C RESEARCH CORPORATION OF THAILAND

RESEARCH PROGRAMME NO. 38
PROTEIN FOODS

RESEARCH PROJECT NO. 38/9
FORMULATION OF PROTIEN FOODS

REPORT NO. 8
EXTRUDED PROTEIN SNACK FOODS
I. COOK-EXTRUSION TECHNIQUE OF PUFFED MUNG BEAN AND RICE FLOUR MIXTURE

BY
WIBOONKIET MOLEERATANOND

ASRCT, BANGKOK 1975
not for publication

APPLIED SCIENTIFIC RESEARCH CORPORATION OF THAILAND

RESEARCH PROGRAMME NO. 38
PROTEIN FOODS

RESEARCH PROJECT NO. 38/9
FORMULATION OF PROTIEN FOODS

REPORT NO. 8
EXTRUDED PROTEIN SNACK FOODS
I. COOK-EXTRUSION TECHNIQUE OF PUFFED MUNG BEAN AND RICE FLOUR MIXTURE

BY
WIBOONKIET MOLEERATANOND

ASRCT, BANGKOK 1975
not for publication

CONTENTS

F O R E W O R D

The purpose of this study is to introduce new process in high temperature/short time extrusion process to convert the mixture of raw material including dehulled mung bean flour and rice flour to a high protein cereal base. The prototype products from this extruded cereal base is going to be a protein-enriched puff snack food.

The present work was part of the Research Project No. 38/9 "Formulation of protein foods".

EXTRUDED PROTEIN SNACK FOODS

I. COOK-EXTRUSION TECHNIQUE OF PUFFED MUNG BEAN AND RICE FLOUR MIXTURE

By Wiboonkiet Moleeratanond*

SUMMARY

Cook-extrusion process is used in producing protein-enriched puff snack food from mung bean and rice. The techniques in operating the extruder have been studied. The process has been developed in extruding puff cereals snack which gives a crispy texture.

INTRODUCTION

Cereals supply sixty-six per cent of total calories in the Far East, fifty per cent in North Africa, West Asia, and East Europe. The United States and Canada derive only forty per cent of their calories from cereals. Rice is the principle source of calories for the Far East, while wheat supplies a large part of calories consumed in West Asia, Argentina, Uruguay, Southern and Eastern Europe, and the U.S.S.R. Corn is the principle cereal for the majority of Africa and other parts of Latin America (West 1969). Many children of the world exist on an inadequate diet, especially in regard to the requirement for protein. The countries most dependent upon cereals for calories and protein are usually heavily populated and with predominantly agricultural economics. Those areas have a low income per capita and are forced to depend upon cereals or single cereal for their calories and protein supply which produces chronic protein malnutrition. Protein malnutrition is a serious problem. Children or even adults are fond of having various kinds of snacks. Those snacks provide mainly carbohydrates and fats which results in protein deficiency causing retardation of physical growth, impairing learning capacity and leading to a high morbidity and mortality rate due to lack of resistance to infections. Therefore, snacks can be specially formulated as high-protein, high-energy, after-school treats; as dietary hunger sappers for the overweight or as weight reducers for the underweight; or as thirst precursors for pubs and as succulent transporters. Beyond that, there are mountainous quantities of snacks consumed by television watchers, sport devotees, bridge

*Biotechnology Group, Technological Research Institute, ASRCT.

players, etc. The snack industry is one of the fastest growing of the food industries, and it finds its way to an amazing extent into the convenience food market over much of the world (Smith 1974).

Protein enrichment of snacks is under serious consideration which leads to the development of cook-extrusion processes. The objective of this study is to introduce a new cook-extrusion process using extruder in extruding protein-enriched snack foods from mung bean and rice flour. The techniques and conditions of extrusion process have been studied for practical application under existing conditions.

MATERIALS AND METHODS

Raw materials such as mung bean, rice, sugar, and salt were purchased from local market. Equipments are listed as follows:

1) Wenger Laboratory Extruder, Model X-5 (Figure 1), using five stainless steel heads for all extrusion work. The auger was driven by main motor of 5 hp, 220/440 volts, 3 phases, 50 Hz, 1200 r.p.m., with variable speed drive adjustable from 352-1000 r.p.m. (Wenger Manufacturing, Sabetha, Kansas, U.S.A.)

