein has increased the global consumption of protein, especially plant protein. Green pea (*Pisum sativum L.*) is one of such plant sources that has been underutilized. It is a leguminous crop rich in nutritive contents that are beneficial to human diet and health. Post-harvest losses occur due to inadequate information on preservation and storage techniques. This study determined the effects of pre-treatments on protein content of green pea (*Pisum sativum L.*) using response surface methodology in Box-Behnken Design. Green peas were blanched in water at 55, 65, and 75 °C for 3, 6, 9, 12, and 15 min. The blanched peas were dried to constant weights using solar and direct sun dryers. The dried samples were stored for 30, 60, and 90 days and their protein contents determined. The independent variables were blanching temperature, blanching time and storage period while the dependent variable was protein content. Generated data were analyzed and optimized using Design-Expert software version 13. For solar cabinet-dried samples, the optimum protein content of 17% was obtained at optimized water temperature, blanching time, and storage period of 73.6 °C, 11.6 min, and 90 days, respectively. And for direct sun-dried samples, the optimum protein content of 21.7% was realized at 73.7 °C, 15 min, and 90 days. The protein content yield for control samples for solar and sun-dried cases were 10.26% and 14%, respectively. Farmers and processors of green peas can apply the findings of this study in processing and storing their product for up to 3 months with assurance of enhanced protein content. The findings have the potential to reduce postharvest losses of green peas. Energy use is also reduced since sun radiation is free and only the blanching water needs to be heated to appropriate temperatures.

KEYWORDS: Optimization, storage period, blanching temperature, blanching time, protein content, green pea

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I. INTRODUCTION

Global population is expected to reach approximately 9.6 billion by 2050 (FAO, 2017), requiring a 50% increase in global food production. To ensure food security, it is crucial to explore new food alternatives, leading to a growing interest in plant-based protein sources. Animal-based proteins are often expensive and less accessible, and their excessive consumption has been linked to health concerns and environmental degradation (Ahnen *et al.*, 2019; Willett *et al.*, 2019; Detzel *et al.*, 2021). In contrast, plant-based proteins, which are typically more affordable and readily available, offer a promising solution to address this rising demand (Sanchez-Sabate and Sabate, 2019).

Green pea is one of such plant sources that are underutilized. Green pea is an important food resource that contributes to the nutritional wellbeing of humans and it is consumed in various diets. It is an excellent source of nutrients and contains appreciable proportion of digestible protein (23-25%) which is comparable to other legumes such as velvet beans (23-35%), lima bean (20.69-23.08%), horse gram (18.5-28.5%) and soyabean (37-42%) (O'Keefe *et al.* 2015; Prasad & Singh, 2015; Yellavila *et al.* 2015; Saxena and Saxena, 2017; Madhuri and Tayade, 2019). Green pea is also a source of micronutrients and phytochemicals and has very low anti-

nutritional factor (Wang *et al.*, 2008, Nguyen *et al.*, 2015). Its nutritional properties have been linked to the reduction of various cancers, LDL cholesterol; type -2 diabetics and heart diseases (Roy *et al.*, 2010; Cryne *et al.*, 2012; Ladjal and Chibane, 2015, Song *et al.*, 2016). Green peas can be boiled and eaten as vegetable, dried or prepared as soup and salad; they are also marketed fresh, canned or frozen for future use (Sharma *et al.*, 2015) and can also be used for biscuits (Garg, 2015).

Green peas are valued for their nutritional benefits, being rich in protein, complex carbohydrates, vitamins, minerals, dietary fibre, and antioxidants. But their high moisture content (75-80%) makes them highly perishable due to enzymatic and microbial activities leading to post-harvest losses especially in the tropics where high temperatures accelerate the activities of spoilage agents and necessitating use of effective post-harvest preservative methods to extend their shelf-life while maintaining quality (Elamin, 2024; Saxena and Saxena, 2017; Madhuri and Tayade, 2019). Effective preservative pretreatment methods include blanching, drying, and proper storage. However, the important parameters of these methods must be optimized to balance enzyme inactivation, moisture removal, microbial load reduction with nutrient retention (Elamin, 2024). The qualities

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of blanched and dried products depend significantly on the time–temperature combinations and the type of product (Abu-Ghannan and Jaiswal, 2015).

