PN-ABP-238

SUSTAIN

GUATEMALA & HONDURAS

AUGUST 2 - 7, 1992

EXTRUSION & FLAVOR TECHNOLOGIES SEMINAR

S haring
U nited
S tates
T echnology to
A id in the
I mprovement of
N utrition

A U.S. Private Food Industry initiative
in collaboration with the U.S. Agency for International Development
through a Cooperative Agreement with the National Cooperative Business Association

Upgrading the Food Processing Industries in Developing Countries.

Why SUSTAIN?

SUSTAIN represents a successful collaborative effort between the U.S. food industry and the Agency for International Development (A.I.D.) to upgrade food processing in developing countries. It provides an excellent model for similar private-public sector joint ventures in health, agriculture and other areas of concern to developing countries.

Food processing is a major contributor to development. It serves multiple roles. Food processing can increase the available food supply by extending the life of perishable food products. It can improve the nutritional quality of the diet by making nutritious foods available the year round. It can lead to the growth of related enterprises in transportation, storage, distribution and marketing. And, it can produce much needed foreign exchange by creating value added products both for export and for internal substitution of imported processed foods.

The U.S. food industry has embraced the concept that freely sharing its expertise and knowledge is of mutual benefit to recipient and donor - to the recipient by improving current operations - to the donor by contributing to a healthier global future.

How SUSTAIN Works

A.I.D. missions and trade associations in developing countries publicize SUSTAIN's goals and activities. Executives of U.S. food companies with technical expertise and overall knowledge of the food industry serve as the SUSTAIN Steering Committee, providing guidance and overseeing activities.

Food related companies in developing countries submit their requests to SUSTAIN through the A.I.D. mission or a designated organization in their country. SUSTAIN screens all incoming requests and if necessary asks for additional information. Appropriate U.S. companies are then invited to respond.

Some problems can be readily resolved by providing information. Others require that consultants be sent. When a consultant is sent, the usual assignment is for one to three weeks. Upon completion of the assignment, the consultant prepares a report describing findings and making recommendations. Depending on need, some consultants may return for follow-up visits to ensure that recommendations have been appropriately implemented.

SUSTAIN Helps

Requests are diverse. Help may be needed to solve processing problems, to identify equipment needs and sources of new and used equipment, to train personnel in the use of new equipment and new technologies, to find new uses for indigenous commodities, to establish or improve quality assurance procedures, to control insects and rodents in food processing plants and to improve plant layouts and materials handling.

In the past, U.S. food companies, large and small, have provided technical assistance in the form of information, consultants and training to food processors in Africa, Asia, Latin American and the Caribbean.

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PN 82650

SUSTAIN PROGRAM

EXTRUSION AND FLAVOR TECHNOLOGIES SEMINAR

Guatemala

AUGUST 2 - 4, 1992

Honduras

August 5 - 7, 1992

Volunteers:

Dr. Ross Sheldon

Director-Europe, Universal Flavors International, Inc.

Mr. Robert C. Miller

Robert C. Miller Consulting Services

Administrative:

Elizabeth Turner

SUSTAIN

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TABLE OF CONTENTS

	Page
Introduction	1
Itinerary	2
Summary of Presentations	4
"Extrusion Technology" by Robert Miller	5
"Consumer Acceptance" by Dr. Ross Sheldon	7
"Nutritional Value: Development of Nutritionally Improved Foods" by Dr. Luiz Elias Translated from the Spanish	9
Appendices	10

I List of Attendees in Guatemala and Honduras

II Articles: "Food Extrusion by Jack L. Rossen and Robert C. Miller

"Continuous Cooking of Breakfast Cereals" by Robert C. Miller

III Presentation: "Consumer Acceptance" by Dr. Ross Sheldon

IV "Development of Better Nutritional Foods" (Spanish)

V On-site Visits by Messrs. Miller and Sheldon

VI Curricula Vitae of Messrs. Miller and Sheldon

VII Certificate of Appreciation to Elizabeth Turner

VIII Local Newspaper Advertisement of the Seminar

IX Program of Seminar (In Spanish)

INTRODUCTION

In the production of many snack foods, extrusion and flavor technologies are employed. Food Extrusion, in short, is the process where a food material is forces to flow, under one or more of the various conditions of mixing, heating, and high-pressure shearing, through a tiny opening, or die which is designed to form or puff-dry the food as it emerges from the die. The formulation of extruded snack foods also requires the careful use and addition of flavoring materials, especially those which can withstand these extreme conditions. In Central America there is a significant interest on the part of food processors to manufacture nutritious snack foods. However, these technologies are not readily available to these processors. Hence, at the request of the International Chamber of Commerce in Honduras (INTERCHAM), and subsequent collaboration between the Institute for Nutrition in Central America and Panama (INCAP), the Guatemalan Association of Food Technologists (AGTA), and SUSTAIN, a seminar entitled "The Role of Extrusion and Flavor Technologies in the Production of Nutritious Foods" was organized and held in Guatemala, and subsequently in Honduras, from August 3-7, 1992.

The purpose of these seminars was to provide an opportunity for one - on- one consulting and problem-solving through subsequent site - visits. To present the seminars, SUSTAIN sent two volunteer consultants: Robert C. Miller of Robert C. Miller Consulting Services, a chemical engineer specializing in extrusion technology; and Dr. Ross Sheldon, Managing Director-Europe and flavor chemist, with Universal Flavors International, Inc. While in Guatemala, the host organizations were INCAP and AGTA. And while in Honduras, the host organizations were INCAP and INTERCHAM.

ITINERARY

"ROLE OF EXTRUSION AND FLAVOR TECHNOLOGIES IN PRODUCING NUTRITIOUS FOODS"

Seminar & Site Visits: August 3-7, 1992

Travel Dates: arrive August 1/return August 8

Location & Host Organizations: Guatemala INCAP & AGTA); Honduras (INTERCAHM, AGTA)

Participants: SUSTAIN, AGTA, INCAP, local food manufacturers, government, & local universities.

Sunday, August 2: Guatemala

Morning or Afternoon Meeting of Seminar Speakers (Dr. Miller, Dr. Sheldon, INCAP, AGTA)

Monday, August 3: Guatemala

Site visits and one-on-one technical assistance

Tuesday, August 4: Guatemala

Seminar: **"Role of Extrusion and Flavor Technologies in Producing Nutritious Foods"**

8:30 - 10:45	Extrusion Technology: •What it is and how it works •Types of equipment available •Cost factors/Capital investment •Product Protection	Dr. Robert Miller
10:45 - 11:15	Coffee Break	
11:15 - 12:45	Nutritional Value: •Impact of processing nutritional value of ingredients •Formulations •Fortification	INCAP/AGTA
12:45 - 2:15	Lunch	
2:15 - 4:00	Consumer Acceptance •Flavor, Texture & Appearance •Sensory Evaluation •Shelf-life	Dr. Ross Sheldon
4:00 - 4:30	Break	
4:30 - 5:30	Panel Discussion: Challenges in Marketing Nutritious Foods INCAP, AGTA, Dr. Miller, Dr. Sheldon	

ITINERARY (Continued)

Wednesday, August 5: Guatemala/Honduras

Morning: travel to Honduras
Afternoon: site visits

Thursday, August 6: Honduras

Seminar: --same as August 4th

Friday, August 7: Honduras

Morning: site visits and one-on-one technical assistance.
Departure (Saturday, August 8)

SUMMARY OF PRESENTATIONS

"ROLE OF EXTRUSION AND FLAVOR TECHNOLOGIES IN PRODUCING NUTRITIOUS FOODS"

EXTRUSION TECHNOLOGY

Dr. Robert Miller
Robert C. Miller Consulting Services

Definition of extrusion: extrusion is defined as the out (Latin 'ex') thrust (Latin 'trudere') of a material through a restriction by pressure. Modern food extrusion has evolved into a more complex operation which can only be defined in general terms: it a continuous process which applies the interactions of mechanical geometry, rheology, chemistry and energy in a controlled environment of pressure and shear to improve food properties, and to create food products with special characteristics.

I Products Made With Extrusion
- Snacks
- Breakfast cereals
- Feeds
- Pasta
- Candy
- Cookies
- Chocolate

II Types of Extruders Available
- Screw extruders
  - single screw
  - twin-screw
  - ram (piston)
  - roller

III Unit Operations Accomplished with Extrusion
- Mixing
- Cooking
- Forming
- Drying (Through vent or at discharge)
- Puffing
- Stage Operations

IV Product Environment Within Extruder
- Time
- Temperature
- Shear
- Moisture

V Effect of Environment on Product Characteristics
- Overall Characteristics
- Shear Damage

VI Classification of Extruders by Product Environment

- Adiabatic Extruders
- High-shear Cooking Extruder
  - with steam
- Low-shear Low-pressure Extruder
- Low-shear High-pressure Extruder

VII Energy Inputs to Extrusion Process (Especially important for cooking extrusion)

- Conversion of Mechanical Energy
- Conduction of External Heat
- Convection of Steam

VIII Classification of Extruders by Energy Input

IX Principles of Operation

- Pressure Generation and Restriction Working Together
- Pressure Generation and Flow
- Shear, Mixing and Heat Generation

X Die Design

- For Restriction
- For Forming

XI Scale-up

- Adiabatic Operation
- Heat-Transfer Processes

XII Process Variables--Interactions and Control

XIII Ancillary Equipment

- Feeders
- Mixers
- Pre-cookers
- Fryers
- Dryers/Toasters
- Flavor Coaters

XIV Cost Factors

- Ingredients (In replacing other operations with extrusion)
- Energy
- Wear and Maintenance
- Capital

"ROLE OF EXTRUSION AND FLAVOR TECHNOLOGIES IN PRODUCING NUTRITIOUS FOODS"

CONSUMER ACCEPTANCE

Dr. Ross Sheldon
Universal Flavors International, Inc.

As consumers, we are making daily choices concerning the products we buy. Our decisions are driven by product performance and efforts to get the best possible value for the money that is available for us to spend. As manufacturers, it is our task to understand market needs and deliver those products which respond to consumer needs. It is not too difficult to get someone to buy your product once. However, as food manufacturers, our business is based upon repeat sales having an acceptable frequency. We clearly must deliver a product which is relevant to the market and has value to the consumer.

Consumer acceptance is, clearly, very subjective and difficult to measure. As manufacturers we have to find the right balance in order to deliver the right product, at the right time, and at the right price. for today's discussion we are going to assume that our marketing department has pointed us in the right direction. Our task then becomes one of considering technical aspects of how to deliver the right product quality.

When my children ask for a certain type of toothpaste, they are not thinking about fluoride additives to prevent cavities. No, they want a particular product because of the way it tastes. Building on this point, when was the last time you heard somebody talk about a juice, brown strawberry having a crunchy texture? With foods, all of the attributes have to fit and be fully integrated in order to deliver an overall sensory effect. With foods, consumers have pre-set opinions as the product's texture, appearance, aroma and taste. If the manufacturer does not deliver, the product does not survive.

We need to spend some time looking at unit process considerations relative to extrusion cooking, flavors and their impact upon product quality. There are four primary process variables in extrusion cooking.

Flavor: When thinking about the application of food extrusion for the preparation of ready to eat cereals or other products for that matter, the extrusion cooking is the preferred technology. What seems to be a process capable of offering a wide range of advantages, for flavors and other ingredients sensitive to rigorous processing, other means of addition have to be pursued. During extrusion cooking, the process operates at elevated temperatures and pressure. If the flavoring were added together with he dry ingredients before extrusion, the result would be a significant loss of flavor impact. Further, the flavor would become unbalanced because the various constituents would be lost at different rates. There are a number of programs which find ways to reduce in-process flavor loss. Encapsulation is clearly one technique which is showing promise.

Color: Like flavor, color is essential to product acceptance. Unlike flavor, color can be efficiently added to the pre-extrusion food mixture.

Texture: Using ready-to-eat cereal products and snacks as a point of reference, one can easily see the range of textures which are available in the market. On the one hand, breakfast cereal manufacturers have products which can remain crunchy even in a bowl of milk. At the same time, one can find snack products with a "melt in your mouth' texture. The full range of texture becomes a function of the ngredients, treatments, dough modifiers, and importantly the processing conditions. Again, moisture

content, shear force applied and thermal energy and retention time are vital aspects which impact on the final texture.

I think it would be useful to spend some time discussing starch ingredients and general aspects related to their chemistry. While all dough ingredients are important, the starch additives are clearly the key material in determining the final texture. With starch, we are dealing with two basic types of molecules, namely amylose and amylopectin. Starch chemistry is complex. No doubt you are well familiar with gelatinization procedures. With gelatinization, we are dealing with water absorption by the starch molecule. When we look at starch, the following properties apply: density control, strength, shelf-life improvement, flavor, water-holding capacity, and fat-binding.

Vitamins: Many vitamins are heat labile and are therefore denatured during the thermal processing during extrusion. High temperatures increase the rate of vitamin loss. Good retention is possible with careful processing. Knowing that some losses will occur, the food mixture can be enriched so that desired RDA levels can be obtained in the finished product.

Consumer Acceptance and Product Modeling: Relying upon the excellence of our sales and marketing departments, we will assume that they have properly identified the new opportunity for our company and, second, they have provided us with guidelines the market we intend to penetrate. We need to understand how these factors apply:

Market Acceptance: How is the market now being served? What is the market share of the existing brands?

Unit Cost Objectives: It is the responsibility of marketing to determine the selling price and how much they intend to earn in margin per unit.

Label Claims: Are there any restriction? Is there an opportunity to differentiate ourselves from our competition.

Product Variations - Line extensions: The introduction of new flavors, new shapes, or maybe new textures or combinations of each.

The product development project is accomplished through Product Modeling.

ROLE OF EXTRUSION AND FLAVOR TECHNOLOGIES IN PRODUCING NUTRITIOUS FOODS

NUTRITIONAL VALUE: DEVELOPMENT OF NUTRITIONALLY IMPROVED FOODS

Dr. Luiz G. Elias
Head, Division of Agricultural and Food Sciences
INCAP
(Translated from the Spanish by Patrick Wright, SUSTAIN)

The development of nutritionally improved foods dates back more than 30 years, and the initial purpose of its creation in developing countries was principally improving the quantity and quality of protein from foods of animal origin such as meat, milk and eggs which were not accessible to these populations. For the formulation of these foods, proteins of plant origin were developed-they included legumes, oilseeds, cereals and tubers that when combined resulted in foods of higher nutritional value.

Previously it was determined that there was a necessity to add other nutrients-with the result being a greater contribution to a healthier nutritional state to priority groups within these same populations.

Actually, the interest in the use of formulated foods based on products of vegetable origin has increased notably not only for its role in nutritional areas, but also for the association between diet and health. In the development of these formulations one has to consider the following aspects: a) the disposal of raw material; b) with respect to formulation of these foods, there must be a definite rationale for their use; it can be used as the only food, as a dietary supplement, directed to specific groups, or to the general population. Related to this is the nutritional quality of the products as well as the physical and organoleptic properties; c) the evaluation of the intrinsic qualities and properties - nutritional, technological and sanitary - of the product. d) finally, processing aspects that invoke studies of technical/economical statistics: such as commercialization as a form of presentation, distribution, advertising and others. With respect to processing, special attention will be given to the process of co-extrusion, principally that which refers to the advantages of this process in the inactivation of anti-nutritional factors present in oilseeds and legumes, thus its beneficial effect on the quality of the protein and minerals and a minimal damage to the vitamin content.

APPENDICES

AGTA
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TECNOLOGIA DE EXTRUSION Y SABORIZANTES EN LA PRODUCCION DE ALIMENTOS

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FOOD EXTRUSION

JACK L. ROSSEN and ROBERT C. MILLER

□ FOOD EXTRUSION is a process in which a food material is forced to flow, under one or more of a variety of conditions of mixing, heating, and shear, through a die which is designed to form and/or puff-dry the extrudate.

The single-screw extruder was first applied to food processing in 1935 for the continuous extrusion of pasta products. Since 1935, there has been an increasingly greater use of single-screw extrusion in the food industry, particularly in those processes which require cooking or gelatinization at some stage, such as in the preparation of snacks, cereals, pasta foods, confectionery products, pet foods, animal feed, sausage products, protein supplements, and meat analogs.

The functions of food extruders include gelatinization/cooking, molecular shearing, mixing, sterilization, forming, and puffing/drying. Inherent in the extrusion process is a combination of one or more of these functions. It is important to realize that the extrusion process cannot be separated from the overall process because a great deal of interplay exists between the extruder operating conditions and what happens before and after extrusion.

CLASSIFICATIONS OF EXTRUDERS

Food extruders can be classified in two ways—thermodynamically and by the manner in which pressure is developed. Food extruders can be thermodynamically classified into the following groups:

THE AUTHORS are with Nabisco, Inc., Research Center, 2111 Route 208 Fair Lawn, N.J. 07410

- **Autogenous (Nearly Adiabatic) Extruders** generate their own heat by conversion of mechanical energy in the flow process itself. No attempt is made to introduce heat or to cool the unit through the jacket. Puffed snack extruders approach this condition.
- **Isothermal Extruders.** Constant temperature is maintained throughout the extruder by cooling to remove heat generated by conversion of mechanical energy.
- **Polytropic Extruders** operate between the autogenous and isothermal extreme conditions. All food extruders are polytropic, but some tend more toward being autogenous and others more toward being isothermal.

Although extruders may be called upon to serve a variety of functions, they are primarily a type of pump, and like pumps, can be broadly classified, as in Table 1, according to the manner in which pressure is developed:

- **Direct or Positive-Displacement Type.** Direct extruders include the ram or piston-type extruder and the intermeshing twin-screw extruder. The ram extruder has found major application in sausage stuffing operations and in extrusion of corn masa to make fried corn chips. It is desirable for these applications because virtually no shear occurs, and the properties of the extruded product are therefore essentially unchanged from those of the feed material. It should be emphasized that in the extrusion process, the intensity of shear to which the food material is subjected and where the shear takes place are critical items.

Intermeshing twin-screw extruders are also of the

Table 1—**CLASSIFICATION** *and applications of extruders*

Types of extruders	General characteristics	Applications						
		Snacks	Cereals	Pasta	Confectionery	Pet foods, animal feed	Sausage products	Protein supplements & meat analogs
Direct (positive-displacement)								
Hydraulic or pneumatic ram	Very low shear, continuous	×			×		×	
Intermeshing twin screw	Low shear, continuous				×			
Hybrid of direct and indirect								
Non-intermeshing twin screw	High shear, continuous				×			
Indirect (viscous-drag)								
Roller	Low shear, continuous	×	×		×		×	
Single screw	High shear, continuous	×	×	×	×	×		×

positive-displacement type, but they subject materials to some shear due to viscous drag between the intermeshing flights and also subject the materials to a high degree of extensive mixing. They find major use in compounding operations such as manufacturing chewing gum or chocolate.

