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Design Of Extruder Device And Examination Of Chemical Parameters Of Pulses Fed With Designed Extruders

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Abstract: *In this study, an extruder device design having an important role in preserving the nutritional values of foods in food production systems was performed (feeding II).Two different extruders, (feeding I) belonging to a private enterprise and (feeding II) designed in the laboratory, were used in this study. The before and after chemical changes of the pulses fed with the extruder machines were examined. The analyses of three samples were carried out as dry bean, green lentil, kidney bean. Protein, colour, pH and moisture analyses were performed on the samples before and after the extrusion process. It was used Kjeldahl protein determination method for protein analysis, moisture determination method in the drying oven for moisture analysis, analysis method with Ph meter for pH analysis, and finally Lovibond Tintometer for the conducted colour analysis.*
It was detected that there were differences in the before and after process values of pulses fed with extruder according to the results of the analysis. To conclude, it was observed that the protein values of analysed pulses increased significantly after they were processed by the extruder while their pH values and moisture decreased. In addition, it was found out as a result of the colour analysis that red yellow colours increased in kidney bean and green lentil whereas these colours decreased and their gloss values enhanced obviously in dry bean. Significant increases were observed in gloss values as a result of the feeding of the designed extruder.
Keywords: *Design of extruder device, fed values, pulses, protein, chemical properties*

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I. Introduction

Extrusion cooking method has a wide range of uses in the food industry. Extruder cooking is a process that combines mixing, cooking, moulding and shaping to produce food products such as breakfast cereals, snack foods, pulses, confectioneries. The extrusion cooking process performed for pulse with the short-term industrial processing technique at high temperature is the most effective feeding system that can transform food raw materials into highly nutritious, delicious and quality foodstuffs.

A wide range of products is obtained from cereals and legumes, which have significant properties and rich nutrient content, such as flour, snack foods, breakfast cereals through extrusion. According to the studies, the extrusion process applied to the pulses lightly (high moisture content, low residence time, low temperature) improves and increases the nutritional quality of the pulse products and facilitates the digestion. Extrusion process provides some protein increase in the pulses. Extrusion process at high temperatures (less than 200°C), low moisture content (15 g/100 g) and unsuitable formulations (such as the presence of high reactive sugars) affect the quality of nutrition negatively for pulses[1].Pulses are a cheap and important plant-based protein source in terms of nutritional value and are consumed in considerable quantities by the population in Turkey [2]. Dried pulses have rich nutrient content in terms of protein, fibre, carbohydrate, mineral and vitamin[3].Lentil (*Lens culinaris*) is a type of cool seasonal pulses grown in many parts of the world, usually growing in the Mediterranean or colder climatic conditions. Lentil has significant effect concerning protein and is the most important integral component of more than one food systems as the fixation of atmospheric nitrogen and a means of promoting agriculture in a sustainable manner [4].Green and red lentils also contain sugar alcohols, raffinose family oligosaccharides, fructooligosaccharides, and resistant starch providing benefit for human health [5].Dry bean (*Phaseolus vulgaris L.*) is a staple food product for many countries in the world. After the beans are processed, they have a high nutritional value and are taken through daily diets and included in diets for consumers. Dry bean is the most important legume type used in the world in terms of human consumption. Kidney bean consumed as foodstuffs contains a very rich dietary fiber, protein, carbohydrate, mineral and phytochemical sources, including phenolic compounds. Dietary fiber and resistant starch, such as indigestible carbohydrates in kidney bean, are useful in many aspects such as reducing weight loss, balancing blood sugar, decreasing heart disease, and improving intestine health[6].

In this study, firstly, an extruder device was designed in laboratory conditions. After green lentil, dry bean and kidney bean pulses were fed from the extruder device that we designed in the laboratory, ph, moisture, colour and protein analyses were performed. The obtained analysis results were compared with the results of ph, moisture, colour and protein analyses of green lentils, dry beans and kidney beans fed by the extruder device existent at the enterprise of Goze Mersin Integrated Plant. The efficiency and analyses results of the extruder we designed were compared with the extruder device under operating conditions and a literature comparison was performed.