Blanching methods include: hot water blanching, steam blanching, and microwave blanching. Hot water blanching is the most traditional method; steam blanching minimizes water–product contact; while microwave blanching offers rapid and uniform heating. Blanching and drying methods should be chosen based on cost, infrastructure availability, and the intended use of the product (Elamin, 2024).

Drying is the oldest post-harvest processing operation used to extend the storage life, improve quality, and reduce losses and transportation cost of agricultural crops (Srivastava and Sharma, 2022). By lowering moisture content, drying inhibits enzymatic activity, microbial growth, and chemical reactions that help cause spoilage (Priyadarshini *et al.*, 2013; Shete *et al.*, 2015; Pandey *et al.*, 2016; Madhuri and Tayade, 2019). For green peas, a moisture content of 10 % or less is ideal for inhibiting microbial growth and enzymatic activity (Elamin, 2024), but 15-16% is also good for storage (Ganjloo *et al.*, 2018). Drying methods include: hot air oven drying, hot air vacuum drying, freeze-drying, microwave drying, direct sun drying, and solar cabinet drying; fluidized bed drying (Veerakumar *et al.*, 2014; Prakash *et al.*, 2019). Despite the functional advantages of microwave and freeze-drying methods over others, they are not economically viable for poor local farmers (Elamin, 2024). Capacity and cost-wise, direct sun-drying, solar cabinet drying and hot air drying are preferred by local farmers in that order (Kalogirou, 2009). By selecting appropriate drying methods and adopting proper pretreatment and storage practices, the shelf life of horticultural crops can be significantly extended (Elamin, 2024). The efficiency of drying is enhanced when preceded by blanching. The synergistic effects of blanching and drying include: shelf-life extension, improved texture, colour, and flavor of dried products (Elamin, 2024).

Proper storage conditions are intended to keep produce for longer period without affecting the quality and quantity. Several storage methods have been employed for prolonging green pea such as cold room storage, canning, freezing (Rahul *et al.*, 2016; Jayaranjan *et al.*, 2016; Preetinder *et al.*, 2021). However, several of these methods are expensive to maintain and do not promise enhancement and prolongation of green pea protein.

Several types of legumes and processing methods have been studied to investigate potential improvement of their nutritional value and protein content (Pandey *et al.*, 2016; Doymaz and Kucuk, 2017; Kapadiya *et al.*, 2018). Malting of green gram and raji was found to have increased their protein content from 22.74 to 25.17% and 1.2 to 1.47%, respectively (Shingote *et al.*, 2021). Soaking, germination, and boiling pretreatments had a positive effect on protein content of field bean; values for raw, soaked, germinated, and boiled flours were 21.45%, 24.79%, 26.36%, and 21.45%, respectively (Narale *et al.*, 2022). Deshmukh and Pawar (2020) reported that soaking pretreatment decreased the protein content of moth bean from 21.3% to 21.09%, while its germination pretreatment caused an increase from 21.3% to 23.82%.

Roasting pretreatment increased the nutritional composition of wheat, maize, groundnut, and mung bean (Kavitha and Parimalavalli, 2014). The crude proteins of blanched carrots, onions, garlic, cabbage and some pulses was found to be slightly higher than that of raw samples (Mutiara, *et al.*, 2013). Protein content of African yam bean (AYB) slightly increased by soaking (Aminigo and Metzger, 2005).

A study of blanched and control samples of green peas dried at 50, 60, and 70 °C showed that blanching pretreatment enhanced the drying rate; and the drying temperature affected the quality of green peas (Manzoor *et al.*, 2019). A more recent, related research (Afolabi, 2023) on the effect of water, steam, and microwave blanching techniques followed by hot air oven drying highlighted the efficacy of the pretreatments and recommended that the processes should be optimized exploring the effect of varying blanching times, temperatures, and drying methods.

The demand for plant protein, eco-friendly environment, reduction of greenhouse gases, the need for proper handling processing methods that will enhance green pea protein for food and pharmaceutical industries as well as farmers and consumers friendly; cost-effective and user-friendly method for optimizing green pea processing, yield and reduction in postharvest losses, justifies the need for this study. Furthermore, reviewed literature revealed not much information on the effect of blanching temperature, blanching time, drying methods and storage period on protein content of green pea has been reported. Considerably, when numerous variables and interactions impact the intended response, response surface methodology (RSM) can be employed because it yields significant data faster and with fewer experiments (Devika *et al.* 2014). Furthermore, detailed experimental designs like Box–Behnken Designer (BBD), are used to achieve optimal processing conditions (Lv *et al.*, 2011, Rojas *et al.*, 2022, Santos-Silva *et al.*, 2024, Badjona *et al.*, 2024). And to the author's knowledge, no study has been done on the optimization of pretreatment processes for enhanced protein content of stored green peas.