- **Indirect or Viscous-Drag Type.** This type of extruder develops viscous drag and therefore modifies the characteristics of the extruded product. There are several types of indirect extruders. One type is the roller extruder, which is used to a great extent with very sticky materials which do not require high-pressure forming.

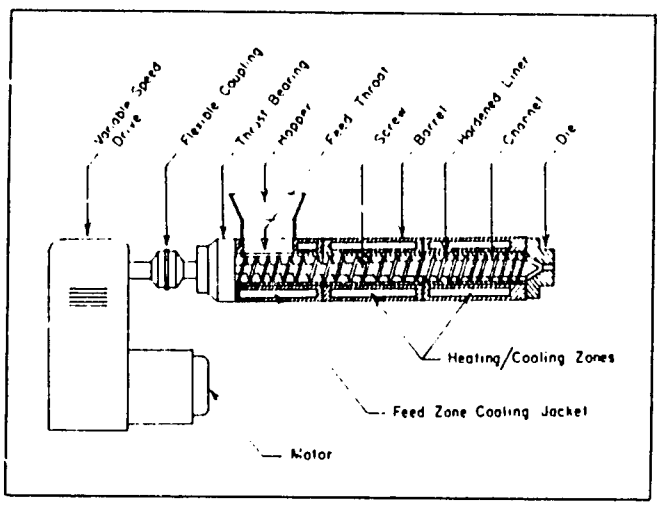


Fig. 1—**ELEMENTS** *of a single-screw extruder*

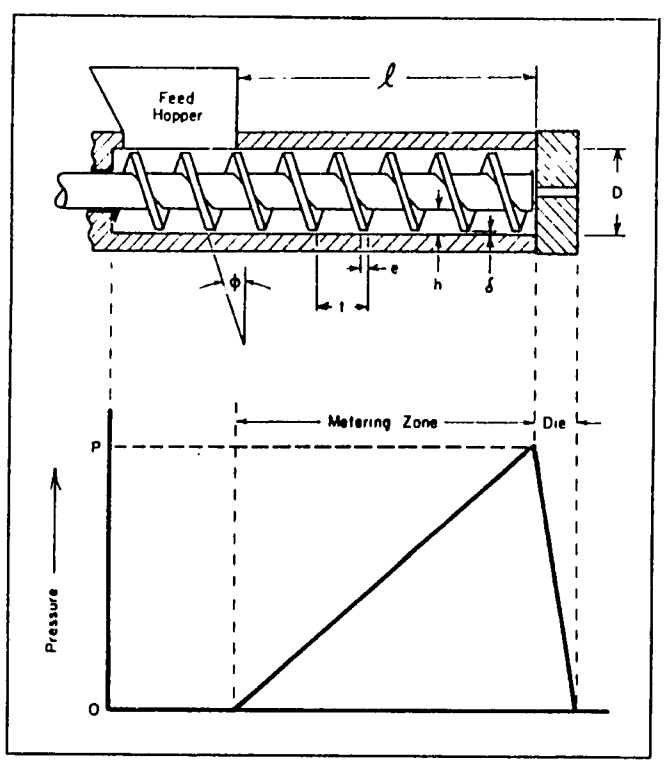


Fig. 2—**PRESSURE PROFILE** *of an idealized single-screw extruder*

Its primary application is in the confectionery industry.

Other types are the single-screw extruder, which will be described below, and the non-intermeshing multiple-screw extruder, which developed from the single-screw extruder. The non-intermeshing multiple screw extruder operates on the same pumping principles as the single-screw extruder and is used for special applications such as dough sheeting across a wide conveyor.

ELEMENTS OF AN EXTRUDER

The important elements of a single-screw extruder are shown in Figure 1. The food material is fed from a hopper through the feed throat into the channel of the screw. The screw rotates in a barrel which has a hardened liner. A motor drives the screw through a gear reducer, and the backward thrust of the screw is absorbed by a thrust bearing.

As the food material is conveyed along the screw channel, it is simultaneously subjected to mixing, heating, and shear. When it is close to the discharge end, i.e., near the die, it has been transformed into a thermoplastic, viscoelastic material at high pressure. Finally, the material flows through the die.

IDEALIZED MODEL AIDS DESIGN

For several reasons, a well-defined theory has been developed for the extrusion of plastics (Bernhardt, 1967; Griff, 1968; Schenkel, 1966), but not for the extrusion of foods. The properties of foods are far more complex than those of plastics and are therefore very difficult to define. For example, food materials do not simply melt, as do plastics, and irreversible time-dependent changes, such as occur during gelatinization of starches, complicate the rheology of foods during extrusion. Consequently, there is very little published information on the rheological and chemical changes occurring during extrusion of foods.

Since the rheology of the food material, the geometry of the screw, and the operating variables are very much inter-linked, the pronounced lack of data concerning the rheology of foods during extrusion tremendously limits the design of extruders.

Nevertheless, it is possible to overcome these limitations in analyzing extruder operation by using several simplifying assumptions:

- **The Product** is a Newtonian fluid.
- **The Extruder** is isothermal, and therefore no changes in viscosity result.
- **The Screw Geometry** is simple and constant throughout its length.
- **The Barrel** fits tightly over the screw.
- **The Feed Zone** is neglected in the analysis.

By using these assumptions, an idealized model of the action of a single-screw extruder can be derived (see Fig. 2). Although one can certainly not use this model for accurate design, it does permit qualitative predictions and offer direction in solving practical problems in food extrusion.

Although these assumptions do not apply directly to real food extrusion operations, the general equations derived from them can be used for predicting the response of the processing conditions to changes in operating variables. For example, the effect of each variable on the throughput of an extruder can be evaluated

by using a combination of experimental data and idealized equations. The analysis can then provide sufficient information for a rational decision as to which variable should be changed in which direction to achieve the desired result. If enough experimental data are obtained to develop operating curves, the predictions can be quantitative.

The idealized model of the single-screw extruder will be analyzed in the following sections.

THE FEED ZONE

The functions of the feed zone are to compress the feed material and convey it to the metering zone. Equations for polymer extruder feed zones have been developed based on the assumption that the feed material forms a solid bed which slides along the screw and barrel surfaces in a rigid fashion. Food materials do not normally form a solid bed, but probably behave as a hybrid of solid bed and fluid flow in the feed section. The analysis of the idealized model, however, neglects this zone.

THE METERING ZONE

The metering zone is perhaps the most important part of the extruder. Its function is to receive the compressed feed material, homogenize it, and force it through the die at constant pressure. Homogenizing is accomplished by intensive mixing (shear) and extensive mixing of the down-channel and transverse flows.

The mathematical treatment of this zone assumes that the material acts as a true fluid, exhibiting strain in shear, with no slip at the screw and barrel surface. In many respects, this section of the extruder behaves like a centrifugal pump, with the pumping capacity inversely related to pumping pressure.

The mechanism of this pressure effect can be described by separating the net extruder flow into two separate fictitious components called drag flow, Q_d, and pressure flow, Q_p (Bernhardt, 1967, p. 173):

$$Q_{net} = Q_d + Q_p \qquad [1]$$

• **Drag Flow.** The forward component is called drag flow for reasons that become obvious from Figures 3 and 4. The velocity of the barrel with respect to the screw, v_b, can be divided into two components. The component in the down-channel direction, v_d, is responsible for drag flow. The cross-channel component, v_c, does not directly affect flow, but contributes to mixing and shear.

The velocity distribution of the material in the channel in the down-channel direction is also shown in Figure 3. The velocity varies from zero at the screw surface to v_d at the barrel surface which "drags" the material down the channel. The drag flow rate is proportional to the average velocity in the channel, and is described by the following equation (Bernhardt, 1968, p. 174):

$$Q_d = \alpha N \qquad [2]$$

where $$\alpha = \frac{1}{2}\pi^2 D^2 h\left(1-\frac{ne}{t}\right)\sin\phi\cos\phi \qquad [3]$$

As shown, the drag flow component is dependent only on screw speed and geometry, and is independent

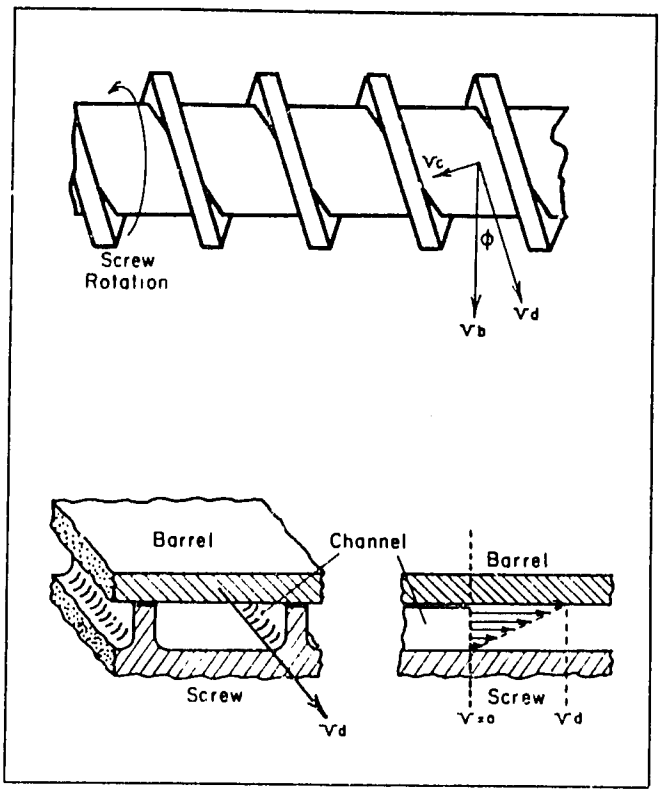


Fig. 3—**DRAG FLOW COMPONENT**

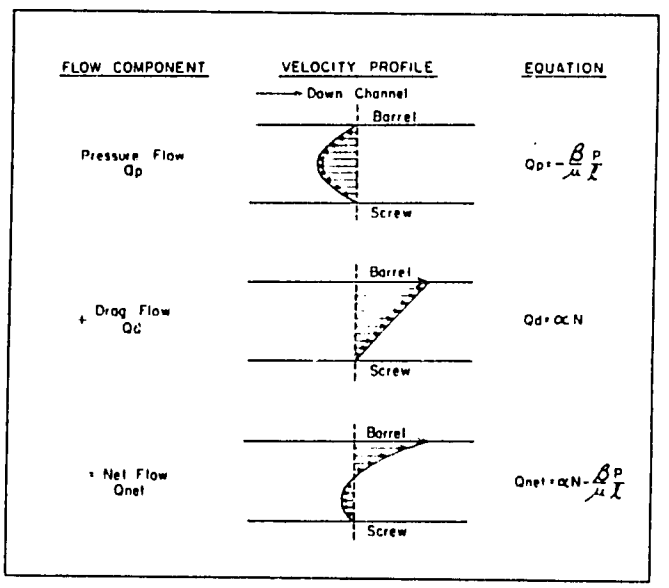


Fig. 4—**SUPERPOSITIONING** *of flow components*

of pressure and viscosity. Generally, however, cooling the screw tends to retard drag flow and reduce output. Heating the screw will increase drag flow. When drag flow is much larger than pressure flow, the output increases.

• **Pressure Flow.** The pressure flow component can be visualized by imagining a non-rotating screw with fluid flowing backward from the high-pressure discharge end. As in any fluid flow situation, the rate of flow is proportional to the driving force (pressure gradient) along the screw, and inversely proportional to the re-

sistance (viscosity and screw geometry). An equation relating these variables is (Bernhardt, 1968, p. 175):

$$Q_p = -\frac{\beta}{\mu}\frac{P}{l} \qquad [4]$$

where P/l is the pressure gradient. The size and shape factors for screw geometry are contained within β (Bernhardt, 1968, p. 174):

$$\beta = \frac{1}{12}\pi D h^3 (1-\frac{ne}{t})\sin^2\phi \qquad [5]$$

For any extruder screw, β is constant, and the pressure flow depends only on P and μ.

- **Net Flow.** The velocity distribution of the net flow can be pictured by superposition of the individual distributions as shown in Figure 4. In this example, a large pressure flow has created a negative velocity area near the screw. In reality, this "backward" flow creates eddy currents which contribute to mixing and shear.

THE DIE

The pressure in our ideal extruder reaches a maximum at the end of the screw, and then drops to zero as the material passes through the die. The flow rate through the die is a function of viscosity, die geometry (resistance), and pressure drop (driving force), as shown in the following equation (Bernhardt, 1968, p. 249):

$$Q_{die} = k\frac{P}{\mu} \qquad [6]$$

where k is the die constant, a function of die geometry.

Die constants for various simple shapes are shown in Figure 5; die constants for complex shapes are best determined experimentally. The k values are particularly sensitive to changes in the smallest linear dimension of the die cross-section. For example, small changes in the diameter of a circular die or thickness of a slit die will result in large changes in flow rate, viscosity, and/or pressure.

SCREW AND DIE COMBINED

So far, we have considered the extruder and die as separate entities, but mathematically, they are connected by the pressure and flow rate terms. The extruder generates a pressure sufficient to force a quantity

—Text continued on page 52

OVERCOMING OPERATING PROBLEMS

The following discussion is intended to answer frequently asked questions about extruder operation.

WHAT CAUSES SURGING?

Surging is one of the most common and difficult problems to solve in extrusion. Typical causes and solutions are as follows:

- **Erratic Drive:** Check uniformity of screw speed.
- **Erratic Feed:** Starved extruders require very uniform feeding, since the throughput is determined by the feed rate and the low residence time provides very little damping effect.
- **Poor Mixing:** Zones of material exhibiting variations in rheological properties, density, etc., can cause drastic changes in extruder performance. Segregation in holding tanks for feed materials can cause surges of long duration.
- **Temperature Variations:** Fluctuations in heating/cooling systems should be minimized. Automatic temperature control systems should be stable to avoid this problem.
- **Incipient Slip in the Barrel or Die:** Surging due to periodic slip at the barrel surface can be eliminated by reducing screw speed, redesigning the extruder to reduce shear stresses, or grooving the barrel. Formula adjustments can also be made to increase adhesiveness and reduce lubricity.

Slip can also be a problem at the die. When the product breaks away from the die surfaces and changes from true fluid flow to a plug flow condition, the pressure drops and flow increases. The plug flow condition can become cyclic. This type of surging can be eliminated or reduced by using longer die lands (higher pressure), more die holes (lower shear stresses), rougher die surfaces, and/or greater product adhesion (accomplished by formula adjustment).

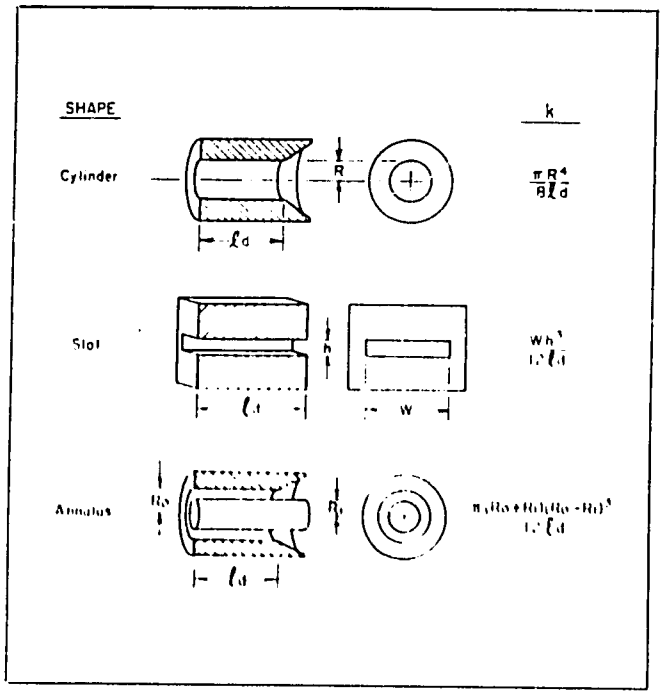
- **Poorly Designed Feed Sections:** Reluctance to flow in the feed section or variations in pressure at the screw entrance can cause large fluctuations in extruder output pressure. Feed paddles and force feeders can be useful for uniformly packing feed material into the screw but if improperly designed can themselves cause fluctuations. The extruder screw can also exhibit problems if the feed section does not deliver sufficient flow to fill the downstream channel. This can be overcome by operating at higher pressures to avoid starved zones in the screw.
- **Dead Spots:** Stagnation points in the equipment often cause intermittent discharge of material which has become overheated or otherwise changed in physical properties. Starved extruders are especially sensitive to surging due to dead spots. All wetted surfaces in the equipment should be streamlined.

HOW CAN AIR ENTRAPMENT BE AVOIDED?

Bridging and poor feeding should be eliminated to avoid the formation of air pockets (opacity and bubbling). Compression screws can help by compressing the material enough to force air backward through the feed section and out the hopper.

WHAT CAUSES DIE PLUGGING?

Dies normally plug because the particle size of the feed material is too great, the operating pres-



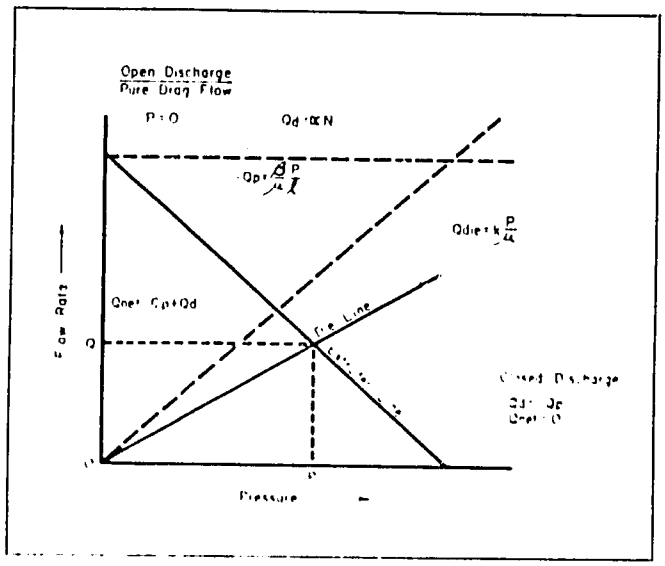


Fig. 6—**OPERATING LINES** *for extruder and die*

Fig. 5—**DIE CONSTANTS** *(Source: Bernhardt, 1968, p. 249)*

sure too low, or dead spots allow large pieces of overcooked material to enter the stream and lodge in the die. Some corrective actions are: frequent die cleaning, streamlining the equipment, and screening of feed material.