Component parts including:

- A percentage feeder with stainless steel bin and agitator driven by 1/3 hp, 220 volts, 3.2 Amp., single phase, 50 Hz, 1425 r.p.m. with variable speed control.
- An X-5 knife with a flexible cable driven by 1/8 hp, 115 volts, 1.2 Amp., single phase, 50 Hz, 1725 r.p.m. with variable speed control unit of Model W53, Minarik.
- Thermo couples (Iron-constant) connected to the potentio-meter.
- A rotometer for water-meter of the water pressure tank.
  Power supplied with steam, compressed air, water, and electricity. (Wenger Manufacturing, Sabetha, Kansas, U.S.A.)

2) Buhr Mill. 110/220 volts, 8.2/4.1 Amp., single phase, 50 Hz, 1440 r.p.m. CeCoCo (Central Commercial Company), Ibaraki, Osaka, Japan.

3) Kenwood Major Mixer, Model A707/A. 450 watts, 200/240 volts, single phase, 50 Hz. Kenwood Manufacturing (Working) Ltd., New Lane,

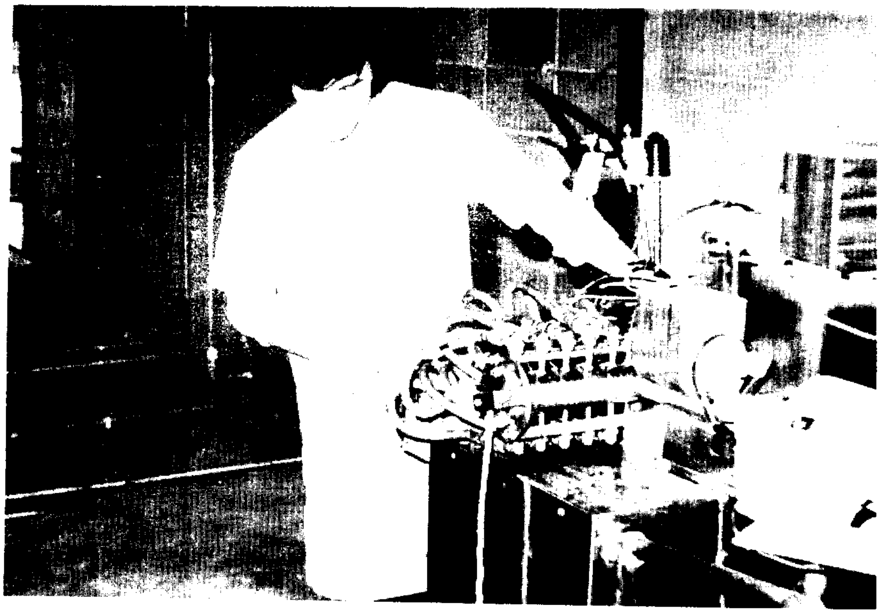

Figure 1. Wenger Laboratory Extruder, Model X-5.

Havant, Hampshire, England.

4) Hobart Kneader and Mixer, Model A-200 FT. 1/3 hp, 220 volts, single phase, 50 Hz, 1425 r.p.m. (Hobart Manufacturing Company, Troy, Ohio, U.S.A.)

5) Sieve Shaker, Model Retac 3 D, 80 watts, 220 volts, single phase, 50 Hz. (Retsch, West Germany.)

6) Oven, type-BS, size No. 2, model OV-160. 1.5 kW, 220/240 volts, 6.6 Amp., single phase, temperature range up to 250°C. (A. Gallenkamp Co. Ltd., London, E.C. 2, England.)

Preparation of mung bean flour

Whole mung beans were soaked overnight in tap water at room temperature. After draining the soaked beans, hot 0.5% sodium hydroxide solution was poured into the beans at the ratio of 3:2 (volume:weight) with steady agitation for about 3 minutes. Then the beans were washed with water and rubbed by hands to remove the hulls. The loose hulls were separated by rinsing off with running water. The dehulled beans were drained and dried in Gallenkamp oven at 60°C overnight. The dried dehulled mung beans were milled by CeCoCo Buhr Mill to pass through the sieve having openings of 400 microns (German Standard DIN 4188).

Preparation of rice flour

Polished rice was ground by CeCoCo Buhr Mill to pass through the sieve having openings of 400 microns (German Standard DIN 4188).