II. Material and Method

Material

Inverter materials were purchased commercially as 3 phase bridge diode, IGBT 1200 Volt, Mos-fet, PCB printed circuit, socket, cable, box. Raw green lentils, dry beans and kidney beans were obtained from Mersin province Goze Integrated Plant (Turkey). Computer and the asynchronous motor were supplied by Istanbul Aydin University.

Method

Moisture Analysis in Drying Oven

The moisture content in foods is mostly carried out by drying in the oven.It is based on the principle of evaporating water in a sample to be analysed under a certain temperature and finding moisture content from the weight loss.The drying oven was heated to 105°C and kept for 30 minutes. After 6 petri plates were kept in the oven set at 105 ^{0}C for 1 hour in order to bring to the constant weighing, were left in the desiccator for 30 minutes to cool down. After determining the tares of the petri plates brought to constant weighing, 5 grams of dry bean, kidney bean and green lentil samples were weighed before and after the feeding.Petri plates that were sample were kept in the drying oven at 105 °C for 3 hours. The petri plates were then placed in the desiccator for cooling and kept for 30 minutes and each petri plate containing the sample kept in the drying oven was weighed separately.

pH Analysis

2 grams of the dry bean, kidney bean and green lentil samples were weighed before and after the feeding to measure the pH values of the samples. Weighed samples were taken into beakers and 100 ml of distilled water was added to each.The mixture was stirred on a magnetic stirrer at room temperature for 1 hour.Each mixture was then filtered on filter paper. After the pH meter device was calibrated, the ph value of each sample was measured.

Protein Analysis with Kjeldahl Method

1 gram of each sample pulverised in the mortar were taken and put on filter papers for the process of burning which is the first step in the protein determination with Kjeldahl method, and they were placed into the Kjeldahl tubes. 25 ml of concentrated sulfuric acid and Kjeldahl tablet as catalyst were added to the tubes. The prepared 6 tubes were first placed in the kjeldahl burning unit set at 100 °C. The prepared 6 tubes were first placed in a kjeldahl burning unitset at 100 °C. When the temperature of the Kjeldahl device reached 400 °C by increasing it by 50 °C for every half hour, the process was completed by applying the burning process for 1 hour. 50 ml of 4% boric acid and 2 drops of methylene blue-methylene red indicator were dropped into an erlenmeyer and mixed, and the colour was observed to be purple. The erlenmeyer was placed into the distillation equipment together with the solution in the first Kjeldahl tube received from the burning device.After the distillation process set for the grain group was completed, the erlenmeyer was taken from the device and its colour was observed to be green. Considering the third and last step of titration process; the erlenmeyer, which was taken from the distillation unit, and 0.1 N HCl solution placed in the burette were titrated until its colour was turned from green to purple. The amount of protein was calculated by writing down the consumption. The distillation and titration steps were repeated in the same way for the other 5 samples.

Colour Analysis with Lovibond Tintometer Method

The tintometer device was turned on, and after its cuvette was cleaned with acetone, the dry bean sample was placed into the cuvette as much as its capacity of ¾ before the sample infiltrated, the cuvette was placed on the rightmost of the tintometer. L*, a*, b* values were recorded as a result of the measurement. The measurement was repeated for the other 5 filtered samples.

Design of Extruder Device

The extruder used for foodstuffs has the elements of screw (single or double), paddles, outer body and final forming elements. Screw and paddles carry out the process of mixing the food and transmitting the cereal mixture or pulses in the extruder device from end to end. For this purpose, the product to be extruded is first transmitted to the transfer section and then to the mixing section. After this stage, the product is transferred to the cooking and high-pressure sections where it will be processed thermomechanically.