Therefore, the objectives of the work were to (1) determine the crude protein content (CPC) of green peas used in this study, (2) find the effect of hot water blanching temperature (BT), blanching time (Bt) storage period (SP), and drying method (DM) on the protein content of stored green peas, (3) optimize hot water BT, Bt, and SP for enhanced protein content of solar-dried, stored green peas, (4) optimize hot water BT, Bt, and SP for enhanced protein content of sun-dried, stored green peas, (5) develop experimental model equations for predicting protein content of pretreated green peas as a function of hot water blanching temperature, blanching time, and storage duration for sun-dried and solar-dried samples.

II. MATERIALS AND METHODS

Several pretreatment methods are expensive to maintain and do not promise enhancement and prolongation of green pea protein. Therefore, the blanching and drying methods used in this study were selected because of their low

energy requirements, availability, accessibility, capacity for commercial application, ease of operation, and affordability considering the economic and educational status of majority of our green pea farmers and sellers.

A. Materials and Equipment

The following materials and equipment were used: Freshly harvested green peas (40 kg) was bought from local farmers in Plateau State, and taken to the postharvest laboratory in the Department of Agricultural and Bio-environmental Engineering of Federal Polytechnic Bauchi, Nigeria. The green peas were refrigerated at 18 °C for 24 hours to reduce inter cellular molecular energy, stop metabolic processes and reduce respiration (Arah *et al.*, 2016; Hoffmann *et al.*, 2021; Tan *et al.*, 2023). They were then de-podded by hand to avoid post-harvest injury. They were sorted for uniformity in size, color and texture.

Other items were: water for blanching and cooling, towel for drying the surface bod of blanched peas, sieve for separating blanched peas from water after blanching, trays for drying process, boiler: 3-litre stainless-steel pot for boiling water, blanching containers: 3-litre Thermos flask, laboratory thermometer, a stop watch, and a solar cabinet dryer for drying blanched peas to constant weight (Fig.1)



Figure 1: Solar cabinet dryer

(A cabinet solar dryer of 27kg capacity drying chamber with 4 layers 30 × 30cm sliding rack made of food grade aluminum mesh net. The drying chamber is a 40 × 40 × 30cm box made of food grade aluminum sheets. The body is covered with glass of 4mm thick. The flour is covered with black body. A digital thermometer is affixed at the middle of the door. The solar energy collection chamber is a 60 × 40 × 10cm unit with a black body for the collection of heat energy and air vent of 7cm opening that takes off excess moisture from the product).

B. Experimental Design

The experiment is a factorial design with 3 blanching temperature levels (55, 65 and 75 °C), 5 blanching time (3, 6, 9, 12, 15 minutes) (Pandey *et al.*, 2016; Prakash *et al.*, 2019) and 3 months storage period (30, 60, 90 days). The pretreatment constraints (selected based on previous studies) are shown in Table 1. A 3-level, 3-factor Box-Behnken Design (BBD) for response surface

methodology (RSM) used is shown in Table 2.

Table 1: Constraint for Treatment Conditions

Treatment	Coded	Units	Factor levels		
			-1	0	+1
Blanching Temperature	BT	Degree Celsius (°C)	55	65	75
Blanching Time	Bt	Minutes (min)	3	9	15
Storage Period	SP	Days	30	60	90

C. Experimental Procedure

The green peas after cleaning were divided into 42 portions (34 samples from Table 1 (17x 2 replicates each) plus 6 un-blanching samples x 2 replicates; and 2 fresh samples) each weighing 500 g. Every Run was replicated twice. Sample 1 was blanched in 55 °C hot water for 3 min (Blanching was done using a 3-liter capacity Thermos flask to ensure constant temperatures for each blanching time); sun-dried to constant weight and stored for 30, 60 and 90 days in a room before determination of its CPC (Table 1).