HOW CAN MIXING BE IMPROVED?

Increasing pressure flow, leakage flow, and shear will increase mixing but at the expense of output or higher power requirements. Discontinuous flights, mixing pins (stators), and other devices at the downstream end of the extruder can also be used.

HOW CAN COOKING BE INCREASED?

Cooking can be increased by increasing the power input per unit product output rate, increasing external heating, or holding the hot product from the extruder in a chamber between the extruder and die to increase the cooking residence time.

WHAT CAUSES PRODUCT FLOW VARIATIONS?

Multi-orifice dies, which are prevalently used in pasta, snack, and cereal extrusion processes, are subject to problems of product non-uniformity for a variety of reasons:

- **Orifice Size.** Small variations in orifice size can cause large variations in flow rate. Therefore, for uniform flow, all the die orifices should be the same size. This is a general rule, however, and does not hold for cases of non-uniform pressure distribution.
- **Temperature.** Poor temperature distribution in the die will create higher viscosities in the cooler regions of the die and, correspondingly, lower flow rates through orifices in these regions.
- **Location of Orifices.** Often, multi-orifice dies are made with a circular arrangement of holes symmetrical with respect to the extruder axis. In these cases die-hole entrance pressures are the same. For some applications, however, non-symmetrical arrangements are used. If uncorrected, this will result in hole-to-hole pressure variations and, consequently, variations in flow rate. Some solutions to this problem are: increasing the space between the extruder and die to partially equalize the die-hole entrance pressure, and adjusting individual orifice die constants to correct for the pressure differences.
- **Die Plugging.** (See above.)

WHAT CAUSES "SPLITTING" OF EXTRUDED PRODUCT?

Longitudinal die lines and splitting of extruded product are commonly caused by burrs in the die surface or hard pieces of material partially blocking the flow path. They can also be caused by very high flow rates or poor streamlining, which does not allow a smooth flow pattern to develop.

WHAT CAUSES LATERAL STRIATIONS?

Lateral striations in extruded products can be caused by poor flow pattern development and/or shear stresses in the die orifice exceeding the cohesive strength of the product. Reduction of shear stresses by die design, flow rate reduction, or formula changes to strengthen the product can eliminate this.

of material through a resisting die. In an operating extruder, the extrusion pressure, P, is also the P in the die equation, and the Q for the die is the same as Q_{net} in the extruder.

A good way of visualizing extruder and die interactions is to plot flow rate (Q_{net} or Q) as a function of pressure, P. In Figure 6, we have plotted Q_{die}, Q_{net}, Q_p, and Q_d. Since Q_d is independent of P, the slope of its plot is zero, and the ordinate is calculated from Equation 2.

Q_p is zero at zero pressure and increases linearly, as shown in Equation 4. Q_{net} is simply the sum of Q_d and Q_p (note that Q_p has a negative value). The operating pressure and flow rate of the extruder are found at the intersection of Q_{net} (extruder operating line) and Q_{die}.

The advantages of the graphical solution are that experimental data may be plotted directly on the graph and that the effect of changes in variables may be quickly shown.

POWER REQUIREMENTS

The mechanical energy supplied to the screw is dissipated in two ways. Some of the power is used to convey the material through the channel at increasing pressure, but most of the power is converted to heat by viscous dissipation. The following is an approximate equation for the power, Z, of the idealized extruder (Bernhardt, 1968, p. 201):

$$Z = \pi^3 D^2 N^2 \left(\frac{\pi D}{2h}\mu + \frac{ne}{\delta}\mu_L\right) / \qquad [7]$$

This equation shows the effect of the clearance, δ, between the barrel wall and the flight tips. The term μ_L is the viscosity of the material in this clearance. In cooking extruders, the clearance term is very important since these machines generate a great deal of heat due to shear, especially in the typical grooved barrels.

VARIOUS DESIGNS DEVELOPED

Various designs of extruders have been developed to provide different product characteristics. Extruded puffed cereals and snacks require high-temperature, short-time cooking at the proper moisture level for optimum puffing. Extruders for these products generate heat rapidly in the product by operating at high speeds and usually run "starved" so that a low residence time is assured.

Extruders designed to cook doughy (higher moisture) materials provide a longer, gentler cook by operating at lower speeds; they are usually externally heated and have deeply grooved barrels. Extruders

Table 2—**TYPICAL OPERATING DATA** *for five types of single-screw extruders commonly used in the food industry*

Measurement	Description	Typical operating data: Pasta extruder	High-pressure forming extruder	Low-shear cooking extruder	Collet extruder	High-shear cooking extruder
Feed moisture (%)	Illustrates product characteristics and moisture loss due to flashing	22	25	28	11	15
Product moisture (%)		22	25	25	2	4
Product temperature (°F)	The temperature reached within the extruder; when flashing occurs, the temperature drops to the boiling point as the product flows through the die, with a corresponding loss of moisture	125	175	300	390	300
D/h	Represents the relative flight depths of the extruders	6	4.5	7–15	9	7
n	Number of parallel screw channels (leads)	1–2	1	1	2–4	1–3
N (rpm)	Screw speed	30	40	60	300	450
Applied shear rate (sec^{-1})	A function of D/h and N, used as a rough measure of the intensity of shear applied to the product; other factors such as pressure gradient and leakage flow, especially in a grooved barrel, strongly affect the actual shear rate	9.5	9.5	22–47	140	165
$Z_{total}/Q \left(\frac{hp}{lb/hr}\right)$	The total motor horsepower per unit flow rate required to operate the extruder	0.03	0.07	0.07	0.12	0.22
$Z_{net}/Q \left(\frac{hp}{lb/hr}\right)$	That portion of Z_{total}/Q which is dissipated as heat to the food as it goes through the extruder	0.01	0.02	0.01	0.06	0.07
H_s (BTU/lb)	Z_{net}/Q expressed in thermal units	25	50	25	160	175
H_e (BTU/lb)	Heat added to (+) or removed from (−) the food by application of external heating or cooling	0	0	+75	0	−60
H_{total} (BTU/lb)	The total energy received by the product ($H_{total} = H_s + H_e$); related to product temperature and moisture loss	25	50	100	160	115

used for forming high-moisture materials—often called forming extruders—are designed to run cool by minimizing heat generation through barrel and screw design and external cooling, and to generate the high pressures required for shaping.

Grooves are used in the barrels of forming extruders to aid in processing. Although grooves normally reduce flow rate by increasing heat generation (lower viscosity) and allowing leakage (backward flow) over the flight tips, barrels can be grooved to avoid slip at the barrel surface. Slip occurs when the shear stresses at the barrel surface exceed adhesion of the food material to the barrel, greatly reducing the drag flow. This condition can be identified by a sudden drop in flow rate and increase in product temperature, and can be overcome by grooving the barrels to help the material "stick" to the barrel surface.

Spiral grooves (rifling) are used in some extruders to retard or advance the material in the extruder, depending on the direction of the spiral. Barrels for low residence time extruders often use spirals which tend to move the material forward to further reduce the residence time.

SPECIFIC TYPES OF EXTRUDERS

Five types of single-screw extruders commonly used in the food industry are described below, and typical operating data are presented in Table 2.

- **The Pasta Extruder** is used for forming macaroni and similar products from a dough. Of the five extruder types, it is the closest to the idealized extruder in that it has a smooth barrel and no solid conveying section (dough feed), and usually has a constant screw geometry. It is also the closest to an isothermal extruder since it effects the lowest temperature rise.

- **The High-Pressure Forming Extruder** is used for compressing and shaping a pregelatinized dough feed into products which normally require further processing such as deep-fat frying (snacks) and gun puffing (cereals). The operation of this extruder is similar to that of the pasta extruder, except that its barrel is normally grooved. The grooves require additional power and increase the temperature and amount of heat dissipated to the food.

- **The Low-Shear Cooking Extruder** is used as a continuous cooker for high-moisture dough/feeds. This is a flexible unit and has a wide variety of applications. The cooked product must be further processed by forming, drying, etc. The applied shear is higher than that of the forming extruder, but due to the low viscosity (high moisture), most of the energy required for cooking is applied by external heating, despite the fact that deeply grooved barrels and compression screws (variable D/h or pitch) are normally used.

- **The Collet Extruder** cools, puffs, and forms dry granular feeds such as corn meal to produce puffed snack products such as corn curls. This is a very high shear, short residence time extruder. A high rate of energy dissipation is produced by high applied shear rate, deeply grooved barrels, and high viscosity (low moisture). The subsequent high temperature causes violent flashing of the moisture, creating a puffed, dry product. Although this machine has the advantage of requiring little post- or pre-extrusion processing, it is quite inflexible and produces a narrow range of products from a narrow range of ingredients. This and the high-shear cooking extruder are the furthest from the idealized extruder. Large temperature rises, rheological changes, starved operation, and variations in screw and barrel designs make analysis difficult.

- **The High-Shear Cooking Extruder** is similar in operation to the collet extruder except that the residence time is greater and excess heat is removed by cooling the barrel. It is more flexible than the collet extruder in that it can produce many products such as puffed cereals, snacks, and dry pet foods from a wide range of dry ingredients and mixes. The high applied shear rate and long residence time provide good mixing within the extruder, so that water may be injected in the feed section to provide optimum process moisture.

Since the feed moisture is generally higher than for the collet extruder, a higher product moisture remains after flashing (product expansion), which often requires post-extrusion drying. The product temperature and $H_{...}$ are lower than those for the collet extruder and are controlled by varying the applied shear rate, feed moisture, and cooling rate.

These differences result in a longer-time, lower-temperature cook and less violent expansion than the collet extruder provides. The products are usually browner and harder in texture than those of the collet extruder and have more flavor development.

NOMENCLATURE

D	Diameter (inside) of barrel
e	Axial flight land width
h	Screw channel depth
h_d	Height of slot die
k	Die constant
l	Distance measured axially in die direction
l_d	Die land length
N	Screw speed (rpm)
n	Number of parallel screw channels (leads)
P	Pressure
Q_d	Drag flow component
Q_{die}	Flow through die
Q_{net}	Net extruder flow
Q_p	Pressure flow component
R	Radius of cylindrical die
R_i	Inside radius of annular die
R_o	Outside radius of annular die
t	Screw lead ($t=\pi D\tan\phi$) or pitch
v_b	Velocity of barrel relative to screw
v_c	Cross channel component of v_b
v_d	Down channel component of v_b
w_d	Width of slot die
Z	Power
α	Geometry parameter for drag flow equation
β	Geometry parameter for pressure flow equation
δ	Clearance between screw and barrel
μ	Viscosity
μ_{fl}	Viscosity at flight tip
ϕ	Screw helix angle

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24

CFW
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Continuous Cooking of Breakfast Cereals[1]

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Continuous Cooking of Breakfast Cereals[1]

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Cooking is a necessary first step in every breakfast cereal process for the generation of desirable flavor, texture and nutrition. Continuous cooking methods have become increasingly important in cereal manufacturing, due mainly to the significant economic advantages accruing from decreased energy and floor space requirements. In many cases, product quality can also be improved through better process uniformity and control, and by the elimination of stagnation points required for older batch methods to make them compatible with other continuous operations in the overall process.

Looking over the range of methods used to cook cereals, we find that they fall into seven categories:

1) Boiling Water Cookers
2) Steam Cookers
3) Low-shear High-pressure Extruders
4) Low-shear Low-pressure Cookers
5) Adiabatic Extruders
6) High-shear Extruders
7) High-shear Extruders with Steam Pre-cookers

Three different energy sources are available to provide heat needed to cook the product (Figure 1):

1. Conduction: heat transferred through the cooker surfaces from an external source.
2. Convection (of steam): heat transferred to the product by direct contact with steam. This adds both moisture and heat to the product.
3. Conversion (of mechanical energy): heat generated by agitiation or shearing of the product by the cooker surfaces. Virtually all of the mechanical energy applied to the product by external motors is converted to heat in the product. The amount of energy used by the motors depends on product viscosity, cooker geometry and speed of agitation.

Since cooking energy derives from three sources, any combination of energy inputs may be represented as a point on a triangular diagram (1). As shown in Figure 2, each of the cooking processes operates within a range of energy inputs, indicated by zones in the graph.

At one extreme, 100% conversion (lower right apex), we find the adiabatic extruder which generates all of its heat through shear (2). To be effective, this requires operation at low moisture (8-14%). Generally, processing moisture increases with distance from this apex, reaching a maximum of about 50% at the opposite side of the triangle (100% convection to 100% conduction). Points along this line represent various proportions of convection and conduction with no input from conversion of mechanical energy.

Boiling water cooking uses very little mechanical energy—only enough to agitate the low-viscosity mixture. Energy may be supplied by any combination of convection (by injection of steam directly into the water) or conduction of heat via jackets surrounding the cooking vessel.

Similarly, steam cookers use only a small amount of mechanical energy—enough to convey and agitate the product, which is loosely packed to permit steam penetration and offers little resistance. Most of the energy comes from convection, but a small amount of conduction is possible, so that the operating range of steam cooking extends toward the center of the diagram.

Low-shear low-pressure cookers transfer energy to the product mostly by conduction from external jackets, and sometimes from cored agitators designed to circulate heat transfer fluids. In these systems, mechanical energy contributes a small but significant amount of heat to the product, due to the need for efficient and uniform heat transfer at these surfaces through shear and mixing. Since the process does not compact the product greatly, it is possible to use some convection heating, so the operating range covers an area extending into the center of the diagram.

Other low-shear processes are operated at high pressure by restricting flow at the cooker exit. These cookers generate more heat by conversion of mechanical energy needed to convey the product against the pressure gradient, and are not compatible with steam injection due to the compacted nature of the product.

High-shear extruders are perhaps the most flexible of the available cooking processes in that they can operate with a wide range of energy inputs. It is possible to run these extruders adiabatically, but a substantial amount of energy may be transferred to the product by conduction or convection. The process usually proceeds in stages, beginning with a "starved" feed section (the screw is run at a higher speed than necessary to convey the material) which is followed by screw segments designed specifically to provide any degree of shear desired, or to create other starved sections where the product is susceptible to steam absorption.

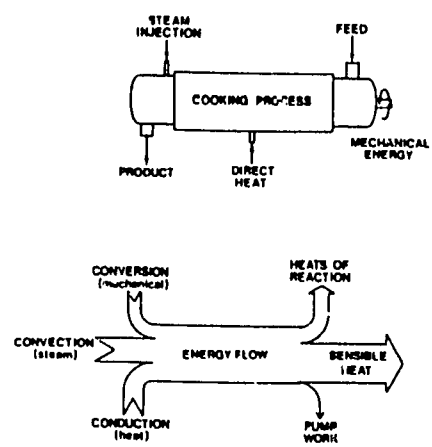

Fig. 1. Generic continuous cooker and energy flow diagram.

[1]Adapted for CEREAL FOODS WORLD® from material prepared by the author for inclusion in a forthcoming book to be published by AACC, entitled *Breakfast Cereals and How They Are Made*, R. B. Fast and E. F. Caldwell, Editors.

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26

Conduction may by accomplished with electrical heaters, jackets, or cored screws.

Staged processing permits use of numerous different operations in series with added flexibility and opportunity for optimization of any particular product. This principle is frequently further extended by preceding the high-shear cooker with a continuous steam pre-cooker which can increase productivity, improve product quality, and decrease operating costs. The operating range of the high-shear extruder with steam pre-cooker is intermediate between steam cooking and plain high-shear extrusion, and is effective in the intermediate to high moisture range.

Continuously Cooked Cereal Products

Finished breakfast cereal products may be classified by the kinds of processing necessary to create their special properties, and fall into the following categories:

1. Flaked Ready-to-eat (RTE) Cereals
2. Puffed RTE Cereals
   a. Gun Puffed
   b. Oven Puffed
   c. Direct Expanded
3. Shredded RTE Cereals
4. Hot Cereals

Flaked cereals are traditionally made from grits or whole grains–along with flavor additives such as malt syrup–in batch steam cookers, which are still in common use. In using the continuous method, an extruded pellet is produced to duplicate the cooked grit properties in the flaking operation. This requires the use of a forming process which is usually a separate step following cooking, but may be integrated into the cooker by creating a distinct process zone for this purpose. Use of extruded pellets in the place of cooked grits has had some success in duplicating traditional products and offers economic, control, and formulation advantages which may lead to eventual replacement of the batch methods.

Much the same can be said about gun-puffed, oven-puffed, and shredded cereals, which began as processed whole grains or grits (3). These also require discrete pieces for further processing after cooking. Extrusion of pellets in a post-cooking forming step can provide the necessary properties for these operations.

Direct expansion, on the other hand, develops most of the final product features within the cooking step. Pre-cooked or instantized cereals similarly undergo most of their structural development in the cooking process, which may also use the direct expansion technique.

Process Conditions

Gelatinization–like any chemical reaction–is not instantaneous, but requires time to proceed. Published experimental results (4, 5) show that the reaction rate is a function of the concentration of ungelatinized starch, which decreases with time. The rate is also a function of temperature, predicted by the classical Arrhenius law (6).

With some modification (4, 5, 7), this has been found to closely reflect the actual gelatinization rate, explaining and quantifying the accelerative effect of temperature on cooking. From these results, the time needed to reach a desired degree of cook is related to cooking temperature by:

$$t \propto \frac{1}{k_o} (e^{E/RT})^{1/T} \propto C^{1/T} \qquad (1)$$

where: t = cooking time (to reach the desired degree of gelatinization)
k_o = reaction rate constant
E = activation energy (also constant for a particular reaction)
R = ideal gas law constant
T = cooking temperature (absolute, K or R)

Although the constants for Equation 1 have been experimentally determined for a range of cereal grains (4), in most breakfast cereal cooking processes, cereal formulas are too complex to allow their direct use. With experimental data on any particular formula and process, however, the form of equation 1 is useful for interpretation and extrapolation of results.