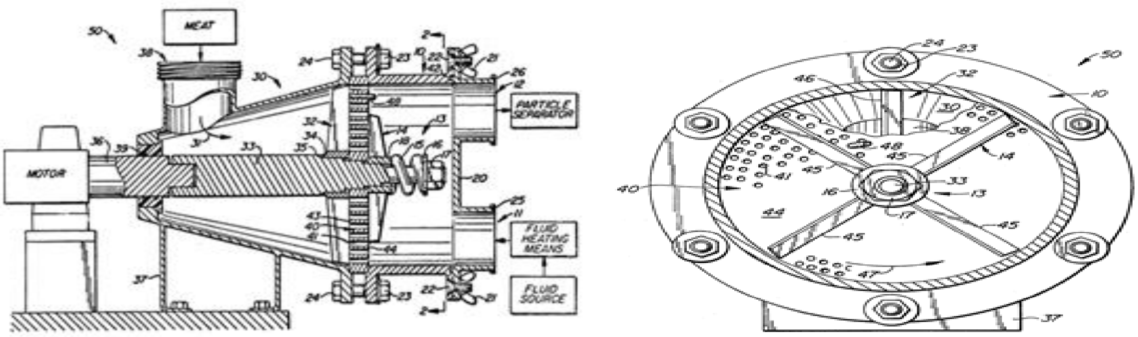


Figure1. Extruder Device

An induction or asynchronous motor is an AC electric motor in which the electric current required to generate torque is obtained by electromagnetic induction from the magnetic field of the stator windings. When the stator windings are fed with voltage, a rotating magnetic field occurs in three-phase asynchronous motors. This magnetic field rotates synchronously. A voltage is induced in the rotor conductors due to the rotating magnetic field at this speed. Due to the short circuit of the rotor terminals, the current will flow on the rotor. As a result of the Biot-Savart law, when a current passes through a conductor placed in the magnetic field, a force trying to move that conductor within the magnetic field acts and the rotor starts to rotate. The speed of the rotor is lower than the synchronous speed and can never reach the synchronous speed.

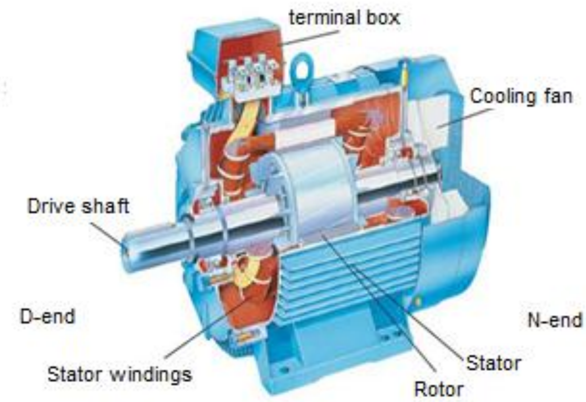


Figure 2. Asynchronous Motor Model

Almost 90% of the asynchronous motors (figure 2)are squirrel cage type because this type of rotor has the simplest and most robust structure. The rotor consists of a cylindrical laminated core with parallel slots to carry rotor conductors. These type of motors have been designed for low power applications. The motor properties used in this study are shown in Table 1.

Table 1. Motor plate used in extruder device and its features

AGM 63 4b	
Rated power:	0,18 kw
Speed:	1500 d/dk
Number of Poles:	4
Voltage:	230/400 v
Frequency:	50 Hz
Insulation class:	F (155 ^{o}C)
Protection class:	IP55
Operation type:	S1

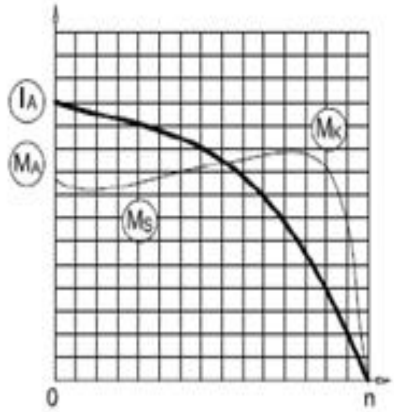
Table 2. Motor data sheet

GAMAK

AGM 63 4b

3-Phase 230/400 V 50 Hz

Duty Type	: S1
Degree of protection	: IP 55 (TEFC)
Insulation class	: F (155 °C)
Temp rise	: Class B (80K)
Mounting Design	: B3



ELECTRICAL DESIGN

Rated output (kW)	: 0.18
Speed (rpm)	: 1340
Rated current (A)	: 0.6
Torque – Mn (Nm)	: 1.28
Cos φ	: 0.73
Moment of inertia J (kgm)²	: 0.00021