Samples 2 – 17 were also treated accordingly. After blanching, the peas were sieved, immediately transferred into water at room temperature of 30 °C, and then towel-dried to stop effect of heat and reduce excess water absorption (Madhuri and Tayade, 2019; Tavares *et al.*, 2022). The blanched samples were placed on an elevated platform as shown in Fig. 2 and dried using direct sun under a temperature range of 27 °C to 40 °C from 9:00 am to 5:00 pm; drying to constant weight was achieved after two days of cumulative 21 hours. Other samples were dried using

Table 2: Three-level, 3-factor BBD

Runs	Independent variables		
	BT (°C)	Bt (min)	SP (days)
1	55	3	60
2	75	3	60
3	55	15	60
4	75	15	60
5	55	9	30
6	75	9	30
7	55	9	90
8	75	9	90
9	65	3	30
10	65	15	30
11	65	3	90
12	65	15	90
13	65	9	60
14	65	9	60
15	65	9	60
16	65	9	60
17	65	9	60

Where BT = blanching temperature; Bt = blanching time;

a solar cabinet dryer as shown in Fig. 3, with removable trays at inside temperature range of 29 °C to 65 °C from 9:00 am to 5:00 pm. Initial average moisture content before drying was 78.22% wb and average final moisture content after drying was 15.98% wb for all samples (Ganjloo *et al.*, 2018). Six un-blanching samples were sun-dried and 2 samples each were stored for 30, 60, and 90 days before CPC determination. The samples were stored on elevated wooden shelves in a room with average temperature of 33.5 °C, relative humidity of 50% (Rahmawati and Muhammad, 2020), and in 250 g-45µm thick low-density polyethylene (LDPE) bags (Fig. 4) (Shinde *et al.*, 2019). Two fresh un-blanching, undried, not-stored samples were subjected to CPC and moisture content determinations.



Figure 2: Direct sun drying



Figure 3: Solar cabinet drying



A. Packaged sun-dried green peas



B. Packaged solar-dried green peas

Figure 4: Packaged and stored treated green pea; (A) direct sun-dried samples, (B) solar dried samples

D. Determination of Crude Protein Content (CPC) of Green Peas

The CPC of the stored peas was determined using the Kjeldahl method with a conversion factor of 6.25 for legumes (AOAC, 2005; Banerjee *et al.*, 2022; Chinju *et al.*, 2022) and according to the method described by Hannington *et al.* (2020).

E. Statistical Analysis

The CPC data generated using Table 1 (sun-dried and solar-dried) shown in Tables 3 and 4 were analyzed using Design-Expert Version 13 software. In

this study, a prediction model for CPC as created using least squares method and established based on analysis of variance (ANOVA). ANOVA was used to analyze the regression model and identify the interactions between variables. The desirability function was used to determine the optimal levels of each independent variable for maximum CPC. Goodness of fit of prediction models were based on coefficient of determination (R^2), adjusted R^2 , predicted R^2 and coefficient of variation (CV).

F. Model Validation

Validation tests were carried out using independent data collected at BT of 55, 65, and 75 °C for 6 and 12 min and for 30-, 60- and 90-days storage period which were not used in the BBD levels for developing the models.

III. RESULTS AND DISCUSSION

A. CPC of Green Pea for Solar-dried and Sun-dried samples, controls, and fresh

Results of 17 experimental runs showing the treatment combinations and their effect on the CPC using BBD

is presented in Tables 3 and 4 for solar cabinet dryer and direct sun dryer, respectively. Table 5 shows the results of the control samples. Table 3 and 4 show that the average CPC of blanched, solar-dried, and stored green peas was 14.36%, while that of blanched, sun-dried, and stored green peas was 19.66%. Table 5 indicates the average CPC of un-blanched, solar-dried, and stored green peas was 12.34%, while that of un-blanched, sun-dried, and stored green peas was 15.27%. Similarly, that of fresh untreated green peas was 23%. Generally, pretreated green peas yielded higher protein than untreated samples (19.66% >15.27%; 14.36% > 12.34%)

Table 3: Test results of RSM (for solar-dried samples) based on Box-Behnken design

Run	Independent variables			Response variables	
	A: Blanching temperature (°C)	B: Blanching time (Mins)	C: Storage period (days)	Protein yield Actual value (%)	Predicted value (%)
1	55	15	60	13.90	14.13
2	75	3	60	16.52	16.44
3	55	3	60	11.14	11.82
4	65	9	60	15.71	15.29
5	65	3	30	15.00	14.90
6	65	15	30	16.85	17.22
7	65	9	60	15.71	15.29
8	65	9	60	15.71	15.29
9	55	9	30	14.01	13.75
10	65	9	60	15.71	15.29
11	65	3	90	13.52	13.36
12	65	9	60	15.71	15.29
13	75	15	60	19.61	18.76
14	75	9	90	16.25	16.83
15	55	9	90	12.14	12.20
16	65	15	90	15.08	15.67
17	75	9	30	17.32	18.38
				14.36%	