To be of practical size, continuous cooking processes must operate at elevated temperatures which reduce cooking time. Actual cooking methods follow this trend closely, ranging from more than one hour in boiling water at 100° C to only a few seconds at up to 180° C in adiabatic extruders.

Water is a reactant in gelatinization, and also affects the process time – gelatinization proceeds more easily in the presence of excess moisture. In cereal cooking, low moisture processes are associated with high shear stresses, however, which increase the reaction rate by mechanically disintegrating the starch granules, mitigating the low-moisture effect (7). It should also be noted that water activity, not merely water content, is important. Hygroscopic ingredients such as salt and sugar compete with starch for moisture, reducing the effective concentration available for gelatinization, and requiring the use of higher temperatures or longer times to achieve the same results.

The actual time needed to cook cereal products is generally a function of both moisture (interacting with shear) and temperature. Using these variables, a three-dimensional graph may be constructed to show all possible cereal cooking conditions. The typical range of conditions for each of the seven cooking processes is shown as an area on the overall operating surface in Figure 3.

The operating surface is also convenient for illustrating the range of product characteristics from the cooking processes (Figure 4). These are also generally

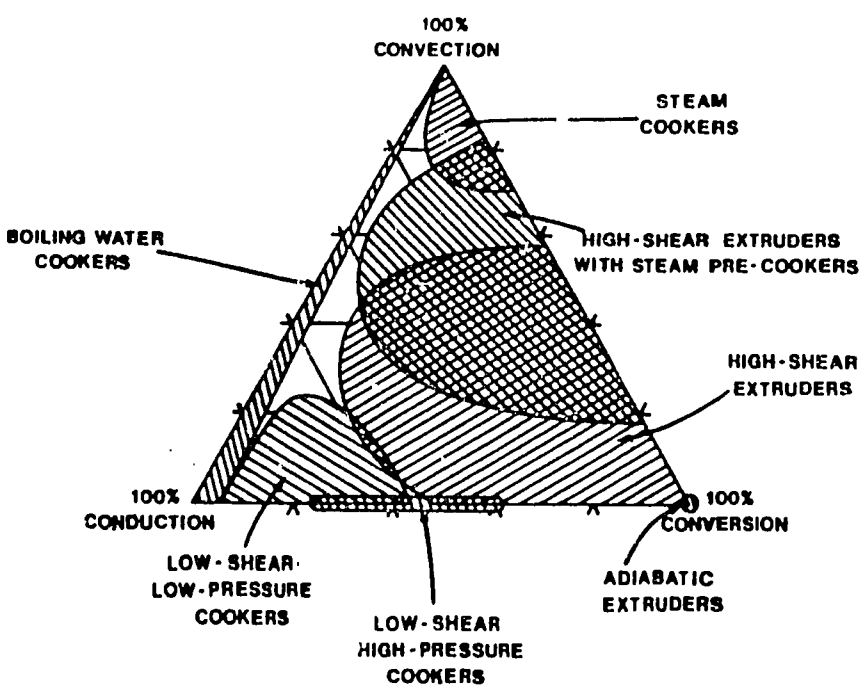

Fig. 2. Three-component energy diagram for cereal cooking processes with typical operating ranges. At any point, the energy derived from each source is proportional to its nearness to each apex. The sides opposite each apex represent all combinations of the other two sources, with no contribution from the first source.

- 71

functions of time, temperature and moisture. Low-moisture, short-time cooking requires the highest temperature, and results in a dry, puffed product, typical of adiabatic extrusion. Increasing the moisture and time decreases the temperature requirement, permitting puffing, but at a higher moisture—typical of high-shear extruders with or without steam pre-cookers. The high-shear cooker with steam pre-cooker can also produce a granular cooked product similar to that of steam cooking when operating under less severe conditions for a longer time. Steam cooking alone produces a granular product from a whole-grain or granular feed, and boiling water is generally useful for whole grains, requiring a long cook time at high moisture and low temperature. Low-shear, low-pressure processes, overlapping to a degree in operating conditions with the high-shear extruders, produce a granular product. High-shear, high-pressure extruders produce a dense, moist product which often forms bubbles of expanded water vapor, but lacks a good puffed structure.

Continuous Cooking Equipment

Boiling Water Systems

The use of boiling water in continuous cooking systems has not become an important method due primarily to the long residence times and associated large equipment sizes needed. Also, the advantages of continuous operation do not easily apply to boiling water cooking, which has been used primarily for whole grain applications and where starch degradation must be absolutely minimized, such as for shredded wheat.

Whole grain boiling usually requires a long holding time (at least several hours) after cooking, to equilibrate product moisture within the grain. This is compatible with batch cooking, normally used for these products. Nevertheless, there has been some activity (8) in developing continuous boiling processes for special purposes.

Steam Cookers

As in the case of boiling water cookers, the use of continuous steam cooking as a complete process is severely limited by residence time considerations. As one component of an integrated cooking system, however, continuous steam cooking has become an important method. When used to precede high-shear cooking extrusion, steam cooking can improve productivity by adding another source of energy, thus generating more energy than the extruder alone could provide. It can also reduce energy costs by replacing expensive mechanical energy (from electricity) with a cheaper form of heat. Of more significance to the product are the effects of longer residence time and reduced shear. Replacing mechanical energy with steam generates heat with less starch damage, and the longer residence time allows moisture to penetrate the product more evenly for a more uniform and complete cook. Typical steam pre-cooker residence times are from one to several minutes, followed by an extrusion time of up to one minute.

Several styles of precooker are available. Sprout-Bauer (Sprout-Bauer, Inc., Muncy, PA) uses pressurized steam (about 10 N/sq cm or 15 psig) to raise product temperature to about 115° C (240° F) in a residence time of about two minutes before it is fed to the extruder, where the temperature is further increased to its maximum value by conversion of mechanical energy. A single-shaft paddle mixer is used to agitate the product for better exposure to the steam and to convey it toward the extruder.

Wenger (Wenger Manufacturing, Inc., Sabatha, KS) uses a similar but less intense pre-cooking step where atmospheric steam raises the temperature to about 100° C in about one minute before extrusion, where more steam may be injected. A double-shaft mixer is used in the pre-cooker.

The system used by Anderson (Anderson International Corp., Cleveland, OH) combines precooking and extrusion by preceding the flighted portion of the screw with a large steam injection section containing mixing blades. Their design lies in a "grey area" between extruder steam injection and precooking, but is closer to precooking in its effect on the product—little mechanical energy is absorbed until the product is conveyed into the flighted part of the shaft. Although the residence time in the steam section is less than that of the separate units at about 15 seconds (9), the steam is efficiently utilized by the direct transfer to the extruder screw.

Low-Shear High-Pressure Cookers

In the early 1950s, the idea of utilizing extrusion as a means of cooking foods began to assume significance, particularly in breakfast cereal processing. The cereal companies became pioneers in adapting equipment originally intended for ceramics or plastics manufacturing (10). Early successes in the field were achieved in a two-stage process of cooking and forming, both done by low-shear single-screw extruders (Figure 5) a method still in common use. In newer systems, this is sometimes accomplished in distinctly separate zones on the same extruder shaft.

Low-shear high-pressure cooking uses relatively low screw speeds to generate less than about 100 sec of applied shear. Average shear rate may be calculated approximately by applying the equation of motion (11) with simplifying assumptions as follows: the product is an ideal (Newtonian) fluid in an annular space between an inner rotating cylindrical surface (the screw root) and an outer concentric stationary surface (the barrel surface):

$$\bar{\gamma} = 8\pi N \frac{(\kappa r_i)^2}{(R^2 - r_i^2)^2} \ln \frac{R}{r_i} \qquad (2)$$

which, in the case of a thin annulus (shallow screw flight) may be further simplified to:

$$\bar{\gamma} = \pi N \frac{R + r_i}{R - r_i} \qquad (3)$$

These expressions may be used to

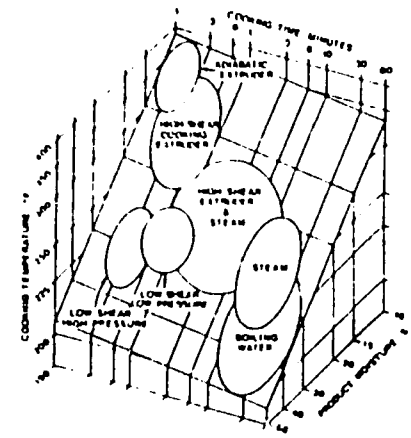

Fig. 3. Range of cereal cooking conditions: Time, Temperature, and Moisture, with typical ranges of cooking process styles.

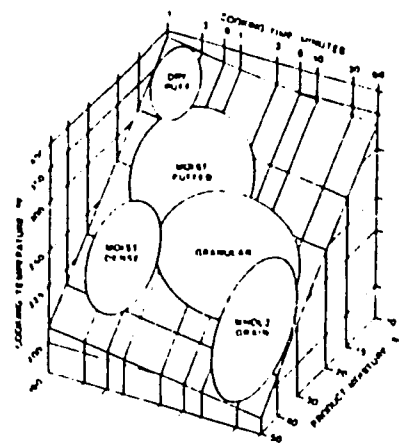

Fig. 4. Product characteristics from different regions in the range of cooking process conditions.

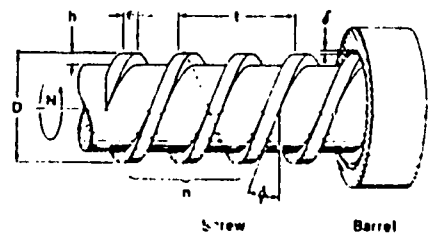

Fig. 5. Single-screw extruder screw geometry.

estimate the product shear at any point along the extruder length for rough comparative purposes. (For a more rigorous calculation, the actual rheological properties of the product, extruder geometry and operating conditions must be taken into account.)

The feed material is usually a dough or wet (about 30% moisture) granular mix which is choke fed, meaning that the feed hopper is kept full and the feed rate is determined by the ability of the screw to draw material from the hopper. In the Bonnot system (The Bonnot Co., Kent OH), a long screw and barrel (L/D, or screw diameter to length ratio, of about 20) is used to generate extrusion pressure and to provide sufficient surface area for efficient heat transfer from the surrounding steam jackets. Most of the cooking energy is supplied by this conductive heating, but a substantial amount (about 30%) is generated by conversion of mechanical energy. Mechanical energy is required for mixing, good heat transfer and homogenization of the product, and is created by high-pressure operation (several hundred N/sq cm or psi) caused by discharging the product through a small orifice or die.

The Bonnot type extruder also normally utilizes a compression screw (up to 9:1 reduction in channel volume) with variations in both screw pitch and channel depth. This is useful in eliminating air in the product by squeezing it out of the feed hopper, but is more important in generating the desired pressure profile which typically reaches a maximum before the die. Grooved barrels are also the norm. These serve two functions: reduction of slippage at the barrel surface and increase of back-flow over the flight tips where shear and heat transfer are maximum.

By borrowing again from the plastics industry, another type of low-shear extruder has been adapted to cereal cooking—the counter-rotating twin-screw machine (Figure 6). The principle of this extruder differs in several important ways from that of the single-screw. It is more of a positive-displacement pump and therefore does not necessarily generate much heat by conversion of mechanical energy. The flow patterns developed in the intersecting screw channels nevertheless create sufficient mixing for good heat transfer so that conduction heating is efficient. Enormous pressure can be generated if desired, even with low viscosity materials, which is particularly useful for high moisture cooking. When shear is desired, it must be generated in a separate process. Textruder (Textruder Engineering AG, Portugal/Raymond Automation Co., Norwalk, CT) accomplishes this with tapered and straight screw models by supplying a follow-up unit consisting of a single-screw extrusion stage or a special shear disk unit. Similar equipment is available from Cincinnati Milacron (Cincinnati Milacron, Cincinnati, OH). Twin-screw extruders of both the counter-rotating and co-rotating variety (discussed next) may also be used for high-shear cooking.

A great deal of attention is now being paid to the latest style of extrusion cooker, the co-rotating intermeshing

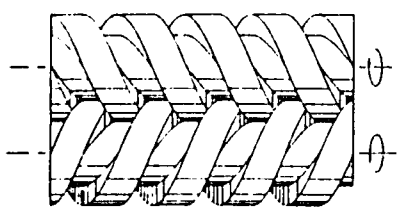

Fig. 6. Intermeshing counter-rotating extruder screws.

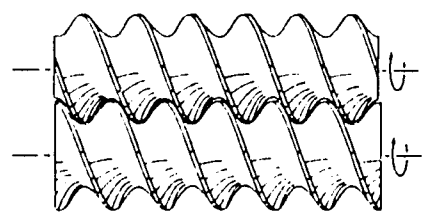

Fig. 7. Intermeshing co-rotating extruder screws.

twin-screw type, also adapted from the plastics industry (Figure 7). It has seen widespread use for foods only in the last decade. Several companies offer similar equipment, including Clextral (Clextral, Inc., Odessa, FL), who made the earliest significant penetration into the food industry. Clextral was followed quickly by others (Werner & Pfleiderer, Inc., Ramsey, NJ and Baker Perkins FES, Inc., Grand Rapids, MI), who had also been suppliers of plastics machinery. Responding to competitive pressure, other food extruder companies, including Wenger and Buhler (Buhler Miag, Inc., Minneapolis, MN), have introduced their own versions of the co-rotating twin-screw extruder.

The co-rotating twin is the most versatile (and expensive) style of extruder available, in that it can operate over a range of conditions including those of most of the other more specialized machines, depending on the particular screws and operating variables selected. A self-wiping action between the intersecting screws makes it very effective as a heat exchanger so that conductive heating in the low-shear mode can be used efficiently. In this mode, where screws are selected to limit shear, the residence time distribution is quite narrow (meaning that the product receives more uniform processing), although still wider than that of the counter-rotating twin (12, 13, 14). It is difficult to differentiate between high and low shear operation in the co-rotating twin except by an arbitrary standard, since there is a continuum of possible conditions as more shear is added with reverse pitch screws and mixing elements and with increasing screw speed, which is variable over a wide range up to about 400 rpm.

As a pre-forming high-moisture cooker, however, the co-rotating machine does the same job as the low-shear, high-pressure cooking extruder. It requires a post-cooking step which can be a single or twin-screw extruder, a forming stage within the cooker, or some other forming step for the cooked, plastic (high moisture) material.

Low-Shear Low-Pressure Cookers

Several kinds of equipment have been developed for continuous cooking under low-shear and low-pressure conditions for minimum starch degradation. This is an assorted category with no common underlying principles beyond the main goal. The following examples illustrate some of the approaches which satisfy the stated needs.

Mapimpianti (MAPA, Heat and Control, Inc., Lancaster, PA) has developed a cooking process based on an extended macaroni extruder design. It uses a single-screw extruder with a series of compression stages which redistribute the flow for improved heat transfer in the absence of high shear or pressure development. The product is not compacted, and remains in a granular state throughout the process, making it suitable for incorporation of other ingredients after cooking and before forming. MAPA supplies a modular process line which includes an intermediate mixing/tempering stage. To maintain the desired granular structure, the product is not forced through a die, but emerges through an essentially open discharge after the last compression stage. Small, stationary blades at the discharge are used to break up agglomerates.

A different approach is used in the Readco cooker (Teledyne Inc., Readco Division, York, PA), which is based on the co-rotating twin-screw extruder principle, but with exaggerated geometrical proportions. Since this cooker was developed as a continuous mixer, the screw flights are very deep and taper off to a very thin cross-section at their tips. Efficient mixing is achieved by the transfer of material between the screws. This does not consume a great deal of mechanical energy, but is conducive to good heat transfer from the jacketed barrel and, in larger sizes, from cored screws. The machine is not capable of generating high pressure, and discharges

through a large opening which is usually fitted with a swinging gate to control resistance. This in turn controls residence time and mechanical energy consumption–important factors in determining the degree of cook. Alternately, the cooker can discharge directly into a single-screw extruder mounted perpendicularly to the cooker axis to form the product or generate pressure when desired.

A third approach to low-pressure cooking has been taken in the unique Buss-Condux design (Buss-Condux, Inc., Elk Grove Village, IL), which had a similar origin in continuous mixing. This design uses a single cut-flight screw which intermeshes with blade-shaped stators extending inward from the barrel. The screw not only rotates, but reciprocates axially so that the stators are wiped on both upstream and downstream surfaces by the screw segments, which are in turn also wiped. In many respects, this mechanism accomplishes the same ends as the co-rotating twin-screw extruder, with similar advantages in heat transfer efficiency. Like the Readco machine, however, it cannot generate high pressure, and must be linked to other processes to complete the system.

Adiabatic Extruders

Adiabatic extrusion combines cooking, forming, puffing and partial drying in one high-temperature short-time process. It is a specialized method limited to direct-expanded products, with very high shear rates generating all of the cooking heat. This kind of extruder is available from Dorsey-McComb (Dorsey-McComb, Inc., Denver, CO), among others.

High-Shear Extruders

High-shear extrusion is the most versatile of the cooking processes; wide ranges of operating conditions and product characteristics are made possible by the various energy input options. Commercial extruders, in single and twin-screw styles, have some or all of the features shown in the generalized extruder drawing, Figure 8.

Cereal ingredients in an uncompacted state have a density of about .43 to .80 g/cm^3 (15). Unless made into a high moisture dough with fluid properties, this low-density is maintained in feeding devices where the material must be capable of flowing freely. Once inside the cooking process, the feed is subjected to pressure and shear, which compact it to a density of around 1.2 to 1.6 g/cm^3, depending on moisture and formulation (16, 17).

To accommodate low feed density, feed screws must be of long pitch, with high volumetric capacity. Twin-screw feeding is aggravated by poor conveying efficiency in the feed throat. In fully developed flow, material shifts back and forth between the intermeshing screws. This pattern takes a finite time to reach equilibrium, however, so that in the feed section, one screw – the one which pulls the feed downward – runs "full," while the other is more or less empty for the time required for product transfer between screws. This results in a volumetric efficiency as low as 50% for the first increment of screw length in the feed section.

Since the feed material in high-shear cooking is usually granular, the feed section is normally run "starved" to permit easy flow into the extruder throat. The feed rate is externally controlled and maintained at a point below the volumetric screw capacity, further reducing conveying efficiency.