	4/4	3/4	1/2
Efficiency %	: 59.7	59.7	55.8

Direct On Line

Locked rotor Current – Ia (A)	: 2
Ia / In	: 2.9
Locked rotor Torque – Ma (Nm)	: 3
Ma / Mn	: 2.0

Y / Δ Starting

Locked rotor Current – Ia (A)	: -
Ia / In	: -
Locked rotor Torque – Ma (Nm)	: -
Ma / Mn	: -
Breakdown Torque – Mk (Nm)	: 3
Mk / Mn	: 2.0

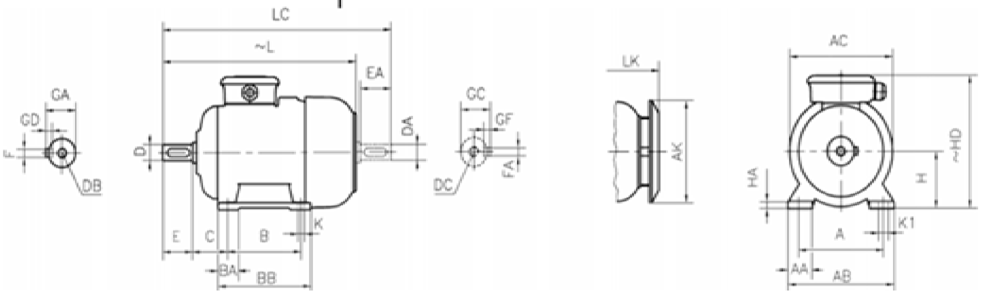
Table 3. Mechanical design data of the extruder

MECHANICAL DESIGN

Frame	: Aluminium
End shields	: Aluminium
Cooling fan	: Plastic
Terminal box	: Plastic
Cable gland	: Pg 11
No of cable glands	: 1

Bearing Arrangement

	Drive End	Non Drive End
Standard design	6201 ZZ	6201 ZZ
Reinforced design	-	-
Noise Level (dB-A)	: 43	
Paint	: RAL 7031- Grey	
Approximate weight (kg)	: 3.9	



Stator voltage and frequency control method were used in this study. The reason for choosing this method is that its output frequency can be controlled and power transformation between different frequency values can be provided. In addition, it was aimed to avoid the negative effects of other methods such as harmonic and noise generation, motor heating and excessive power consumption. As the drive provides output frequency and voltage required to change the speed of a motor, this is done through Pulse Width Modulation Drives. Pulse width modulation (PWM) inverter generates pulses of variable width combined to produce the desired waveform [7].

In this study, the motor speed control was performed by using the inverter circuit to convert the DC voltage to the AC voltage and keeping the V/F ratio constant. The inverter circuit diagram is shown in figure 3.

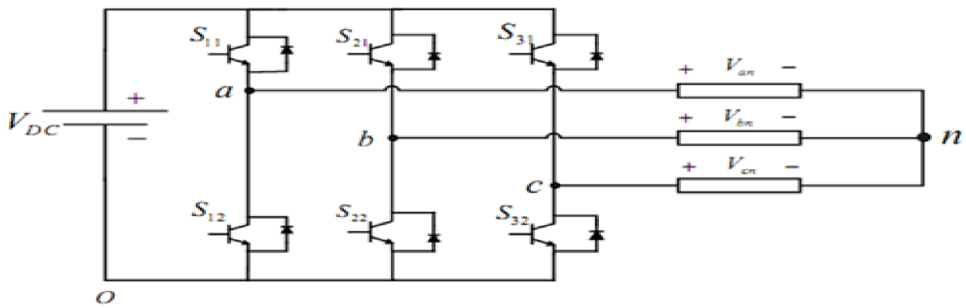


Figure 3. Inverter circuit diagram

The circuit consists of six semiconductor switching elements. A positive and negative alternans must be established in order to convert the DC voltage to AC voltage. When referencing to the KVL and KCL laws, the two switching elements on the same leg cannot be activated at the same time, if they are activated it will cause a short circuit. For this reason, a sinusoidal waveform was obtained by creating a phase difference between the switching elements and performing an on/off (switching) process. The inverter circuit was tested in a laboratory environment, and output charts and voltage values were observed. Values different from the values in the project were used due to laboratory conditions.