Mixing of ingredients

The prepared dehulled mung bean flour and rice flour were mixed together with powdered sugar and salt in the Kenwood Major Mixer or Hobart Kneader and Mixer. The proportion of the ingredients was shown in Appendix I.

Extrusion

All component parts were connected and checked according to the directions in Wenger instruction before starting the extrusion. Therefore, the extruder screw was operated to determine if there was any misalignment of barrel heads and auger, which would result in drag. The percentage feeder, the water in the pressure tank, the water and steam hose couplings, thermocouples, and all power supply, were checked before operation.

The operation was started by using the exact sequences of the following steps:

1) Fill the percentage feeder with mung bean-rice flour to be extruded.

2) The screw speed was set at 500 r.p.m. by using the probator.

3) The water valve was opened to let the water fill in the pressure tank. After it was full, the valve was closed and the compressed air regulator was adjusted to maintain the pressure at 80 psig in the pressure tank. In this way, the water can be added into the barrel by setting the rotometer.

4) Steam was applied to the jacket on the final head until the temperature read approximately 100°C.

5) The extruder screw was started, and the water flowing into the extruder barrel was set by rotometer in order not to exceed 1 GPH (The

flow rate over this limit will result in flooding into the percentage feeder bin).

6) Then the percentage feeder auger was started immediately by setting the number of turns at 5. It is necessary to have the water flowing into the extruder barrel before the flour was fed to the extruder screw, as failure to follow this procedure resulted in immediate plugging of the barrel.

7) After running for a short period, the speed of feeder was increased and/or the flow rate of water addition was reduced very slowly and carefully and/or the steam valve or water valve was open one at the time, until it was in proper condition.

Allow the time for each adjustment to let the product extruded out for a short period. During each adjustment, watch the ampere panel and make sure that the energy consumed not exceeding 8 amperes. (Failure to follow this instruction will result in jamming.)

8) The temperatures of the head (discharge end) and the middle zone (transition zone) must not be the same (at least 25-30^{o}C difference is recommended). Therefore, cooling should be done by opening the water valve to decrease the temperature of the 3rd head. The temperature was measured by means of thermocouples (iron-constant) connected to a potentiometer, which was also designed for iron-constant thermocouples.

Retention time of the product in extruder barrel was roughly estimated by averaging the time from the start of the percentage feeder to the first appearance of product discharging from the die.

The desired texture of the extrudate was achieved by the proper combination of temperature, flour feed rate, water flow rate, extruder screw speed, and die size. Usually all operating variables were set and held constant except the temperature, water flow rate and percentage feeder which were varied to produce the desired product.

The puffed prototype snack product was made with a relatively low moisture content in the extruder barrel in order to expand the extrudate and produ[redacted] low density product suitable for a snack food.

Determination of extrudate density

It was determined by cutting the dried extrudate into two-inched pieces. The dried extrudates were weighed and their diameters were measured by using vernier calipper. The density was then calculated according to the procedure shown in Appendix II.

Determination of expansion ratio

The ratio was determined by dividing the dried extrudate diameter by the extruder die hole size (see Appendices III and IV)

Analysis of food composition

The food samples were analysed by the Analytical Unit, TRI, using the AOAC method (Horwitz 1965).

RESULTS AND DISCUSSION

The extrusion processing within the food industry is still a young and growing field of interest. The use of extrusion processing is still considered to be more art than science. Therefore, experience is the greatest asset in applying extrusion techniques in the new food processing field. The data obtained in the experiment associated with extrusion of mung bean-rice flour are the calibration of the rotometer, the measurement of feed rate, etc. to be used as references for extruding the cereal products.

From Table 1, the calibration curve of the flow rate setting of rotometer versus the actual flow rate of water addition in barrel using 80 psig of compressed air was constructed (Figure 2).

Figure 3 shows the curve of the number of turns setting related to the revolution of the auger in percentage feeder. The data were obtained from Table 2.

In Table 3, the feed rates of mung bean-rice mixture at 60:40 ratio versus the number of turns setting were shown. The curve was constructed and shown in Figure 4.