Once past the feed throat, at a point where flow patterns have been developed within the surrounding barrel, the screw pitch is reduced to start compressing and intensively mixing the feed. In some processes, special mixing elements are used for this purpose. They may consist of cut flight or reverse-pitch screws or -- in the twin-screw extruder—lobe or disk-shaped kneaders. The mixing section is useful for intimate blending of solids, which may be fed as separate streams into the feed section, and for incorporation of liquid streams, which are commonly injected through the barrel at this point. This configuration is sometimes repeated at other points along the barrel in staged processes which require the addition of other ingredients after some processing has been completed—a useful way of adding heat-sensitive components such as flavorings.

Conductive heating or cooling may be employed in the feed and mixing sections. Cooling can help to develop flow patterns for pressure generation and can condense any water vapor flowing back from the high temperature cooking section, a particular problem in single-screw extrusion where steam rising through the feed throat can interfere with feeding and create a mess. Where these problems do not exist, the cooking process may be given a head start by adding some heat to the mixing zone.

The screw channel is commonly full at the mixing zone exit, creating a barrier to

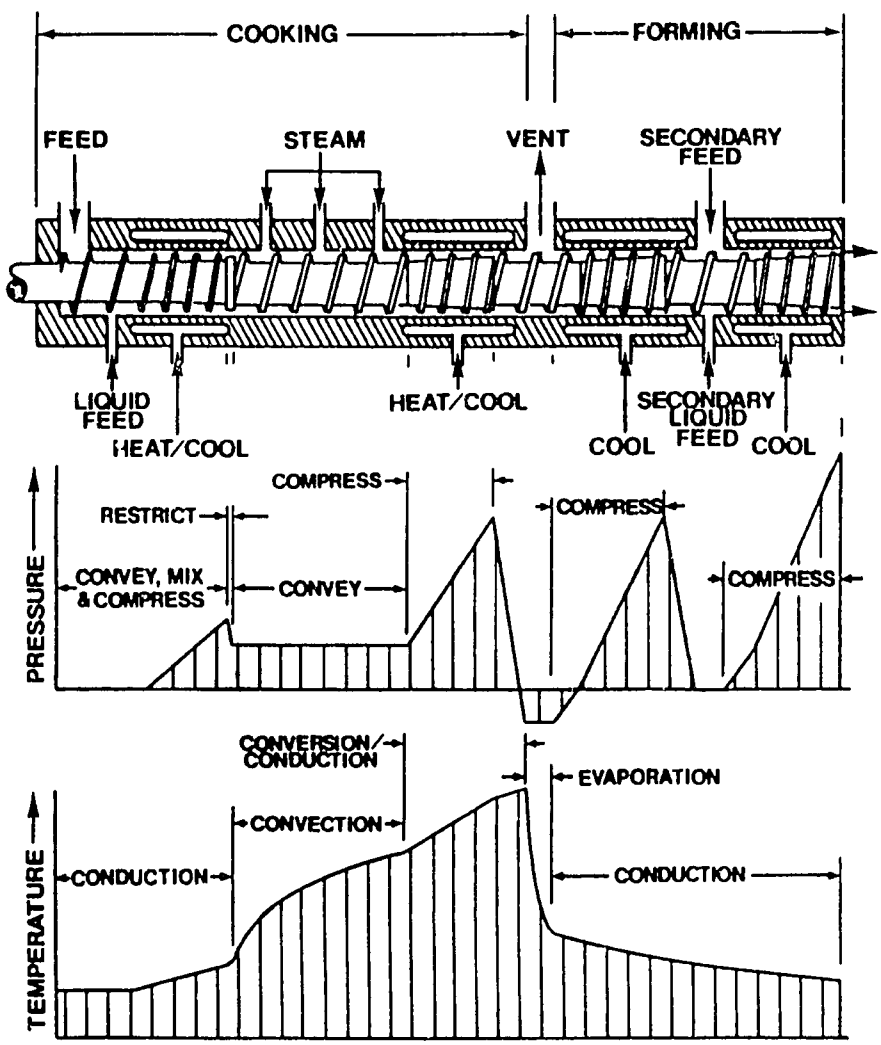

Fig. 8. Generalized high-shear cooking extrusion process with integral forming section. Center: Schematic pressure profile corresponding to sections of the high-shear extruder, with mechanical functions of screw elements. Bottom: Schematic temperature profile of extruder with zones of energy output.

31

backward vapor flow. Where desired, a full channel is purposely created by the selection of screws, mixing elements or flow restrictors to cause the material to build up as pressure rises. With a barrier in place, steam may be injected through the barrel to accomplish the first cooking stage. (As noted under Steam Cookers, this is done in a separate operation in some systems, and not at all in others.) The degree of heating possible with steam cooking is limited by the allowable moisture gain in the product (for low-moisture extrusion it is not appropriate), and by practical limitations on steam pressure (for short residence-time continuous cooking, a temperature of 180° C (350° F) would require a steam pressure of at least 100 N/sq cm or 150 psig). As a first stage, however, it is an efficient way of rapidly and uniformly increasing product temperature without the danger of scorching; steam "seeks out" and condenses on the coolest portions of the product, and also it is not subject to the scale-up limitations of heat exchange surfaces. To insure intimate and effective steam/product contacting, however, a sufficient open volume must be provided within the barrel. This is done by creating another starved section using long pitch screws.

The final cooking stage is done at elevated pressure and under high shear, which serves two functions--generation of heat by conversion of mechanical energy, and improvement of heat transfer efficiency. In the final cooking stage, conductive heating may be applied from a jacketed barrel (steam or heat transfer fluids) or electric heating elements (resistance or induction) but is limited by heat transfer rates. The final temperature rise is therefore normally accomplished by conversion of mechanical energy.

Pressure in the final cooking stage is maintained by forcing the product to exit through a restrictive orifice. If the product emerges from the process in its superheated state, it rapidly flashes off enough moisture to cool it down to equilibrium with the atmosphere. This effect may be increased by flashing the product off into a vacuum, accomplished by the use of a vent port through the barrel wall. Venting requires that fluid pressure be reduced to zero to prevent flowing into the vent. This is assured by creating another starved section with long-pitch screws, and is more easily done with twin-screw extruders, which have better pumping characteristics. In cases where rapid cooling is not needed, and where product expansion is to be avoided, conductive cooling may be applied after cooking.

Barrel vents may also be used for feeding additional ingredients to the system after cooking is completed. This is especially useful for the addition of heat-sensitive materials, and is normally used only when followed by an integral cooled forming section.

Conclusions

With all of the options available, how does one choose a cooking process? The first criterion is that of product identity-starting from the desired product configuration, several options may be eliminated as inappropriate. Thereafter, the choice becomes one of economy and quality. Economic evaluation may be accomplished to a degree by theory (selecting the cheapest form of energy for a particular geographical area, for example) to further narrow the field. Alas, after this point, further winnowing of the options depends on experience, normally requiring tests with various methods to determine their effect on particular product characteristics. Fortunately, most equipment manufacturers have excellent pilot plant facilities for this purpose, and can also provide some direction in obtaining the best results with their processes (along with a litany of their superiority over everyone else in the field).

In interpreting the information thus gathered, it is important to think in terms of the product environment in each case, and how that environment affects the product—regardless of superficial mechanical differences. There is more than one way to skin a cat—or to puff a groat.

Robert C. Miller, P. E.

Robert C. Miller is a consulting engineer specializing in extrusion processing methods and extruded food products. A licensed professional engineer, he received his degree in chemical engineering at Newark College of Engineering (NJIT).

Miller has been developing new industrial applications of food extrusion since 1965, particularly in the R & D laboratories of Nabisco Brands and Borden Foods, and as an independent consultant. His experience also includes other areas of food technology, including fruit and vegetable processing while at the New York State Agricultural Experiment Station (Cornell University). Miller is the author of numerous research papers and articles and has been awarded a number of patents for food processing methods.

He is member of AIChE, IFT, ASAE, R & D Associates for Military Food and Packaging Systems, and VITA.

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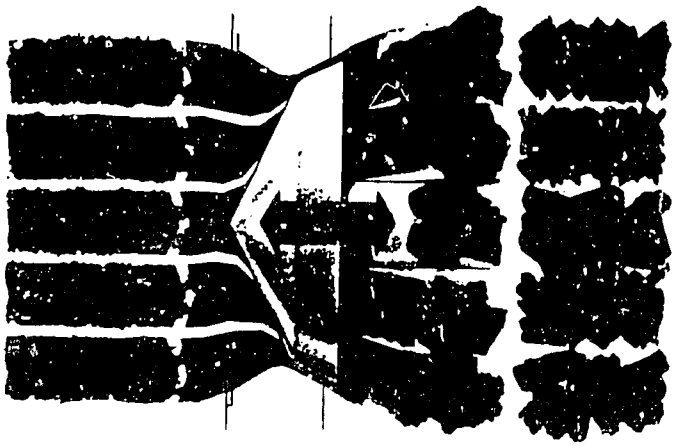
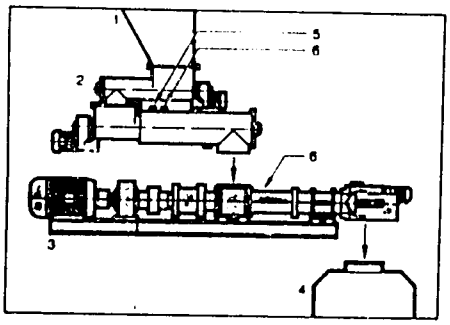
32

High-Pressure Conditioning with the Annular Gap Expander

The short-term conditioning technique with high temperature before pelleting!





1 bin
2 dosing and mixing combination
3 annular gap expander
4 pelleting press
5 fat/molasses
6 steam

Outlet cross section, pressure and temperature can be adjusted during operation

Hygienized product

Salmonellae killer

Starch modification

Increased press output

Improved pellet quality

High fat and molasses additions

No higher total energy consumption

Victam-Asia Stand 607-707

Improvement of the Compound Feed

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Kahl

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Extrusion COMMUNIQUÉ

Six words summarise Extrusion Communiqué's first attempt to compile an extruder directory - Extruder users are spoilt for choice!

In preparing the food/feed industry's first ever International Directory of Extruder Manufacturers, we were pleasantly surprised to discover an impressive line-up of highly developed machines readily available.

We have taken care to present information which will assist prospective buyers during the initial inquiry stage and help him understand machine differences and similarities. It is not our intention to draw comparisons between machines nor recommend one machine over another.

In fact, we would recommend buyers approach as many equipment manufacturers as possible in the area of their choice as there is more to successful extrusion cooking than a compilation of technical statistics.

Some manufacturers have chosen not to disclose machine details while others, unfortunately, missed the deadline. A number of these suppliers are located at the end of the directory where they are listed alphabetically.

When using information from this directory to contact equipment manufacturers, please refer to the First International Extrusion Directory. Your reference will ensure bigger and better-value directories in future.

Au cours de la préparation du Premier Annuaire International des Fabricants d'Extrudeurs nous avons été impressionné par le nombre important de machines de pointe disponibles dans le monde. Notre but est de faciliter les premières démarches de l'acheteur potentiel en l'aidant à comprendre les différences et similitudes entre les machines.

In Vorbereitung des ersten Internationalen Verzeichnisses über Extruder-Hersteller für die Nahrungs-/Futtermittelindustrie, sind wir auf eine beeindruckende Auflistung hochentwickelter Maschinen, die weltweit verfügbar sind, gestoßen. Wir haben uns bemüht die Informationen zu erarbeiten, die einem Interessenten die Vorauswahl erleichtern und ihm helfen sowohl die Unterschiede als auch die Ähnlichkeiten verschiedener Maschinen zu verstehen.

식품 및 사료산업을 위하여 처음으로 익스트루더 제조업체에 대한 명부를 작성함에 있어 전세계적으로 가장 진보된 기계의 공급회사들만을 수록하였습니다.

특히 기계간의 차이점과 유사점 등도 파악될 수 있도록 노력을 하였으니 좋은 참고가 되길 바랍니다.

爲了籌備第一期國際食品／飼料工業擠出機製造商名錄，我們蒐集了世界性高度發展的機器。
這些資訊對於買主在最初的詢價階段會有助益並且可以協助買主了解各個機器間的不同處或相似點。

First International Directory

COMPANY NAME	Model	Type: Single			Type: Twin					Price range	Main motor (kW)				Screw		Barrel		Control			
KEY: ■ This facility is optional ○ This facility is offered *Prices are given as a guide only*		*Form/Shape*	*Tapered*	*Barrel bolts*	*Steam locks*	*Counter rotating*	*Co-rotating*	*Tapered*	*Parallel*	*Fully self-wiping*	*Intermeshing*	US$ ('000)	*No of motors*	*Total kW*	*Gear box*	*Belt drive*	*Diameter (mm)*	*Maximum screw speed (rpm)*	*Length (number of diameters) Min-max*	*Capacity (kg/hr) Min-max*	*Fully-auto start*	*Semi-auto start*	*Manual start*	*Process control*
Almex BV PO Box 1043 7230 AA Warnsveld The Netherlands *Tel +31 5750 11012* *Fax +31 5750 18222*	AL 50	○		○	○							50-200	1-2	35	○	○	50	30	6	50	○	○	○	○
	AL 150	○		○	○								1-2		○	○					○	○	○	○
	AL 200	○		○	○								1-2	DC	○	○					○	○	○	○
	AL 300	○		○	○								1-2		○	○					○	○	○	○
	AL 400	○		○	○								1-2	500	○	○	400	450	16	10t/hr	○	○	○	○
Anderson International Crp 6200 Harvard Avenue Cleveland Ohio 44105, USA *Tel +216 641 1112* *Telex 980259* *Fax +216 641 0709*	12" EEC			○								Price on request	1	186-373		○	304.8	360	12	10t/hr		○		
	10" EEC			○									1	112-373	■	○	254.0	360	12	8t/hr		○		
	08" EEC			○									1	56-93		○	203.2	360	12	4t/hr		○		
	06" EEC			○									1	37		○	152.4	280	12	1t/hr		○		
	4.5" EEC			○									1	19		○	114.3	280	12	250		○		
Amandus Kahl NACHF Dieselstrasse 5-9 Postfach 1246 D-2057 Reinbek b. Hamburg Germany *Tel. +49 40 727710* *Telex: 217875KAHL D* *Fax: +49 40 72771100*	OE 15			○								Price on request	1	45	○	○	150	300	8	3t/hr	○	○	○	○
	OE 23			○									1	200	○	○	280	300	4	15t/hr	○	○	○	○
	OE 38			○									1	305	○	○	380	300	5	25t/hr	○	○	○	○
	OE 38/2			○									2	400	■	○	380	300	5	30t/hr	○	○	○	○
APV Baker Ltd Westfield Road Peterborough PE3 6TA England *Tel: +44 733 262000* *Telex: 32311* *Fax: +44 733 265017*	MPF 40					○		○	○	○		Price on request	1	14	○		40	500	15	70	○	○	○	○
	MPF 50					○		○	○	○			1	28	○		50	500		150	○	○	○	○
	MPF 65					○		○	○	○			1	60	○		65	500		300	○	○	○	○
	MPF 80					○		○	○	○			1	115	○		80	500	25	600	○	○	○	○
	MPF 100					○		○	○	○			1	225	○		100	500		1200	○	○	○	○
	MPF 125					○		○	○	○			1	350	○		125	400		2400	○	○	○	○
	MPF 160					○		○	○	○			1	600	○		160	325	35	3200	○	○	○	○
	BPF 100	○											1	6.7	○	○	100	40	6	200	○	○	○	○
	BPF 200	○											1	30	○	○	200	40	10	1000	○	○	○	○
Berga SpA Quinto di Traviso via Fratelli Bandiera 3 31065 Italy *Tel: +39 422 379431* *Telex: 410316 311870 BERGA I* *Fax: +39 422 370462*	ES/S 3.2	*Initial spin processing*						○				55-92	1	55		○	202	110	3200mm	800	○	○	○	○
	ES/C 3.2	*Crystals processing*						○					1			○	202	220			○	○	○	○
	ES/PF 2.5	*Purpose Compounding*						○					1	110		○	202	300	2500mm	3500	○	○	○	○
Brabender Ohg Duisburg KulturstraBe 51-55 D-4100 Duisburg 1 Germany *Tel: +49 203 738010* *Telex: 855 603* *Fax: +49 203 7380149*	DSE 35/12					○			○		○	Price on request	1	8.5	○		35	200	12	30-40			○	○
	19/20 DN	○											1	3.3	○		19	250	20	5-10			○	○
Buhler AG CH-9240 Uzwil Switzerland *Tel: +41 73 501111* *Telex: 883131 GBU CH* *Fax: +41 73 503379*	BIEX											Price on request												
	DNDL -44					○			○				1	18	○	○	44	450	12-40	10-80	○	○	○	○
	DNDG -62					○			○				1	72	○	○	62	450	12-40	100-600	○	○	○	○
	DNDH -125					○			○				1	300	○		125	300	12-40	1000-5000	○	○	○	○
	DNDJ -175					○			○				1	600	○		175	300	12-40	3000-8000	○	○	○	○
	DNEB -130												1	75			130	500	5.5-8	500-700			○	