B. Effect of BT, Bt, SP, and DM on CPC of Green Peas

Figures 5 and 6 are 3-D response surface graphs of the effect of BT and Bt on CPC of solar and direct sun-dried and stored green peas. These figures show that protein content increased with increasing blanching temperature (BT) and blanching time (Bt). Similar results were reported by Hadidi *et al.* (2020) and Chinju *et al.* (2022). This could be attributed to higher driving force for protein mass transfer which facilitates protein movement from cells (Bedin *et al.*, 2020). Or as a result of increased breakdown of

hydrogen bonds and increasing surface charge of protein molecules which led to enhanced protein content (Sari *et al.*, 2015), or as a result of increase in biomass of the internal cells which invariably acted as a defence mechanism. Santos-Silva *et al.* (2024) also reported that increase in time from 20 to 40 min and temperature from 30 to 50 °C increased the protein content of Aparagus leafy by-products. This is similar to the reports of Garg *et al.* (2020), Ghosal *et al.* (2022), and Santos-Silva *et al.* (2024) for protein optimization from *prosopis cineraria* seeds and heat effect on protein.

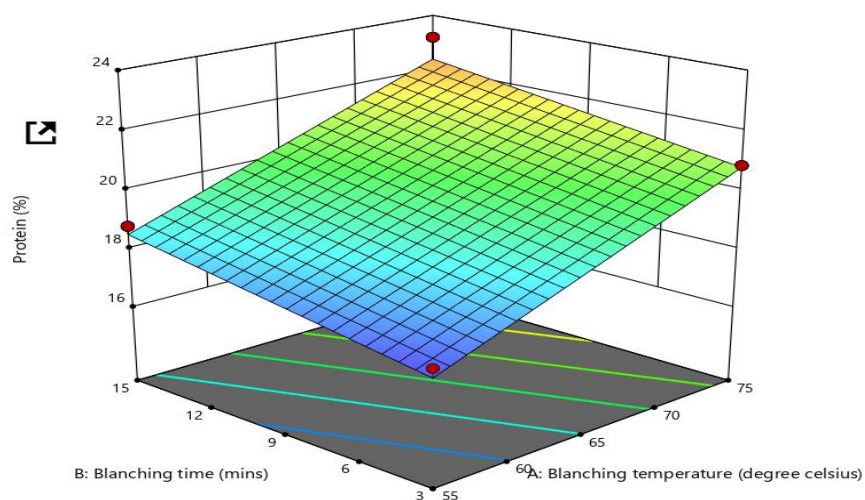


Figure 5: 3D-Response surface plots of blanching temperature, blanching time and Protein solar dried

Table 4: Test results of RSM (for direct sun dried) based Box-Behnken design

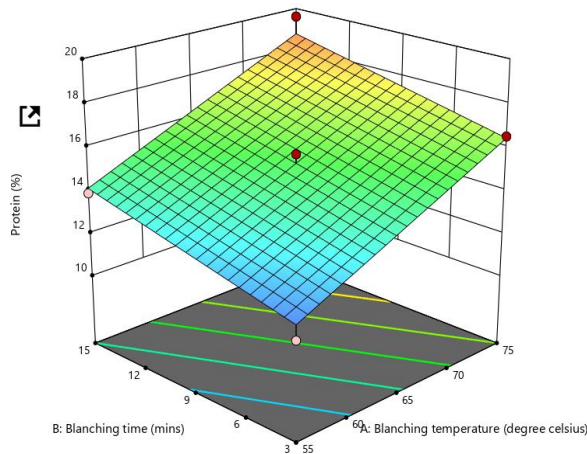
Run	A:Blanching temperature (°C)	B:Blanching time (Mins)	C:Storage period (Days)	Protein yield Actual value (%)	Predicted value (%)
1	75	9	30	21.97	22.02
2	65	9	60	19.59	19.66
3	75	9	90	20.64	21.19
4	75	3	60	20.86	20.80
5	75	15	60	23.21	22.41
6	65	9	60	19.59	19.66
7	65	9	60	19.59	19.66
8	65	15	30	20.51	20.88
9	65	9	60	19.59	19.66
10	65	9	60	19.59	19.66
11	55	9	30	18.09	18.12
12	65	15	90	19.97	20.05
13	65	3	30	19.17	19.27
14	65	3	90	18.80	18.43
15	55	15	60	18.80	18.52
16	55	3	60	17.20	16.90
17	55	9	90	17.00	17.29
				19.66%	