Table 4 shows the yield of soaked dehulled mung bean and dried dehulled mung bean prepared from 1 kg of dry whole bean. The yield of

TABLE 1. CALIBRATION DATA FOR FLOW RATE SETTING OF ROTOMETER WITH ACTUAL FLOW RATE OF WATER USING COMPRESSED AIR AT 80 PSIG

Rotometer setting GPH	Actual flow rate GPH
0.2	0.08
0.3	0.21
0.5	0.43
0.75	0.71
1.0	0.99
1.5	1.57
2.0	2.09
3.0	3.23
4.0	4.25

Transferred from notebook No. 828, p. 8.

TABLE 2. NUMBER OF TURNS SETTING RELATED TO THE SPEED OR REVOLUTION OF FEEDER AUGER

No. of turns	5	10	15	20	25	30
R.p.m.	19.6	52.2	88.9	131.9	162.2	200

Transferred from notebook No. 828, p. 5.

TABLE 3. RATE OF FEEDING FOR MUNG BEAN-RICE MIXTURE (60:40) RELATED TO NUMBER OF TURNS SETTING

Rate \ No. of turns	5	10	15	20	25	30
Weight of 60:40 mixture, g/min	124.4	351.5	579.9	851.3	1163.5	1490.8

Transferred from notebook No. 828, p. 6.