Feeder					THE BARREL								Wear resistance								Safety				Optional extras	Application	
					Mixing/Cooking					Die/Cutters			Barrel				Screw										
Capacity (ltrs)	Drive (kW)	Twin-screw	Single-screw	Loss-in-weight	Length of temp control zone (no of dia)	Vacuum venting	Secondary feed ports (no)	Max operating temperature	Max discharge pressure	Motor (kW)	Variable speed	Co-extrusion	Through-hard	Bi-metalic	Nitrided	Other	Through-hard	Bi-metalic	Nitrided	Other	Guard at throat	Guard at barrel	Guard at die	Guard at cutter		Food products	Feed products
150	0.33	○	○	■	4	■	■	210	60	1.5	○	■	○		■		○	○	○	■		○	○	○	Flaking equip. pre-cooker, contivar die head, forming equipment	Crl, flakes	Aml, P/F, Rms, Oil, Oth
—	—	○	○	■	—	■	■	210	60	—	○	■	○		■		○	○	○	■		○	○	○			
—	—	○	○	■	—	■	■	210	60	—	○	■	○		■		○	○	○	■		○	○	○			
200,	—	○	○	■	—	■	■	210	60	—	○	■	○		■		○	○	○	■		○	○	○			
000	4	○	○	■	16	■	■	210	60	15	○	■	○		■		○	○	○	■		○	○	○			
					5-6			205	68	7.5	○			○		○		○		○	○	○	○	○	Constant water-pressure systems, international sourcing of ancilary equipment, total process system engineering, auto-steam injection programmable	Snk, Csm-Cfm's, infant foods, pre-gelatinised starches	Aml, P/F, Rms, Oil, poultry and piglet feeds
					5-6			205	68	7.5	○			○		○		○		○	○	○	○	○			
					5-6			205	68	3.7	○			○		○		○		○	○	○	○	○			
					5-6			205	68	1.5	○			○		○		○		○	○	○	○	○			
					12			205	68	1.5	○			○		○		○		○	○	○	○	○			
			○			○		150	60	3.0	○	○		○				○			○	○		○			
			○			○		150	60	5.5	○			○				○			○	○		○			
			○			○		150	60	5.5	○			○				○			○	○		○			
			○			○		150	60	22	○			○				○			○	○		○	Product pressure control by annular gap (hydraulic)		Aml, P/F, Oil, Rms, Oth
			○			○		150	60	22	○			○				○			○	○		○			
■		○	○	○	2.5	○	■	350	155	11-15	○	○		○	○	○				○	○	○	○	○	Dies - standard to customer spec, die support arms, cooling, additional feed ports, barrel value, controlled cooling of feed zone, additional product temp probes, vacuum venting	Crl, Snk, Crl, Con, Oth	P/F, Aml, Rms Oil, Oth
■		○	○	○	2.5	○	■	350	135	15-22	○	○		○	○	○				○	○	○	○	○			
■		○	○	○	2.5	○	■	350	155	22-37	○	○		○	○	○				○	○	○	○	○			
■		○	○	○	2.5	○	■	350	155	37-75	○	○		○	○	○				○	○	○	○	○			
■		○	○	○	2.5	○	■	350	155	7.5-11	○	○		○	○	○				○	○	○	○	○			
■		○	○	○	2.5	○	■	350	155	11-15	○	○		○		○				○	○	○	○	○			
■		○	○	○	2.5	○	■	350	155	19-25	○	○		○		○				○	○	○	○	○			
					6				135	2.2	○		○						○		○	○	○	○			
					10				135	3.7	○		○						○		○	○	○	○			
			○		3-6	○		125-160	400	5.5	○			○				○					○	○	Complete plants		Aml, P/F, Oil, Rms, Oth
			○		3-6	○		125-160	400	5.5	○			○				○					○	○			
			○		3-6	○		125-160	400	5.5	○			○				○					○	○			
3	0.45		○		2x7	■	■	450	500	0.065	○		■		○		■	■	■	○				○	Torque-pressure measurement control by computer viscosity test with capillary dies	Snk, Crl, Oth.	P/F
20	0.55	○	○		3x3	■	■	450	500	4.4	○		■		○		■	■	○	■			■	○			
0.18		○	○	○	180mm	○	○	250	150	0.75	○	○	○	■		○	○				○	○	○	○	Steam conditioner, direct steam addition	Snk, Crl, Oth.	Aml, P/F, Oil, Rms, Oth
0.25		○	○	○	250mm	○	○	250	150	2.2	○	○	○	■		○	○				○	○	○	○			
1.5		○	○	○	500mm	○	○	250	150	3.0	○	○	○	■		○	○				○	○	○	○			
2.2		○	○	○	750mm	○	○	250	150	3.5	○	○	○	■		○	○				○	○	○	○			
1.0		■	○		150mm			200	150	1.5	■	■			○						○	○	○	○			

35

COMPANY NAME	Model	Type: Single: Form/Shape	Single: Tapered	Single: Barrel bolts	Single: Steam locks	Twin: Counter rotating	Twin: Co-rotating	Twin: Tapered	Twin: Parallel	Twin: Fully self-wiping	Twin: Intermeshing	Price range US$ ('000)	Main motor (kW): No of motors	Main motor (kW): Total kW	Main motor (kW): Gear box	Main motor (kW): Belt drive	Screw: Diameter (mm)	Screw: Maximum screw speed (rpm)	Barrel: Length (number of diameters) Min-max	Barrel: Capacity (kg/hr) Min-max	Control: Fully-auto start	Control: Semi-auto start	Control: Manual start	Control: Process control
Buss AG CH-4133 Prattein 1 Switzerland *Tel: +41 61 8256111* *Telex: 968080* *Fax: +41 61 8256699*	LR 100			○	○					○	○	Price on request	1	45	1		100	300	19	50-700	○	○	○	○
	LR 200			○	○					○	○		1	115	1		200	250	19	250-4000	○	○	○	○
	LR 300			○	○					○	○		1	200	1		300	150	15	500-12000	○	○	○	○
	LR 400			○	○					○	○		1	280	1		400	120	15	1000-16000	○	○	○	○
Cincinnati Milacron Laxenburg StraBe 246 A-1232 Wien, Austria *Tel: +43 222 610060* *Telex: 131518CMAW A* *Fax: +43 222 610068*	CONICAL																							
	CM 45-F					○			○	○	○	180	1	20	○		45-90	80		30-200		○	○	○
	CM 80-SCF					○			○	○	○	360	1	100	○		80-143	63		300-1200		○	○	○
	CMT 35-F					○			○	○	○	100	1	9	○		37-75	50		20-80		○	○	
Clextral Z.I de Chazeau BP 10, 42702 Firminy Cedex France *Tel: +33 77 403131* *Telex: 330402F* *Fax: +33 77 403123*	BC 160					○			○	○	○	Price on request	1	415-2060	○		200	387	11-20	4000-14000	○	○	○	○
	BC 105					○			○	○	○		1	138-645	○		132	421	10-31	800-7000	○	○	○	○
	BC 92					○			○	○	○		1	98-453	○		115	444	9-30	400-4000	○	○	○	○
	BC 82					○			○	○	○		1	71-310	○		102	444	9-30	200-2500	○	○	○	○
	BC 72					○			○	○	○		1	48-226	○		88	485	7-31	100-1600	○	○	○	○
	BC 45					○			○	○	○		1	15-66	○		55.5	614	9-32	40-500	○	○	○	○
	BC 21					○	○		○	○	○		1	2-9	○		25	682	12-36	5-60	○	○	○	○
Kovan Engineering 10 Alexander Drive Burwood, Melbourne Victoria, Australia *Tel: +61 3 8084300* *Fax: +61 3 8888479*	DYSON K 160	○										50-100	1	55	○					160			○	○

KEY:
■ This facility is optional
○ This facility is offered
Prices are given as a guide only

Extru-Tech E750

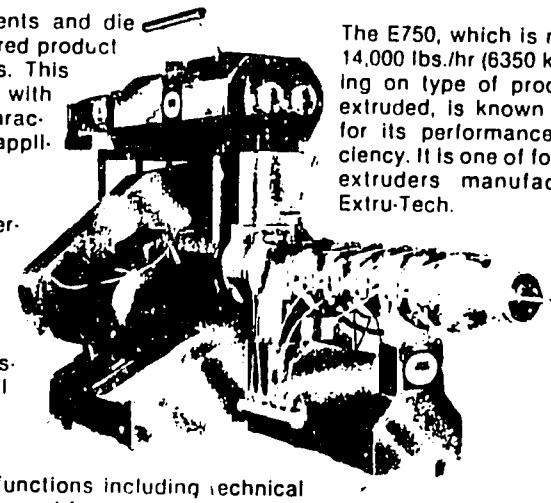
"The one tool no production plant should be without!"

We at Extru-Tech, Inc. see our E750 Cooking Extruder as being a production "tool" that excels in three specific areas:

(1) Product Versatility
With only minor adjustments to barrel components and die plate, the E750 can control density and meet desired product specifications for a variety of extruded products. This allows for efficient production of aquatic feeds with either "sinking", "slow-sinking", or "floating" characteristics, and also for many small animal petfood applications.

(2) Product Quality
Because the E750 can control product characteristics, such as percent cook, product expansion, and product shape, superior product quality can easily be achieved.

(3) Low Maintenance/Less Energy
Due to preconditioning of feedstock prior to processing, the E750 incurs less maintenance cost on barrel components and also enables the machine to be more energy efficient.



The E750, which is rated up to 14,000 lbs./hr (6350 kg) depending on type of product being extruded, is known worldwide for its performance and efficiency. It is one of four cooking extruders manufactured by Extru-Tech.

*Extru-Tech, Inc. offers a wide variety of service functions including technical service, plant layout/design, and research facilities used for product development.

**Extru-Tech, Inc.'s commitment to single supplier responsibility can be seen by their ability to offer other system components such as drying/cooling units, fat application systems, pneumatic conveying equipment, etc.

Corp. Office:
P.O. Box 8, 100 Airport Road
Sabetha, KS 66534, USA
913-284-2153/913-284-2178 or
FAX 913-284-3143

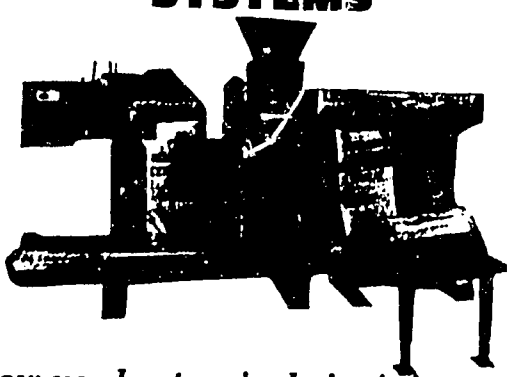
EXTRU-TECH, INC.

Export Division:
P.O. Box 4000, Olathe, KS 66062, USA
913-829-0242, TELEX 417095,
EXTRUTECHINTUD or FAX 913-829-0311

Feeder					THE BARREL					Mixing/Cooking			Die/Cutters			Wear resistance								Safety				Optional extras	Application	
																Barrel				Screw										
Capacity (ltrs)	Drive (kW)	Twin-screw	Single-screw	Loss-in-weight	Length of temp control zone (no of dia)	Vacuum venting	Secondary feed ports (no)	Max operating temperature	Max discharge pressure	Motor (kW)	Variable speed	Co-extrusion	Through-hard	Bi-metalic	Nitrided	Other	Through-hard	Bi-metalic	Nitrided	Other	Guard at throat	Guard at barrel	Guard at die	Guard at cutter		Food products	Feed products
		○	○	○	4	○	○	300	None		○					○				○	○	○	○	○	Drum granul. shaping extruder	Con. Snk, Crl, Oth	P/F, Oth
		○	○	○	4	○	○	300			○					○				○	○	○	○	○			
		○	○	○	4	○	○	300			○					○				○	○	○	○	○			
		○	○	○	4	○	○	300			○					○				○	○	○	○	○			
70	0.5	○			All length	○		300	700	1.5	○	○		○	○		○	○	○		○	○	○	○		Crl, Snk, Con, Oth	Aml, P/F, Rms, Oth.
200	1.5		○			○		300	700	2.5	○	○		○	○		○	○	○		○	○	○	○			
70	0.5	○						300	700	1.5	○	○		○			○	○	○		○	○	○	○			
100-170	9.0	○		○	All length	○	○	280	200	15	○	○	○	○	○	○	○	○	○	○	○	○	○	○	Standard modular barrels, opening of the barrel, double temperature system for heating and cooling	R&D, Con, Snk Crl, Oth	R&D, P/F Rms, Oth, Aml
80-100	2.2	○		○		○	○	280	200	4-6	○	○	○	○	○	○	○	○	○	○	○	○	○	○			
40-100	2.0	○		○		○	○	280	200	4	○	○	○	○	○	○	○	○	○	○	○	○	○	○			
40-100	2.0	○		○		○	○	280	200	2.2	○	○	○	○	○	○	○	○	○	○	○	○	○	○			
40-80	0.37	○		○		○	○	280	200	2.2	○	○	○	○	○	○	○	○	○	○	○	○	○	○			
40	2.0	○		○		○	○	280	200	0.75	○	○	○	○	○	○	○	○	○	○	○	○	○	○			
10	0.37	○		○	10.5	○	○	180	180	0.37	○	○	○	○	○	○	○	○	○	○	○	○	○	○			
200			■					180		0.37	○		○				○	■	○		○	○	○	○	Linked to total plant control	Snk, Crl and coatings	

PACEPACKER

BRITAIN'S TOP SELLING AUTOMATIC PAPER SACK PACKING SYSTEMS



Now used extensively in Asia

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Braintree
England CM7 5RX

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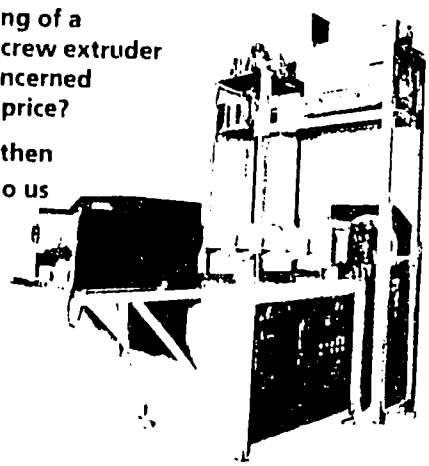
Nam-Sung Twin-Screw Extruder

FESTINA

Thinking of a twin-screw extruder but concerned about price?

If yes, then come to us



We supply the most economic twin-screw extruder with a capacity of over 500kg /hour

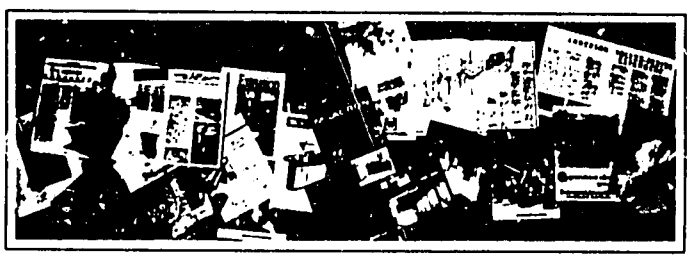
The first Korean-built twin-screw cooker extruder developed with joint technical support from the Korea Food Research Institute

NAM SUNG INDUSTRIAL CO LTD
Room No 205, General Assembly Centre
1007-3 Daechi-Dong
Gangnam-Ku
Seoul, South Korea

Tel +82 2 5569142 4
Tlx. K28882 KEYAGRO
Fax +82 2 5569950

KEY:
■ This facility is optional
○ This facility is offered
Prices are given as a guide only

COMPANY NAME	Model	Type: Single				Type: Twin						Price range	Main motor (kW)				Screw		Barrel		Control			
		Form/Shape	Tapered	Barrel bolts	Steam locks	Counter rotating	Co-rotating	Tapered	Parallel	Fully self-wiping	Intermeshing	US$ ('000)	No of motors	Total kW	Gear box	Belt drive	Diameter (mm)	Maximum screw speed (rpm)	Length (number of diameters) Min-max	Capacity (kg/hr) Min-max	Fully-auto start	Semi-auto start	Manual start	Process control
Eder Extrusion Co Landstetten 4 A-3650 Pöggstall Austria *Fax: +43 2756 2929*	CM 45-F					○		○		○	○	200	1	20	○		45-90	83.5	9.1	80-200			○	
	CM 80-SCF					○		○		○	○	400	1	100	○		80-156	67.3	10.1	400-1200			○	
	CMT 35-F					○		○		○	○	100	1	9	○		37-75	48.7	10.5	20-80			○	
Engineered Systems & Equipment Inc (ESE) Caney Industrial Park Hwy 166, PO Box 250 Caney, Kansas 67333 USA *Fax: +1 316 3318727*	E 20	○		○	○							49	1	200	○					2000-3500	■	○	○	
	E 12	○		○	○								1	125	○					1300-1500	■	○	○	
	E 10	○		○	○								1	100	○					800-1200	■	○	○	
	E 5	○		○	○							140	1	50	○					300-500	■	○	○	
Extrusion Technology Ltd PO Box 55510 Northlands 2116 South Africa *Fax: +27 11 8837961*	MB 1001		○	○	○							29	2	58		○	133	550	827mm	800			○	
Extru-Tech International Inc 2111 E. Santa Fe Suite 122, PO Box 4000 Olathe, Kansas 66062 USA *Tel: +913 829 0242* *Fax: +913 829 0311*	E - 325	○	○		○							Price on request	1	22	○	○	83		6.3-12	50-540	○	○	○	○
	E - 525	○	○		○								1	93	○	○	133		6.3-12	50-2000	○	○	○	○
	E - 750	○	○		○								1	150	○	○	190		7.4-12.6	250-7200	○	○	○	○
	E - 925	○	○		○								1	186	○	○	235		7.9-15.6	1000-13000	○	○	○	○
Fudex Srl V Reisera 17 Settimo T.se (TO) Italy *Tel: +39 11 8014205* *Fax: +39 11 8014208*	F2B 60						○		○	○	○	200	1	32	○	○	60	300	12	70			○	○
	F2B 90						○		○	○	○		1		○	○	90	300					○	○
	F2B 105						○		○	○	○		1		○	○	105	300					○	○
	F2B 135						○		○	○	○	400	1	210	○	○	135	300	20	500			○	○
Hermann Berstorff GmbH Postfach 629 D-3000 Hannover 1 Germany *Tel: +49 511 57020* *Telex: 921348* *Fax: +49 511 561916*	ZE 25					○	○		○	○	○	Price on request	1	5.5	○	○	25	440	18-48	20-30	○	○	○	○
	ZE 40A					○	○		○	○	○		1	30	○	○	43	440	13-48	100-150	○	○	○	○
	ZE 60A						○		○	○	○		1	95	○	○	64	400	13-48	350-500	○	○	○	○
	ZE 75A						○		○	○	○		1	160	○	○	80	350	13-48	700-1000	○	○	○	○
	ZE 90A						○		○	○	○		1	350	○	○	96	350	13-48	1200-1500	○	○	○	○
	ZE 130A						○		○	○	○		1	850	○		140	300	13-48	4000-5000	○	○	○	○
	ZE 180A						○		○	○	○		1	1400	○		192	250	13-48	5000-15000	○	○	○	○
Inotec International Parc Industriel D'Incarville B.P. 116 27100 Le Val de Reuil France *Tel: +32 40 2711* *Telex: 180775F* *Fax: +32 40 5275*	INOTEX Z 300E	○	○		○							Price on request	1	225		○	250	660	5.6-8.56	3000-7000		○	○	○
	200	○	○		○								1	200		○	172	660	5.8-8.7	2000-3600		○	○	○
	125	○	○		○								1	90		○	134	660	4.5-9.32	800-1500		○	○	
	100	○	○		○								1	75		○	134	660	4.5-9.32	600-1000			○	
	50	○	○		○								1	37		○	92	660	5-9	200-5500			○	
Japan Steel Works Ltd Hiroshima Plant 1-6-1 Funakoshi Minami Aki-Ku, Hiroshima Japan *Fax: +81 3 5040727*	TEX-L					○	○		○	○	○	77	1	0.75	○		30	250	10	2	■	■	○	■
	TEX 32F					○	○		○	○	○	150	1	5.5	○	○	32	450			■	■	○	■
	TEX 38F					○	○		○	○	○	210	1	7.5	○	○	38	450			■	■	○	■
	TEX 52F					○	○		○	○	○	290	1	30	○	○	52	400			■	■	○	■
	TEX 69F					○	○		○	○	○	370	1	45	○	○	69	350	40	1500	■	■	○	■
	TEX 82F					○	○		○	○	○	450	1	75	○	○	82	260			■	■	○	■
	TEX 95F					○	○		○	○	○	540	1	150	○	○	95	240	16	10	■	■	○	■
	TEX 128F					○	○		○	○	○	620	1	300	○	○	128	270			■	■	○	■