Table 5: Percentage Crude Protein Content for Control Samples

Storage Period (days)	Solar cabinet-dried	Direct sun-dried
30	14.43	16.80
60	12.28	15.01
90	10.26	14.00
	Average 12.34%	Average 15.17
Fresh green peas	23%	

Figure 6: 3D-Response surfaces of Blanching temperature, Blanching time and Protein under sun drying.

Statistical analysis of variance (ANOVA) test results are shown in Tables 6 and 7. P-values less than 0.05 for protein content yield shows fitted models are significant. The F-values and p-values of lack-of-fit models showed that it was not significant relative to the pure error thereby indicating the suitability of the model for optimization (Sahu *et al.*, 2020; Badjona *et al.*, 2024). From the Tables the model terms: blanching temperature, time and storage period have significant effect on CPC green peas. The R² is 0.9332, while the predicted R² is 0.8740 and is in reasonable agreement with the adjusted R² of 0.9178; that is, the difference is less than 0.2. According to Zaibunnisa *et al.* (2009) and Danbaba *et al.* (2015), the more closely the R² value approaches unity, the more closely the empirical model fits the actual data. When adjusted R² is above 90%, it is most appropriate and very helpful to evaluate model adequacy according to Koocheki *et al.* (2009). Coefficient of variation (CV) which has to be less than 10% (Ali *et al.*, 2017) was used to evaluate



the model accuracy. The value for CV of the fitting model was 3.71% as seen in Table 6, which guarantees the accuracy of the experimental data. The experimental model (equation (2)) for percentage protein content of blanched green peas dried using solar drier is linear, invariably depicting that increase in the independent variables lead to increase in the response variable (protein). Similar results were reported by Nwakalor (2020) and Santos-Silva *et al.* (2024) for linear increase in protein content with increase in moisture content of extruded snacks of yam bean blends and optimization of asparagus leafy protein.

Similarly for direct sun-dried peas (Table 7), the Model F-value of 106.15, R² of 0.9608, predicted R² of 0.9185, adjusted R² of 0.9517, CV of 1.73% indicate model adequacy (Zaibunnisa *et al.*, 2009; Koocheki *et al.*, 2009; Badjona *et al.*, 2024). The experimental model (equation (3)) for CPC of green pea dried using direct sun radiation in percentage is also linear, invariably showing that increase in BT and Bt lead to increase in protein content. The equation showed no interaction effect between the variables, rather increase in blanching temperature (BT) and blanching time (Bt) increased the protein percentage while protein reduced with increased in SP similar to the report of Ghosal *et al.* (2022) and Santos-Silva *et al.* (2024) which can be attributed to increased internal biomass and denaturation of protein as a result of long storage period.

$$Protein (\%) = 0.0595 + 0.2314 * BT + 0.1929 * Bt - 0.0258 * SP \dots\dots\dots (2)$$

$$Protein (\%) = 6.612 + 0.195 * BT + 0.135 * Bt - 0.014 * SP \dots\dots\dots (3)$$

Table 6: ANOVA for Crude Protein (solar dried)

Source	Sum of Squares	Df	Mean Square	F-value	p-value
Model	58.34	3	19.45	60.56	< 0.0001*
A-Blanching temperature	42.83	1	42.83	133.37	< 0.0001*
B-Blanching time	10.72	1	10.72	33.38	< 0.0001*
C-Storage period	4.79	1	4.79	14.92	0.0020
Residual	4.17	13	0.3211		
Lack of Fit	4.17	9	0.4638		
Pure Error	0.0000	4	0.0000		
Cor Total	62.51	16			
R ²	0.9332				
Adj R ²	0.9178				
C.V	3.71				

Significant at p < 0.05

Table 7: ANOVA for Green Pea Protein (direct sun-dried)

Source	Sum of Squares	Df	Mean Square	F-value	p-value
Model	36.98	3	12.33	106.15	< 0.0001
A-Blanching temperature	30.38	1	30.38	261.60	< 0.0001
B-Blanching time	5.22	1	5.22	44.92	< 0.0001
C-Storage period (direct sun)	1.39	1	1.39	11.94	0.0043
Residual	1.51	13	0.1161		
Lack of Fit	1.51	9	0.1678		
Pure Error	0.0000	4	0.0000		
Cor Total	38.49	16			
R ²	0.9608				
Adj R ²	0.9517				
C.V.	1.73				