Values used; 220 V line voltage instead of 380 V line voltage, 60 Hz frequency motor instead of 50 Hz. The circuit has been designed under these conditions. It was seen based on these values that the frequency changes and the voltage values altered, but the V/f ratio remained constant in every case. The inverter circuit diagram is shown in figure 4.

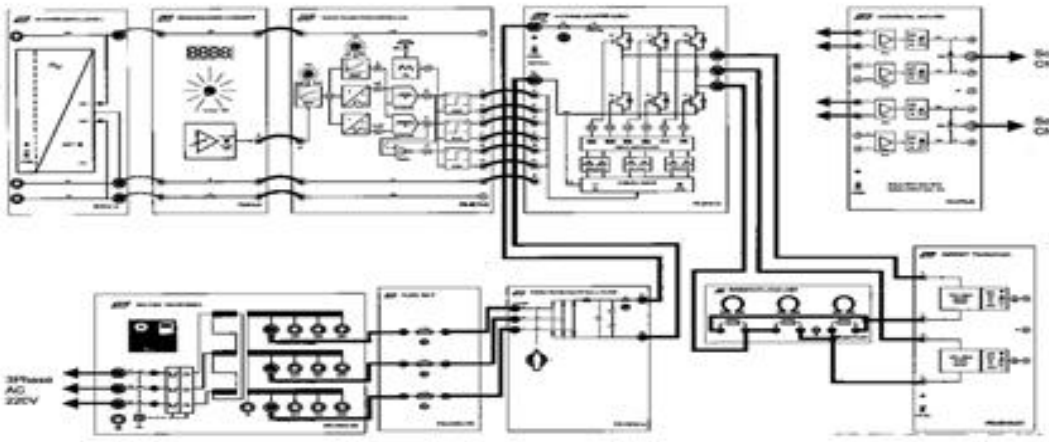


Figure 4. Inverter circuit diagram

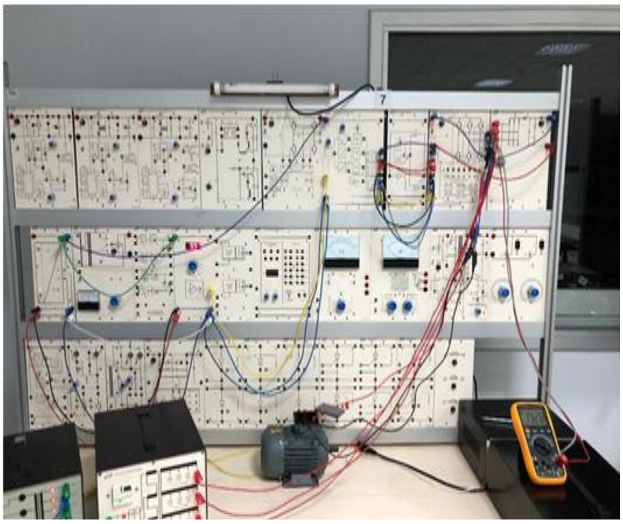
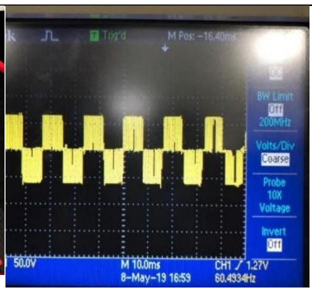
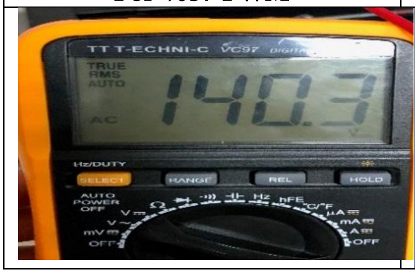
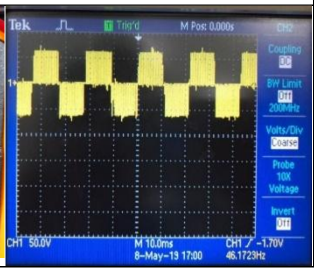