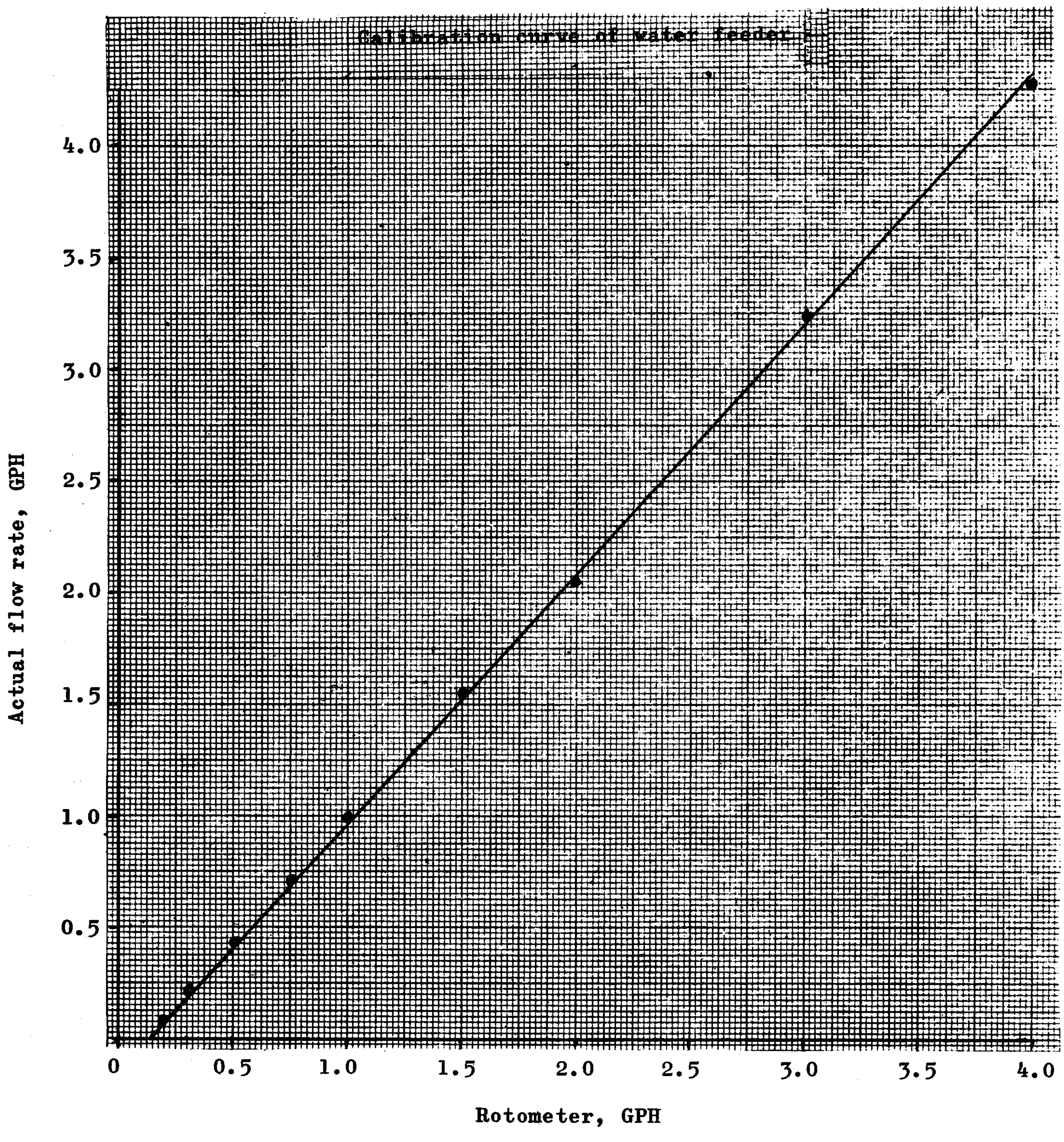

Figure 2. Calibration curve for flow rate setting of rotometer and actual flow rate at 80 psig of compressed air.