Feeder					THE BARREL								Wear resistance								Safety				Optional extras	Application	
					Mixing/Cooking					Die/Cutters			Barrel				Screw										
Capacity (ltrs)	Drive (kW)	Twin-screw	Single-screw	Loss-in-weight	Length of temp control zone (no of dia)	Vacuum venting	Secondary feed ports (no)	Max operating temperature	Max discharge pressure	Motor (kW)	Variable speed	Co-extrusion	Through-hard	Bi-metalic	Nitrided	Other	Through-hard	Bi-metalic	Nitrided	Other	Guard at throat	Guard at barrel	Guard at die	Guard at cutter		Food products	Feed products
70	0.5	○			9.1	○		300	700	1.5	○	○		○				○	○		○	○	○	○		Con Snk, Oth	Rms, P/F Aml, Oth
200	1.0		○		10.1	○		300	700	2.5	○			○				○			○	○	○	○			
70	0.5	○			10.5	○		300	700	1.5	○	○		○				○	○		○	○	○	○			
	2.0	○	■		5			100		3	○	○											○	○	Fully automatic process control (computerised) hydraulic screw extractor, liquid injection system	Crl and tubers, Snk, pastas starch gelat, etc	P/F shrimp- Aml, Rms, vegetable by-product waste
	2.0	○	■		5					3	○	○											○	○			
	2.0	○	■		4					3	○	○											○	○			
	2.0	○	■		4			200		2	○	○											○	○			
100	3.0		○		4			200		5	○		○			○				○	○	○	○	○		Snk, Crl, TVP, Oth	Aml, P/F, Rms, Oth
450	1.1	○	○	○	12	○	○			0.75	○	○	○	○	○		○	○	○		○	○	○	○	Dryers, coolers, fat and flavour equipment, mixers	Snk, Crl Con	P/F, Aml, Rms, Oil
850	3.3	○	○	○	12	○	○			0.5	○	○	○	○	○		○	○	○		○	○	○	○			
1700	4.8	○	○	○	12.6	○	○			5.6	○	○	○	○	○		○	○	○		○	○	○	○			
1700	5.2	○	○	○	15.6	○	○			7.5	○	○	○	○	○		○	○	○		○	○	○	○			
Detailed information on application																									Cooling (pressure water, or oil) of barrel and screw	Crl, Snk, Crl, Oth	Rms, Aml, P/F, Oil, Oth
		○	○	○	2.5	○	1	400	350	0.5	○	○	○	○	○		○		○	○	○	○	○	○		Con, Snk, Crl, Oth	Aml, P/F, Rms, Oth
		○	○	○		○	1	400	350	1	○	○	○	○	○		○		○	○	○	○	○	○			
		○	○	○		○	1	400	350	2	○	○	○	○	○		○		○	○	○	○	○	○			
		○	○	○	5.0	○	1	400	350	4	○	○	○	○	○		○		○	○	○	○	○	○			
		○	○	○		○	1	400	350	6	○	○	○	○	○		○		○	○	○	○	○	○			
		○	○	○		○	1	400	350	8	○	○	○	○	○		○		○	○	○	○	○	○			
		○	○	○	7.5	○	1	400	350	10	○	○	○	○	○		○		○	○	○	○	○	○			
	2.0	○					○	180	50				○	○			○	○			○	○	○	○	Hydraulic screw extraction. Liquid injection pump. Two tank control device	Snk, Crl, Oth	Aml, P/F, Oil, Rms, Oth
	1.5	○					○	220	50	3	○		○	○			○	○			○	○	○	○			
	1.5	○					○	220	50	2.5	○		○	○			○	○			○	○	○	○			
	1.5	○					○	220	50	2.5	○		○	○			○	○			○	○	○	○			
	1.0	○					○	200	50	2	○		○	○			○	○			○	○	○	○			
2	0.4	■	○	■	2			200	200	0.04	○	○		○	○		○	○	○	○	○	○	○	○		Con, Snk, Crl, Oth, Laboratory testing	Aml, P/F, Oil, Rms, Oth
500		■	○	■		○	1-3	200	200	0.4	○	○		○	○		○	○	○	○	○	○	○	○			
		■	○	■		○	1-3	200	200	0.4	○	○		○	○		○	○	○	○	○	○	○	○			
		■	○	■		○	1-3	200	200	0.4	○	○		○	○		○	○	○	○	○	○	○	○			
		■	○	■	11	○	1-3	200	200	0.4	○	○		○	○		○	○	○	○	○	○	○	○			
		■	○	■		○	1-3	200	200	0.4	○	○		○	○		○	○	○	○	○	○	○	○			
		■	○	■	4	○	1-3	200	200	0.4	○	○		○	○		○	○	○	○	○	○	○	○			
10	0.4	■	○	■		○	1-3	200	200	0.4	○	○		○	○		○	○	○	○	○	○	○	○			

COMPANY NAME	Model	Type: Single			Type: Twin					Price range	Main motor (kW)			Screw		Barrel		Control			
KEY: ■ This facility is optional ○ This facility is offered *Prices are given as a guide only*		Form/Shape	Tapered	Barrel bolts / Steam locks	Counter rotating	Co-rotating	Tapered	Parallel	Fully self-wiping	Intermeshing	US$ ('000)	No of motors	Total kW	Gear box	Belt drive	Diameter (mm)	Maximum screw speed (rpm)	Length (number of diameters) Min-max	Capacity (kg/hr) Min-max	Fully-auto start	Semi-auto start	Manual start	Process control
Jasma-Matador AS PO Box 2050 Glentevej 5-7 DK-6705 Esbjerg Denmark *Tel: +45 75 140333* *Telex: 54177 EEMEM DK* *Fax: +45 75 143063*	EX 917	○		○							Price on request	1	250	○	○	177	320	15	3500-6500		○		○
	EX 917 - Convertible	○		○								1	250	○	○	177	320	15	4500-7500		○		○
	EX 920	○		○								1	250	○	○	210	320	12.6	5000-10000		○		○
Kowa Kogyo Ltd 6-16, Oimazoto Minami 4 Higashinari-Ku Osaka 537 Japan *Tel: +81 6 9760037* *Fax: +81 6 9751256*	KEI 65-15, 20 & 25				○	○			○	○	215-270	1	45-75	○	○	70	0-300	15-25	150-200	○	○	○	○
	KEI 45-15, 25 & 30				○	○			○	○	130-230	1	15-33	○	○	46	0-300	15-30	30-60	○	○	○	○
	KEI 115-15, 22, 26 & 30				○	○			○	○	460-885	1	160-500	○	○	125	0-300	15-30	800-1500	○	○	○	○
	KEI 87-15, 20 & 25				○	○			○	○	345-460	1	90-160	○	○	92	0-300	15-25	500-600	○	○	○	○
Millbank Technology Ltd PO Box 12 453 Auckland 6 New Zealand *Tel: +64 9 5251105* *Telex: 30943 PACNET1 att:NZN330* *Fax: +64 9 5251106*	MILTEC 500			○							17-25	1	37		○	93	600	610-760	150-300			○	○
	501			○							25-40	1	37		○	93	750	610-760	150-300	○	○	○	○
	1000			○							30-45	1	75		○	133	550	950-1150	600-1000			○	○
	1001			○							43-60	1	75		○	133	750	950-1150	600-1200	○	○	○	○

Inotec International
Groupe DIEVET

EXTRUDERS:
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Economic
Efficient

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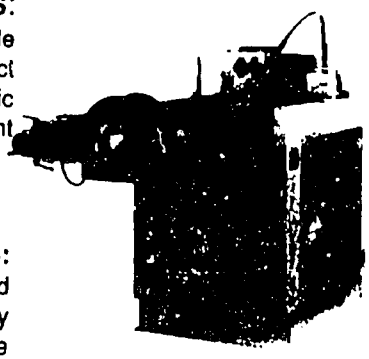

EXTRUDED FEEDS:
Detoxified
Improved digestibility
Increased nutritive value

INOTEX LOW-COST EXTRUSION COOKERS
+ DIEVET NUTRITION TECHNOLOGY
= A COMPREHENSIVE PACKAGE DEAL

For further information, as for the Inotex brochure:
INOTEC INTERNATIONAL

Parc Industriel D'Incarville
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27100 Le Val de Reuil
FRANCE
Tel: 32 40 27 11
Telex: 180775F
Fax: 32 40 52 75

OR

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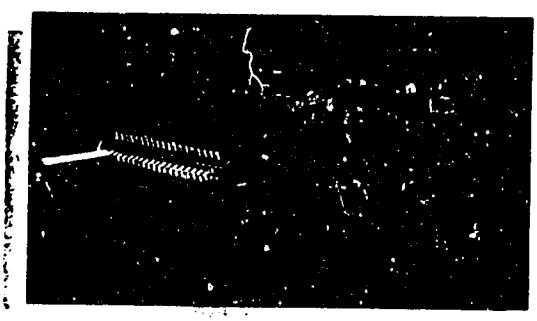
Bush Boake Allen Ltd
Natural Products Division
Blackhorse Lane, London E17 5QP. UK.
Tel: 081-531-4211 Fax: 081-527-6351

ASSOCIATED COMPANIES, TECHNICAL CENTRES, AGENTS WORLDWIDE

140

Feeder				THE BARREL Mixing/Cooking					Die/Cutters			Wear resistance Barrel				Wear resistance Screw				Safety				Optional extras	Application	
Capacity (ltrs)	Drive (kW)	Twin-screw	Single-screw	Loss-in-weight	Length of temp control zone (no of dia)	Vacuum venting	Secondary feed ports (no)	Max operating temperature	Max discharge pressure	Motor (kW)	Variable speed	Co-extrusion	Through-hard	Bi-metalic	Nitrided	Other	Through-hard	Bi-metalic	Nitrided	Other	Guard at throat	Guard at barrel	Guard at die	Guard at cutter		Food products	Feed products
	1.1	O			10.7		18	220	150	3	O		O			O	O			O	O	O	O	Anti plugging system Auto run down at errors Computer monitoring	Cereals	P/F, Aml, Rms
	1.5	O			10.7		18	220	150	3	O		O			O	O			O	O	O	O			
	1.5	O			9		18	220	150	5.5	O		O			O	O			O	O	O	O			
60-600	0.75	O		O	3-7	O	O	399	350	0.75	O	■		O	O	O		O	O	O		O	O	O		Con, Snk, Crl, Oth	Aml, P/F, Oil, Rms, Oth
20-160	0.1	O		O	3-7	O	O	300	350	0.4	O	■		O	O	O		O	O	O		O	O	O			
1600-3000	2.0	O		O	4-8	O	O	399	350	1.5	O	■		O	O			O	O	O		O	O	O			
800-1800	2.0	O		O	4-7	O	O	399	350	1.5	O	■		O	O			O	O	O		O	O	O			
1	0.75		O		370-520		1	180		3	O			O			O	O			O		O	O	Variable main shaft speed, external processing chamber, heating/cooling pre-steam conditioning	Crl, Snk, Con, Oth	P/F, Rms, Aml, Oil, Oth
1	0.75		O		370-520		1	180		3	O			O			O	O			O		O	O			
1.5	1.1		O		550-750		1	200		3	O			O			O	O			O		O	O			
1.5	1.5		O		550-750		1	200		3	O			O			O	O			O		O	O			

The Finishing Touch ...



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Precision Drying and Cooling of Extruded Products For:

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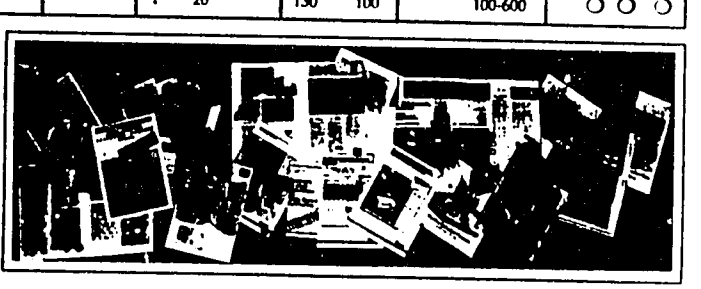
Cable Aeroglide Raleigh USA

Aeroglide Corporation

KEY:
■ This facility is optional
○ This facility is offered
Prices are given as a guide only

COMPANY NAME	Model	Type: Single			Twin				Price range	Main motor (kW)				Screw		Barrel		Control			
		Form/Shape	Tapered	Barrel bolts	Steam locks	Counter rotating	Co-rotating	Tapered	Parallel	Fully self-wiping	Intermeshing	US$ ('000)	No of motors	Total kW	Gear box	Belt drive	Diameter (mm)	Maximum screw speed (rpm)	Length (number of diameters) Min-max	Capacity (kg/hr) Min-max	Fully-auto start	Semi-auto start	Manual start	Process control
Nam Sung Agribusiness Ltd Room No. 205 General Assembly Center 1007-3 Daechi-Dong Gangnam-Ku Seoul,Korea *Tel: +82 2 556 9142* *Telex: K2882 KEYAGRO* *Fax: +82 2 556 9950*	FESTINA																						
	FX - 100					○		○			○	Price on request	1	111	○	○	100	300	12-20	2000		○	○	
	FX - 62					○		○			○		1	45	○	○	62	400	12-20	200-600		○	○	
	FX - 40					○		○			○		1	11	○	○	40	400	12-20	200		○	○	
	SINGLES																							
	NS - 130			○									1	75		○	130	550	7-8.5	300-1000			○	
	NS - 130			○									1	37.5		○	90	550	7-8.5	100-400			○	
Pavan- Mapimpianti SpA Via Europa 25 35015 Galliera Veneta Padova Italy *Tel: +39 49 5969133* *Telex: 430877 MAPIMP I* *Fax: +39 49 5969794*	G 20	○	○	○								100	1	4.0	○	○	55	100	15-18	15-20			○	○
	G 100	○	○	○								270	1	15	○	○	90	100	15-18	90-120			○	○
	G 302	○	○	○								400	1	45	○	○	130	100	15-17	250-350			○	○
	G 502	○	○	○								500	1	75	○	○	160	100	12-15	400-500			○	○
	G 702	○	○	○								600	1	110	○	○	180	100	11-13	650-750			○	○
	G 1000	○	○	○								720	1	130	○	○	200	100	11-13	850-1000			○	○
	F 20	○	○									100	1	7.5	○		55	50	9	20-30			○	○
	F 100	○	○									160	1	15	○		90	50	10	100-130			○	○
	F 300	○	○									260	1	30	○		120	50	16	300-600			○	○
	F 500	○	○									340	1	60	○		140	50	14	500-800			○	○
	F 700	○	○									420	1	70	○		160	50	12	700-1000			○	○
	F 1000	○	○									530	1	110	○		195	50	11	1000-1500			○	○
Plant Flowline Ltd Thurlby, Bourne Lincolnshire PE10 0JA, UK *Tel: +44 778 393888*	SYSTEM 100		○	○								12	3	45	○	○	80	○	1.5-2.5	100-150	○			○
Sprout-Bauer Inc Sherman Street Muncy, PA 17756, USA *Tel: +1 717 5468211* *Telex: 841411. Fax: +1 717 5461140*	TME 2000	○										Price on request	4	168	○		203	280	8	7260-9070			○	
	TME 1500	○		○	○								4	175-	○		197-	514	13.3-	7500-	○	○	○	○
	TME 450	○		○	○								4	66	○		114	450	5.8	2500	○	○	○	○
Information also from: Sprout-Bauer Aust Pty Ltd, 227 Princess Highway, Dandenong, Victoria 3175, Australia. Tel. +61 3 7941555. Fax. +61 3 7932900																								
Textruder Engineering AG PO Box 1040 P-1001 Lisbon, Portugal *Tel: +351 1 3526163* *Telex: 18870. Fax: +351 1 523944*	SINGLE	○			○							Price on request	1	50		○	75					○	○	○
	TWIN	○				○		○	○		○		1	116	○		120					○	○	○
Ulrich Walter GmbH Bollenhöhe 4 D-4020 Mettmann, Germany *Tel: +49 2104 12054* *Telex: 8581230* *Fax: +49 2104 14030*	PIKO - 180	○	○	○	○							Price on request	1	132		○	180	160-	1390max	500-2000	○	○	○	○
	PIKO - 220	○	○	○	○								1	200		○	220		1685max	2000-6000	○	○	○	○
	PIKO - 270	○	○	○	○								1	250		○	270	480	1700	3500-9000	○	○	○	○
Wenger Manufacturing Inc 714 Main Street PO Box 130 Sabetha, Kansas 66534 USA *Tel: +1 913 284 2133* *Fax: +1 913 284 3771*	TX - 195					○		○	○		○	Price on request	1	450	○		195	350	13.5-	7000-16000	○	○	○	○
	TX - 138					○		○	○		○		1	200	○	○	138	450	28.5	550-6400	○	○	○	○
	TX - 52					○		○	○		○		1	25	○	○	52	550	10.5-43.5	50-450	○	○	○	○
	X - 235			○									1	225		○	235	275	14.5	6000-14000	○	○	○	○
	X - 185			○									1	190		○	215	350	11-13	4000-9000	○	○	○	○
	X - 25			○									1	75		○	130	500	6-9.25	100-1500	○	○	○	○
	X - 20			○									1	25		○	80	550	6-9.25	50-450	○	○	○	○
(1) Twin-screw forming extruder	TF - 138					(1)		○	○		○		1	10	○		138	100				○	○	○
(2) Sleeved	F - 200	○											1	60			235	[illegible]		750-4000		○	○	○
(3) Clam-shell barrel	F - 25	○											1	20			130	100		100-600		○	○	○

Due care has been taken in preparing this the industry's First International Extrusion Cooking Directory. Please check specific details with manufacturers. The magazine cannot accept responsibility for any errors omissions.