Figure 5. Inverter circuit diagram laboratory image

Output Voltage Active Value (V)	Frequency values (Hz)	V/F Rate
 **For %97 PWM**		**192.5/60=3.2**
		**140.3/46.172=3.03**

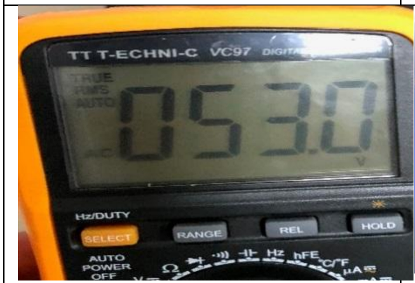
For %75.6 PWM		
 **For %50 PWM**		**89.2/30.187=2.98**
 **For %25 PWM**		**53.0/15.72=3.3**

Figure 6. Circuit results

As shown in Figure 6, the speed control of the asynchronous motor used in the experiment was carried out successfully by controlling the switching times of the semiconductor elements by PWM technique and keeping the V/F ratio constant. It was observed that the constant ratio was maintained for different speed values.

III. Results and Discussion

Moisture Analysis

The moisture percentage values of dry bean, green lentil and kidney bean before and after feeding are shown in Figure 7 and Table 4.While the one coded with feeding I represents operating product, the one coded with feeding II represents the speed rating of 160 and 180 s/m for the extruder that we produced in this study.

Table 4. Moisture percentages of pulses before and after feeding

Sample	Before feeding % moisture	feeding I % moisture 80 d/dk	feeding II % moisture 160d/dk	feeding II % moisture 180d/dk
Haricot bean	7,99	6,87	5,83	5,47
Green lentils	10,39	10,29	10,72	8,23
Kidney bean	7,24	5,32	5,183	5,05

When the values in Table 4are examined, it is concluded that whereas the kidney bean lost maximum moisture and the least moisture decreased in green lentil after feeding. This difference arises from the fact that the moisture content of the pulses is different.

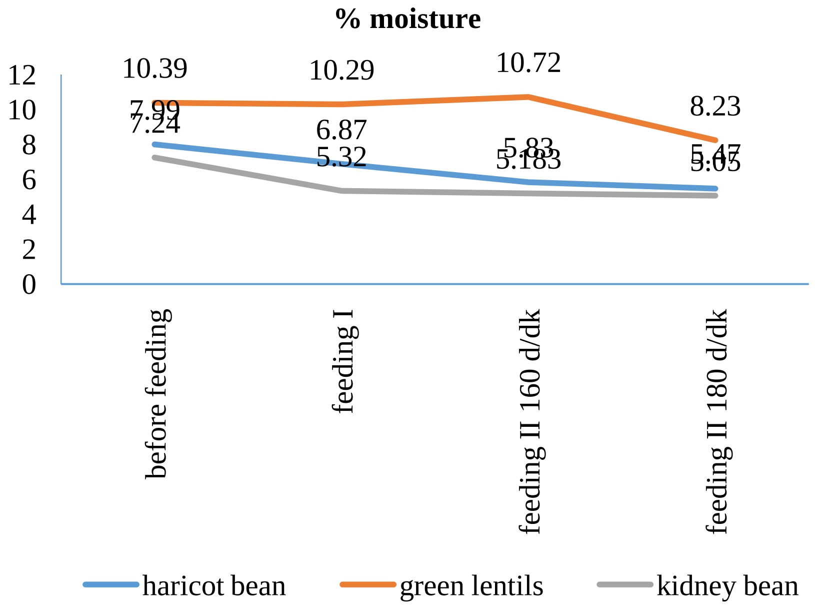


Figure 7.% Moisture change graph of samples

pH Analysis

The pH values of dry bean, green lentil and kidney bean before and after feeding are shown in Figure 8 and Table 5. While the one coded with feeding I represents the operating product, the one coded with feeding II represents the speed rating of 160 and 180 s/m for the extruder that we produced in this study.pH values were found to be higher for all 3 pulses before feeding and lower after feeding in accordance with the pH analysis. According to the Nernst equation; $E=E_0 + S \log a(H+)$. S value is equal to 2.3RT/F (R and F are constant values). T represents the temperature. Sorensen defined the statement of log aH+ as Delta pH.