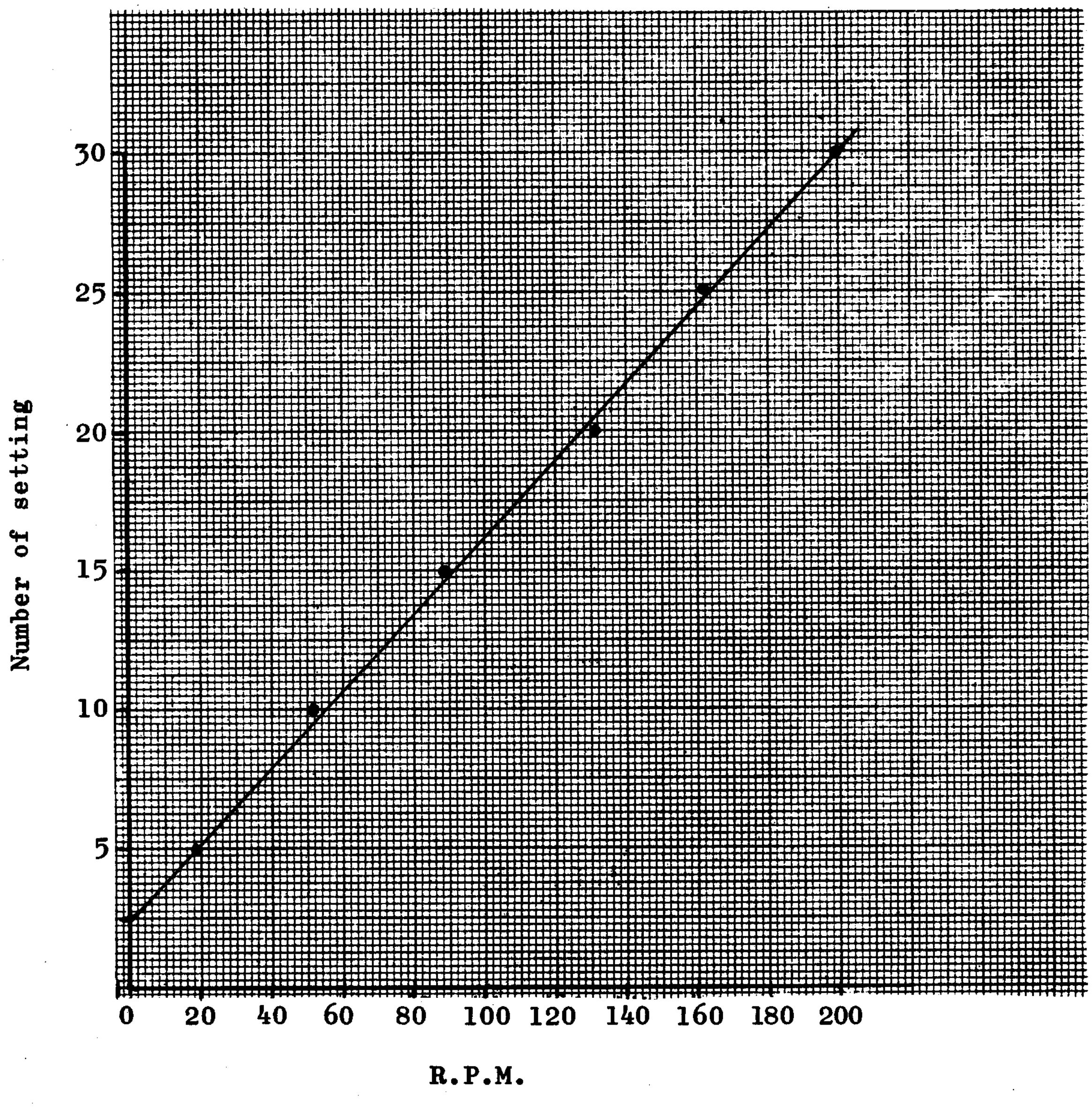

Figure 3. Effect of number of turns setting on r.p.m. of feeder auger.

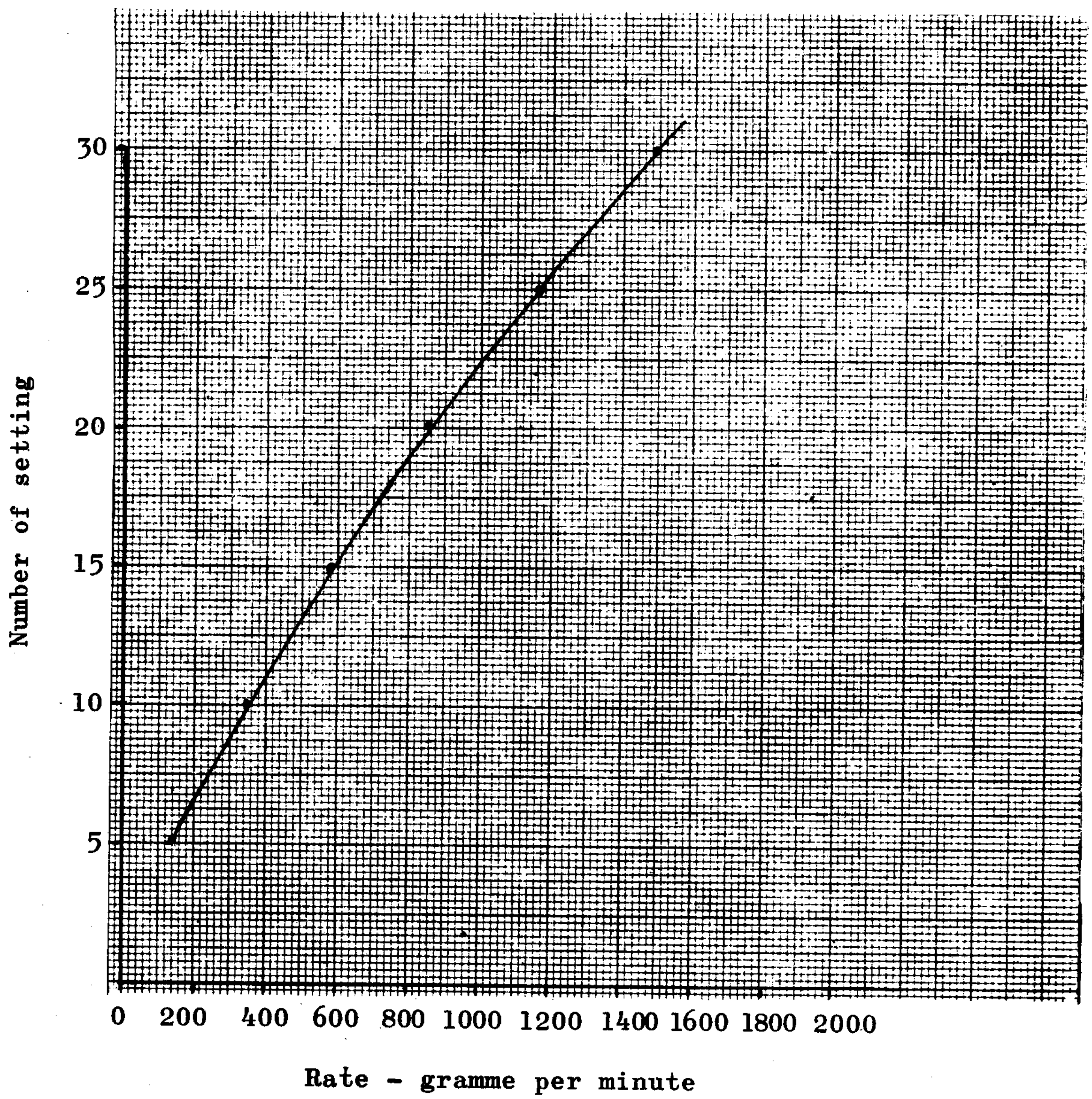

Figure 4. Effect of number of turns setting related to rate of feeding.

about 74 per cent of mung bean flour was obtained.