C. Numerical and Comparative Optimization of CPC of Solar and Sun-Dried Green Peas

The goals that were set for each response are presented in Table 8. The independent variables were all set in range while the predicted response values were set to maximize (Ares, 2014; Badjona *et al.*, 2024) for optimum protein content of green pea processing using solar and direct sun drying. Numerical optimization finds a point that maximizes the desirability function (Jarpa-Parra *et al.*, 2014; Lasisi, 2021). Anuar *et al.* (2013) reported that when a goal is set the response target is to meet the objectives of getting response at the maximum set level as is applicable in this research and can be seen from Table 8, showing the optimal values for factors and responses under the two drying methods at desirability factor of 0.728 which is within range of 0.6 to 0.8 as suggested by Jarpa-Parra *et al.* (2014) and Lasisi (2021).

D. Model Validation Result

Table A (see appendix) shows that the differences between the predicted values and the actual CPC values were not significant (average difference of 0.26 – 0.28).

The results of comparative numerical optimization of protein composition of green peas dried using solar cabinet dryer and direct sun radiation are shown in Table 9. The result shows that the optimum BT, Bt and SP for optimum protein content yield with solar dryer are 73.6 °C, 11.6 mins and 90 days, respectively; while for direct sun-drying the best treatment combination are BT of 73.7 °C, Bt of 15 mins and SP of 90 days. Direct sun-dried pre-treated green peas gave the highest protein content of 21.7% as compared with the solar-dried sample which was 17%. Furthermore, when compared with the control samples, the sample for solar-dried gave average percentage protein content of 12.34%; while that of direct sun drying gave 15.17% (Table 5). The increase in the protein percentage of the direct sun-dried samples could be as a result of the low drying temperature (27 to 40 °C) and for a longer period of two days than the solar dryer (29 to 65 °C) for one day drying period. This could have resulted in the denaturation of protein leading to reduced protein content in the solar-dried samples (Hannington *et al.*, 2020; Ghosal *et al.*, 2022).

Table 8: Goals Used for Numerical Optimization of Green Pea Protein Content

Name	Goal	Lower Limit	Upper Limit
A:Blanching temperature	is in range	55	75
B:Blanching time	is in range	3	15
C:Storage period	is in range	30	90
Protein (solar dried)	maximize	11.14	19.61
Protein (direct sun dried)	maximize	17	23.21

Table 9: Comparative Numerical Optimization of Green Pea Protein Content

Name	Solar-Dried	Direct Sun Dried
A:Blanching temperature (°C)	73.6	73.6
B:Blanching time (min)	11.6	11.6
C:Storage period (days)	90	90
Protein (%)	17	17

IV. CONCLUSIONS AND RECOMMENDATION

This research investigated protein content of pretreated, untreated, and fresh green peas using Box-Behnken Design (BBD) of experiments for response surface methodology (RSM) to optimize protein content. This study shows that hot water blanching temperature, blanching time, storage period and drying methods affect the protein content of green peas. The optimal protein content (17%) for solar-dried green peas was realized at optimized blanching temperature of 73.6 °C, blanching time of 11.6 min and 90 days storage period; while, for direct sun-dried green peas, optimal protein content (21.7%) was obtained at 73.7 °C blanching temperature, 15 min blanching time, and 90 days storage period. The control samples were found to be 10.26% for solar-dried and 14% for direct sun-dried; and fresh green pea 23%. The value for the sun-dried treated green pea gave a better result for the storage period of 90 days. Experimental model equations for the relationship between the independent variables and the response variable were generated. This work has contributed solution to postharvest losses encountered in handling green peas for maximum nutrient retention. Development of new products using pretreated green pea protein as composite material for value addition is recommended. Further investigations are required to determine the effect storage period of more than 90 days. This process can as well be scaled up for industrial purposes for recommendation to urban green pea farmers for adoption.

AUTHOR CONTRIBUTIONS

V.A. Abodenyi: Conceptualization, methodology, data collection, analysis and interpretation, original draft writing and writing review and approval of the final version. **S. L. Ezeoha:** Conceptualization, data analysis, revising and editing the manuscript, supervising the study and approval of the final version.

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