$E=E_0$ - 0.198T log Delta pH.

Delta pH value is the difference between the pH value of the liquid in the pH electrode and the pH value of the liquid measured.As can be understood from this correlation, the pH value decreases as the temperature increases.Some mechanical temperature occurring during feeding plays an active role in the decrease of pH value.Different amounts of pH change originate from the speed differences in the feeding of the extruder and the increase in the mechanical temperature as the speed increases.

Tablo 5.pH values of pulses before and after feeding

Sample	Before feeding	feeding I 80 d/dk	feeding II 160d/dk	feeding II 180d/dk
Haricot bean	7,27	7,24	6,75	6,65
Green lenfils	7,07	7,06	6,93	6,90
Kidney bean	7,44	7,39	6,89	6,87

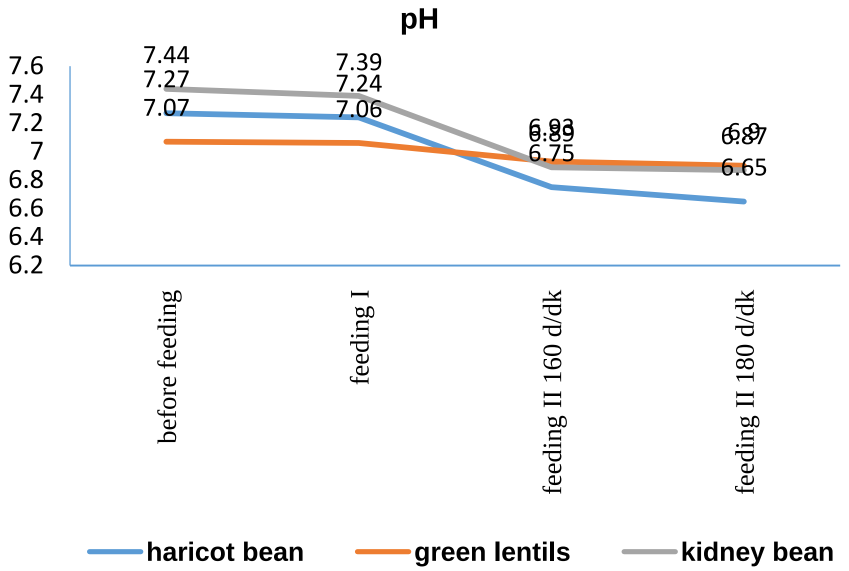


Figure 8.PH change graph of samples

Colour Determination on Lovibond Tintometer

L*, a*, b* values of dry bean, green lentil and kidney bean before and after feeding are shown in Table 6.

Table 6. Color analysis values of pulses before and after feeding

Sample	Before feeding			feeding I 80 d/dk			feeding II 160d/dk			feeding II 180d/dk		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
Haricot bean	19.98	3.72	12.98	17.91	3.72	12.98	62.11	1.76	15.79	51.71	2.68	16.95
Green lentils	-5.42	0.36	1.07	-4.04	0.40	1.47	18.20	2.60	11.12	6.87	1.05	5.24
Kidney bean	9.84	3.01	8.75	9.47	3.56	9.53	61.65	2.62	17.15	52.35	2.34	15.56

Lovibond Tintometer Hunter scale was used for colour determination by tintometer. The physical structure of kidney bean before the feeding in the extruder was found to be glosser and lighter when compared to the values of feeding I while it became redder and yellow colour increased, gloss decreased after the feeding. On the other hand, the dry bean was glosser and consistent before feeding whereas red, yellow colours and gloss increased after feeding.However, significant increases in L*, a*, b* values were observed in all three samples in feeding II values.The reason for this is that the mechanical temperature values, to which pulses were exposed, increased since the motor speed was 80 in feeding I values and the motor speed was 160 and 180 in feeding II values. The casing temperature of extruder significantly influences moisture content, shear force, water absorption index, expansion index and Hunter L value in extruded product production. Evaporation occurs due to the sudden pressure drop taking place when the extrudate is forced for popping out of the body, and texturisation of the extrudate is provided as a result of this[8, 9].