The food compositions of dehulled mung bean flour, rice flour, mixture of mung bean-rice flour in the ratio of 60:40 and the extrudate were shown in Table 5. The protein content of the extrudate is about 18 per cent on a dry basis.

The data on extrusion conditions of the mixture of mung bean and rice flour were given in Tables 6A and 6B. The desirable quality of extrudate can be obtained by following the described procedure and the conditions in this report.

Generally, temperature is one of the controlling factors in successful extrusion processing. It is noted that for each change in processing variable, the conditions employed were held constantly until equilibrium and thus a constant temperature was reached.

It was observed that increasing or reducing the extruder screw speed was effecting the desired extrudate. The speed of 500 r.p.m. was recommended.

The compressed air pressure must be constant at 80 psig, otherwise it will fluctuate the flow rate of water added into the barrel.

Attention must be taken to control the power consumption, the extruder energy must not be over 8 amperes. If any friction sound was heard, the water addition must be increased and the feed rate must be reduced. Failure to do this will result in jamming. If jamming occurred all component parts have to be disconnected. Hydraulic press was used to press out the extruder screw.

The determinations of extrudate density and the expansion ratio were shown in Appendices II and III. The variation sizes of the dies were shown in Appendix IV. The puffed mung bean and rice flour from the present study has the density of 0.25 g/cc, the expansion ratio is 1:2.56 as shown in Table 6B. The die size used throughout the study was 9/64 inch (0.355 cm).

TABLE 4. WEIGHT OBTAINED AT EACH STEP OF THE DEHULLED MUNG BEAN PREPARATION

	Weight of whole mung bean (g)	Weight of wet dehulled mung bean (g)	Weight of dried mung bean flour (g)
	1000	1914	752
	1000	1990	734
	1000	1902	732
	1000	1886	746
	1000	1940	734
	1000	1828	714
	1000	1900	750
	1000	1895	728
	1000	1918	745
	1000	1886	752
Total	1000	1906	738.7
	100	190.6	73.87%

Transferred from notebook No. 828, p. 19 and p. 33.

TABLE 5. PROXIMATE FOOD COMPOSITION OF INGREDIENTS, THE MIXTURE AND THE EXTRUDATE

Sources	Composition per 100 gramme					
	Moisture	Fat	Ash	Fibre	Protein	CHO*
Dehulled mung bean flour	7.86	1.12	2.23	0.68	27.01	61.10
	on dry basis	1.22	2.42	0.74	29.31	66.31
Rice, highly milled	10.70	0.50	0.20	0.40	7.40	80.80
	on dry basis	0.56	0.22	0.45	8.29	90.48
Mung bean-rice mixture of 60:40 ratio	8.46	0.86	2.31	0.40	17.17	70.80
	on dry basis	0.94	2.52	0.44	18.76	77.34
Extrudate of mung bean-rice mixture	9.44	0.15	2.23	0.27	16.75	71.16
	on dry basis	0.17	2.46	0.30	18.50	78.57

*CHO - Carbohydrates

TABLE 6A. TENTATIVE PROCESS CONDITIONS FOR THE PRODUCTION OF MUNG BEAN-RICE MIXTURE BY USING WENGER X-5

Extruder parameters	Mung bean-rice mixture
Extrusion screw	5 heads screw
Screw speed, r.p.m.	500
Steam lock	full
Extrusion head configuration	1, 2, 3, 4 - straight spline 5 - spiral
Extrusion head jacket configuration	1, 2, 3, 4 - idle 5 - steam
Steam pressure, psig	60 - 65
Water pressure, psig	30-40
Compressed air pressure in water pressure tank, psig	80
Die size, diameter in inch	9/64" round
Feeder setting, number of turns	7 - 8
Feeder, r.p.m.	33 - 41
Feed rate, gramme per minute	190 - 240
Extruder amperes	7 - 8
Water addition setting, GPH	0.3 - 0.4
Actual water addition, GPH	0.21 - 0.3
Product temperature, °C	
5th head	110 - 120
4th head	100 - 105
3rd head	60 - 70
Retention time, seconds	40