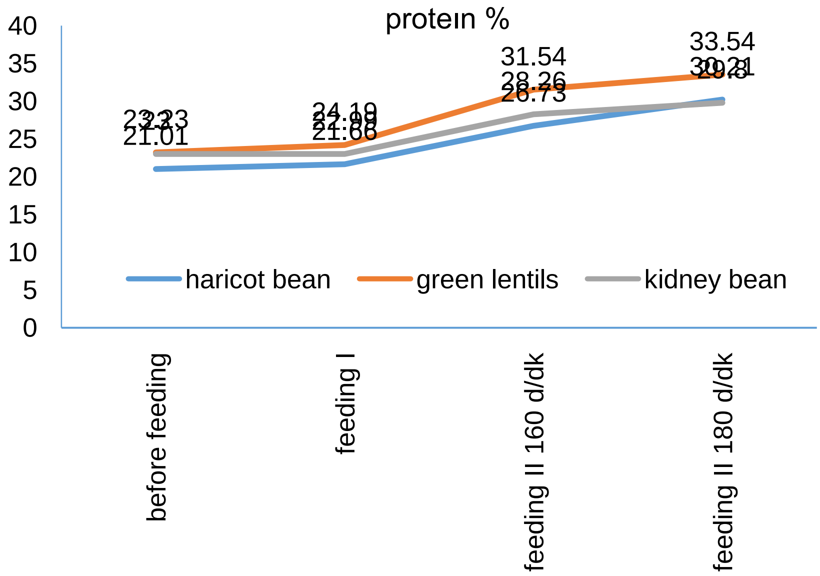
Protein Determination by Kjeldahl Method

The % protein analysis results of dry bean, green lentil and kidney bean before and after the feeding are shown in figure 9 and table 7.

Table 7. Protein analysis values of pulses

Sample	Before feeding %	feeding I % 80 d/dk	feeding II % 160d/dk	feeding II % 180d/dk
Haricot bean	21.01	21.66	26.73	30.21
Green lentils	23.23	24.19	31.54	33.54
Kidney bean	23	22.99	28.26	29.80

The amount of protein before feeding was observed to be lower than after feeding in the protein determination by the Kjeldahl method. It was understood that the reason for the increase in protein amounts after feeding may cause temperature increase occurring during the feeding.The reason for the increase in protein in different amounts is that it is directly proportional to the increase in the temperature value, to which the pulses are exposed, as the speed differences in the feeding in different extruders and the speed increase.An increase in digestibility takes place as a result of the liberation of enzyme junction points of proteins by denaturation after the extrusion process. Disulphide bonding in proteinaceous substances are broken and then regenerate during the extrusion process.Electrostatic and hydrophobic interactions support the formation of insoluble aggregates. What is more, the digestibility of the product increases with the increase of sensitive regions in enzyme activity by transforming high molecular weight proteins into smaller units [10].



Şekil 9.Örneklerin % protein analiz grafiği

Extruder yield analysis
The efficiency analysis results of the device are shown in Table 8.

Table 8. Extruder yield analysis results

Sample	feeding I kg/dk	feeding II kg/dk	feeding II kg/dk
Haricot bean	416	0,21	0,25
Green lentils	458	0,42	0,49
Kidney bean	375	0,20	0,20

IV. Conclusions

In this study, the chemical analyses results of pulses that were fed from an extruder device run under operating conditions and extruder designed at the laboratory conditions were compared. ph, % moisture, colour and protein analyses of the products of feeding I and feeding II of pulses were carried out. It is seen according to the results obtained that a successful design has been performed when the efficiency analyses of the extruder device are compared with the existing extruder device data under operating conditions.

As observed in the analysis results, the observed decrease in pH values after feeding I and feeding II confirms the effect of temperature on ph values according to the Nernst equation. The decrease in moisture percentages originates from the diversity between pulses. According to the results of protein determination, increase in the mechanical temperature with the increase in the speed created significant differences in the protein values of the samples and caused the nutritional values to increase. In particular, the factors such as moisture content of the feeding material, extrusion casing temperature, screw rotation speed textures affect the texture and accordingly various quality parameters closely.

Acknowledgments

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