TABLE 6B. PROCESS CONDITIONS FOR THE PRODUCTION OF PUFFED SNACK MUNG BEAN-RICE MIXTURE BY USING WENGER X-5

Conditions	Mung bean-rice mixture
Moisture of the flour mixture, %	8.46
Moisture of extrudate, % (after extrusion)	9.44
Density of extrudate, g/cc	0.25
Expansion ratio	1:2.56
Extrudate weight output, kg/h	5.5

Determination of the moisture content of the mixture in the extruder

The condition of water addition is 0.21 to 0.3 GPH,

The output extrudate rate = 5.5 kg/h

Moisture content of the feed = 8.46%

$$= 0.0846 \frac{\text{g water}}{\text{g dry matter}}$$

Water addition $= \frac{(0.3 \text{ GPH})\ (3785 \text{ g})^{*}}{(5.500 \text{ g})}$

$$= 0.2065 \frac{\text{g water}}{\text{g dry product}}$$

Moisture content of the mixture in extruder:

for water addition at 0.3 GPH $= \frac{0.0846 + 0.2065}{0.0846 + 0.2065 + 1.0} \times 100$

$= 22.5\%$

for water addition at 0.21 GPH $= \frac{0.0846 + 0.1445}{0.0846 + 0.1445 + 1.0} \times 100$

$= 18.6\%$

Average moisture content of the mixture in extruder is 20.5%

CONCLUSIONS

The extrusion condition of the mixture of mung bean and rice flour was studied by using Wenger Extruder Model X-5. The data collected on the extrusion process can be used as a guideline for extruding other cereal products. The techniques used in the operation of this extruder can also be applied to other extruders.

The product obtained from the present study is a puffed snack food which contains 18 per cent protein, having the expansion ratio of 1:2.56 and the density of 0.25 g/cc.

Further investigation should be made on the flavouring of the product to make it more palatable.

---

* 1 gallon water = 3785 g.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Mrs. Ubolsri Cheosakul and Mrs. Pivan Varangoon for their advice.

He is thankful to the staff of the Analytical Chemistry Unit for their analytical work.

REFERENCES

HORWITZ, W., ed. (1965).—"Official Methods of Analysis of the Association of Official Agricultural Chemists." 10th ed. (Association of Official Agricultural Chemists: Washington, D.C.)

SMITH, Oak. B. (1974).—Extrusion-cooked snacks in a fast growing market. Cereal Sci. Today **19**(8): 312-315 and 343.

WEST, O.M. (1969).—"Protein-Enriched Cereal Foods for World Needs." p. 4. (The American Association of Cereal Chemists: Minnesota.)

APPENDIX I

The proportion of the flour based on 1,000 g of the mixture is indicated as follows:

Dehulled mung bean flour	600 g
Polished rice flour	400 g

(60:40 ratio)

The following ingredients were added to the mixture based on 1,000 g of flour mixture

100 g powdered sugar
15 g fine table salt.

APPENDIX II

Determination of extrudate density:

$$\text{Density} = \frac{\text{weight of cylinder}}{\text{volume of cylinder}}$$

$$\text{Density} = \frac{\text{weight of dry extrudate}}{(\text{No. of pieces})(0.7854)(\text{diameter})^2(\text{length})}$$

$$= g/cm^3$$

$$\text{Density of product} = \frac{7.9833}{10 \times 0.7854 \times .906^2 \times 5.08}$$

(average from three experiments) $= .25\ g/cm^3$

APPENDIX III

Expansion ratio = $\frac{\text{diameter of extrudate}}{\text{diameter of die}}$

Expansion ratio of the product = $\frac{.909}{.355}$

(average from three experiments = 2.56

APPENDIX IV

Inside diameter of dies provided by Wenger X-5 are as follows:

1/8	(0.125)	in	or	0.317	cm
9/64	(0.140)	in	or	0.355	cm
5/32	(0.156)	in	or	0.396	cm
11/64	(0.172)	in	or	0.437	cm
3/16	(0.187)	in	or	0.475	cm
-	(0.194)	in	or	0.493	cm