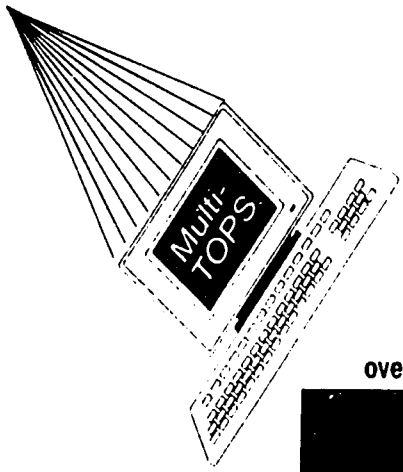
Feeder				THE BARREL								Wear resistance								Safety				Optional extras	Application	
				Mixing/Cooking					Die/Cutters			Barrel				Screw										
Capacity (ltrs)	Drive (kW)	Twin-screw	Single-screw	Loss-in-weight	Length of temp control zone (no of dia)	Vacuum venting	Secondary feed ports (no)	Max operating temperature	Max discharge pressure	Motor (kW)	Variable speed	Co-extrusion	Through-hard	Bi-metalic	Nitrided	Other	Through-hard	Bi-metalic	Nitrided	Other	Guard at throat	Guard at barrel	Guard at die	Guard at cutter		Food products	Feed products
	2.2		O		800-1600	O		200	150	2.2	O				O	O			O	O	O	O	O	O	Auto-process control & monitoring system (closed loop) Torque speed temp pressure Preconditioner unit steam quantity & pressure Heating cooling venting type barrels	TVP, Snk, Crl, Con	P/F, Rms, Oil
	0.75		O		496-992	O		200	150	0.75	O				O	O			O	O	O	O	O	O			
	0.75		O		320-640	O		200	150	0.75	O				O	O			O	O	O	O	O	O			
	0.75		O					180	150	0.75	O				O	O			O	O			O	O			
	0.75		O					180	150	0.75	O				O	O			O	O			O	O			
		O	O		15-18	O		170	60	0.18						O				O	O	O	O	O	Vacuum venting Var. speed cutter Screw stellite surfacing	Con, Snk, Crl, Oth	Aml, P/F, Oil, Rms, Oth
		O	O		15-18	O		170	60	0.37				O						O	O	O	O	O			
		O	O		15-17	O		170	60	0.75				O						O	O	O	O	O			
		O	O		12-15	O		170	60	1.1				O						O	O	O	O	O			
		O	O		11-13	O		170	60	1.5				O						O	O	O	O	O			
		O	O		11-13	O		170	60	1.5				O						O	O	O	O	O			
		O	O		9	O		80	180	0.5	O					O				O	O	O	O	O			
		O	O		10	O		80	180	1.5	O					O				O	O	O	O	O			
		O	O		16	O		80	180	1.5	O					O				O	O	O	O	O			
		O	O		14	O		80	180	2.2	O					O				O	O	O	O	O			
		O	O		12	O		80	180	2.2	O					O				O	O	O	O	O			
		O	O		11	O		80	180	2.2	O					O				O	O	O	O	O			
100	4.0		O		1.5					4.0	O		O				O				O	O	O	O	Complete snack lines	Expanded snacks	
			O		4			+160	100	5.6	O		O							O	O		O	O		Snk, Crl, Oth	Aml, P/F, Oth
	7.5-		O		4	O	2	+160	100	5.5	O		O	O				O		O	O	O	O	O			
	3.7		O		4	O	2	+160	100	3.7	O		O	O				O		O	O	O	O	O			
Detailed information on application																											Crl, P/F and shrimp feed
3000	2.0	O	O		1250	O	4	130-160		5.5	O	O	O				O				O	O	O	O	Conditioning in mixer and cooker; 10-60min The housing can be heated or cooled	Crl, Oth	Aml, P/F, Oil, Rms, Oth
7000	1.5	O	O		1710	O	4	130-160		7.5	O	O	O				O				O	O	O	O			
10000	1.0	O	O		1800	O	4	130-160		11.0	O	O	O				O				O	O	O	O			
	2.0	O	O	O	3.0	O	O	280	200	5.5	O	O			O		O				O		O	O	(3)	Crl, Oth	Aml, P/F, Oil, Rms, Oth
	1.5	O	O	O	3.0	O	O	280	200	3.8	O	O			O		O				O		O	O	(3)		
	0.5		O	O	3.0	O	O	280	200	0.8	O	O	O	O			O				O		O	O	(3)		
	1.5		O	O	2.0	O	O	175	150	5.5	O	O	(2)				O				O		O	O			
	1.5		O	O	2.0	O	O	175	150	3.8	O	O	(2)				O				O		O	O			
	0.8		O	O	1.5	O	O	280	150	2.2	O	O	O				O				O		O	O			
	0.5		O	O	1.5	O	O	280	150	0.8	O	O	O				O				O		O	O			
					6.0			120	7	2.2	O	O				O	O				O		O	O			
					2.0			120	100	3.8	O	O	(2)					O			O		O	O			
					1.5			120	100	2.2	O		O					O			O		O	O			

Options/Applications Key

FOOD
Con - Confectionery
Snk - Snacks
Crl - Cereals

FEED
Aml - Animal feed
P/F - Pet and fish foods
Rms - Raw materials
Oth - Others

Squeeze The Most Out Of Your Pelletisers With Norvidan's New Multi-TOPS System



To be Introduced at Vietam Asia 1991

Multi-TOPS, the complete on-line pellet analysing system, is the latest advanced development introduction from Norvidan Overseas A/S. The new system provides time savings in the control room and a pellet analysis system that reduces production costs and controls up to six pelleting lines simultaneously.

Running on standard IBM-compatible PC's with colour screens, the new PC programme PAS (Pelleting line Analysing System) is a development of Norvidan's existing and highly thought of 'Total Optimised Pelleting System' (TOPS). All new installations will have Multi-TOPS as standard, whilst existing users can upgrade to Multi-TOPS by installing PC-PAS.

We also produce pellet presses, mixcompressors, sifters, crumblers and coolers. If your business is pelletised feed, ours is to help you increase productivity and improve quality.

Multi-TOPS from Norvidan puts the squeeze on the competition.

overseas A/S

Member of the Norvidan Group

NORVIDAN

Stenhuggervej 7-9,
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Phone: +45 65 93 23 90
Telex: 59809 Nordan DK.
Telefax: +45 65 93 20 23

We have subsidiaries, agents and distributors throughout the whole world.

Additional Directory Listings

Extruder manufacturers either not wishing to list their equipment in The Directory or did not return information prior to deadline.

Adams International
Beatrice Companies Inc
8948 NW 24th Terrace
Miami, FL33172
USA
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Telex: 807340

Alimpiaanti SpA
40121 Bologna
Italy
Tel: +39 51 251950
Telex: 520667 ALIMP I
Fax: +39 51 252046

Atlas Industries
Baltorpvej 160
DK-2750 Ballerup
Denmark
Tel. +45 42 974570
Telex: 35178
Fax: +45 42 657333

Azikan
7-3-9 Sho-Ko Centre
Nishi-Ku
Hiroshima
Japan
Tel: +81 82 2777010

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60 East 42nd Street
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NY 10165
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Tel: +1 212 6826407
Telex: 4971518 BRANY
Fax: +1 212 9830953

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265 Prins
Boudewijnlaan
B-2520 Edegem
Antwerp
Belgium
Tel: +32 3 4494240
Telex 31824/7251
Fax: +32 3 4494204

Dorsey-McComb
3255 South Birch
Denver
Colorado 80222-7208
USA
Fax: +303 756 6303

Food Extrusion Dies
2633 Bluff Ridge Drive
St Louis, MO 63129
USA
Tel: +1 314 8464334
Fax: +1 314 8464720

Hans Weber GmbH
Bamberger Str. 19-21
8640 Kronach
Tel: +49 9261 4090
Telex: 642636
Fax: +49 9261 40999

Idah Ltd
2F-1, 77 Keelung Rd
Sec 2, Taipei
Taiwan ROC
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Telex: 20981 IDAH
Fax: +886 2 7360908

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PO Box 61
Cheltenham
Glos., GL50 2SX
England
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Telex: 43735(IPWE G
Fax: +242 221218

Giordana Nimet
Impianti Per L'Industria Alimentare
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10128
Torino, Italy
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Telex: 220248 GRONIM I

Kobe Steel Ltd
1-1 Hinodecho 4
Chome
Nada-Ku, Kobe
Hyogo
657 Japan
Tel: +78 261 63102
Telex: 05622637 KOBSTL J
Fax: +78 261 6314

Koangee Machine Industrial Ltd
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An Ping District,
Tainan
Taiwan 700 R.O C.
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Fax: +886 6 2631842

Kurimoto
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Nishi-Ku
Osaka City
Japan
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Lalesse Machinebouw BV
P Calandweg 11
6827 BJ Arnhem
Holland
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Telex: 45789 LALES NL
Fax: +31 85 643675

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4031 Bronze Way
Dallas, Texas 75237
USA
Fax: +305 388 8620

Mitsubishi Heavy Industries Ltd
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Chome
Chiyoda-Ku, Tokyo
100 Japan
Tel +3 212 9065
Telex: J 22282
Fax: +3 216 3025

Pagani and Co
via G. Marconi 23/25
20027 Rescaldina (MI)
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Telex: 330674
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Robinson Milling Systems
Simon-Barron Ltd
Bristol Road
Glos., GL2 6BY
England
Tel: +684 291111
Telex: 43231 SIMBAR G
Fax: 684 300164

Suehiro Iron Works Ltd
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Japan
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Telex: 72313123
Fax: +711 897 3989

Yashima Bussan Ltd
Nishi-Tenma
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Telex: 5234284
Fax: +81 6 3125888

Yeong Ming Machine Industrial
283 Chang Hsi St
Sec. 2 An Nan
District Tainan
Taiwan ROC
Tel: +886 6 2560361
Fax: +886 6 2559093

THE TASK OF MARKETING
is to concentrate resources on specific customers

MARKET RESEARCH
identifies customer groups that need your product

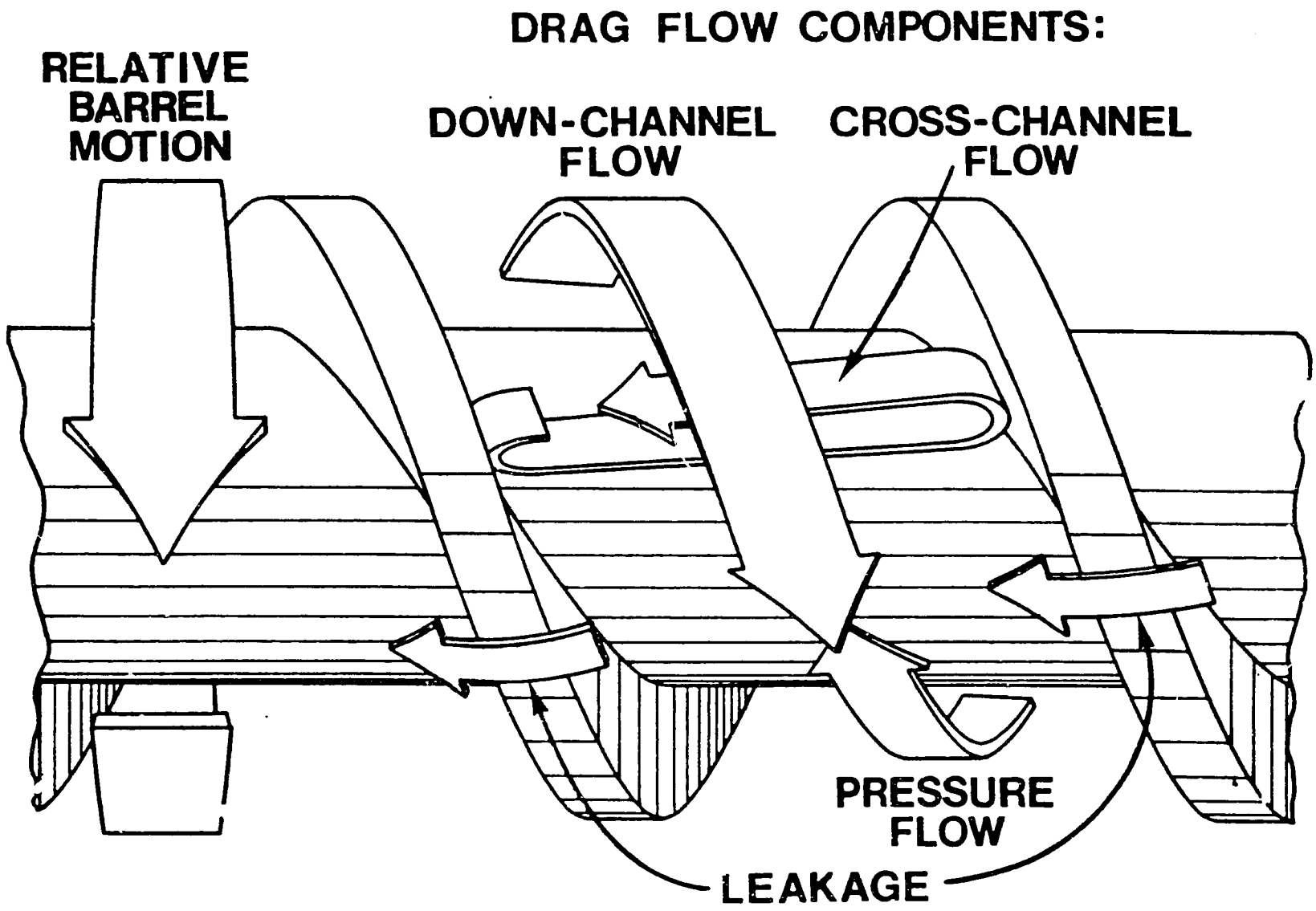
A MARKETING PLAN
spotlights your best strategies for reaching them

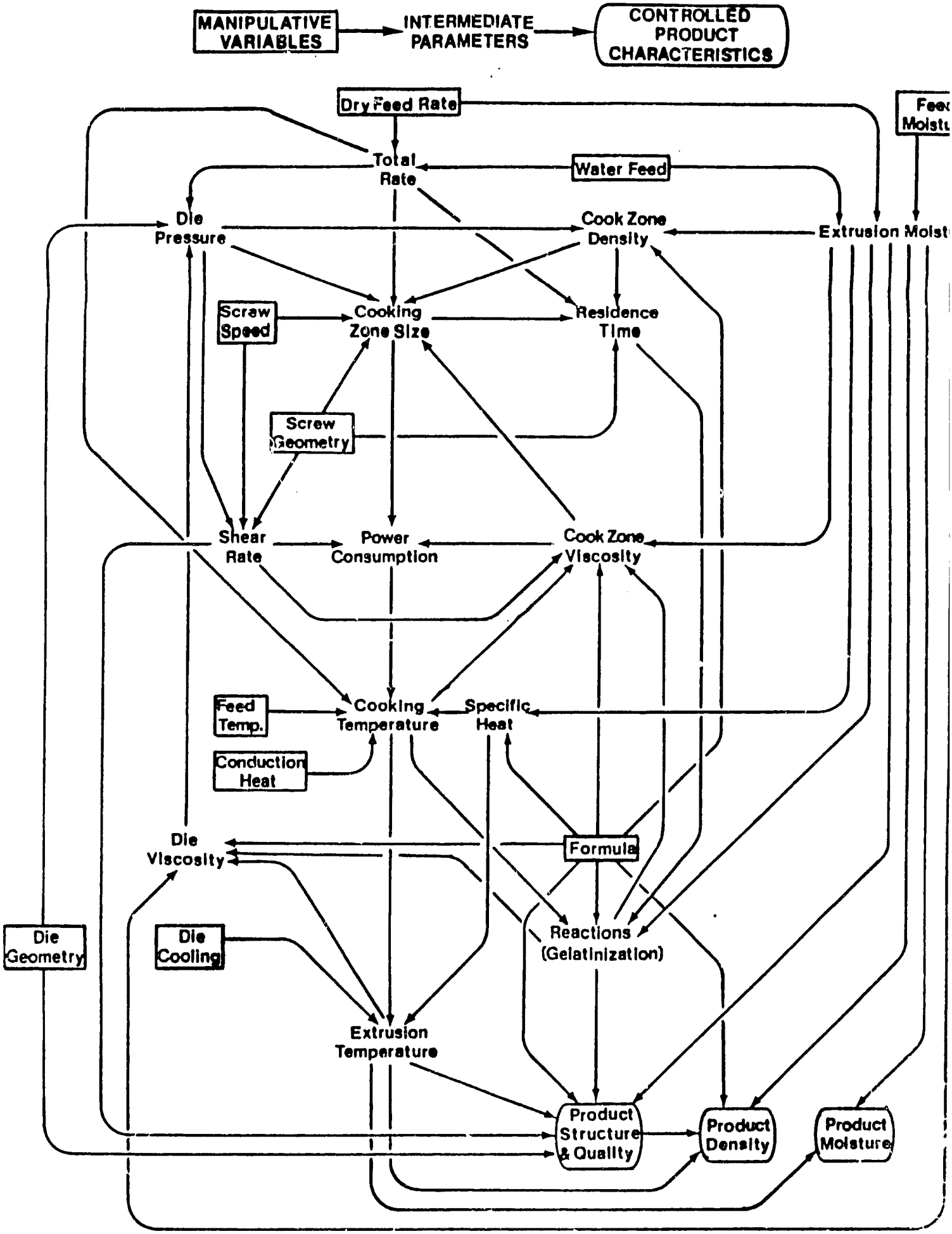
A BUSINESS DEVELOPMENT PROGRAM
pulls it all together so you increase business in your target markets

Keck&Co.
BUSINESS CONSULTANTS
410 Walsh Road,
Atherton,
California 94025, US
1 (415) 854-9588

Marketing, Market Research and Planning for Agribusiness, Food and Supplier Companies

44


DRAG FLOW COMPONENTS:
RELATIVE BARREL MOTION
DOWN-CHANNEL FLOW
CROSS-CHANNEL FLOW
PRESSURE FLOW
LEAKAGE



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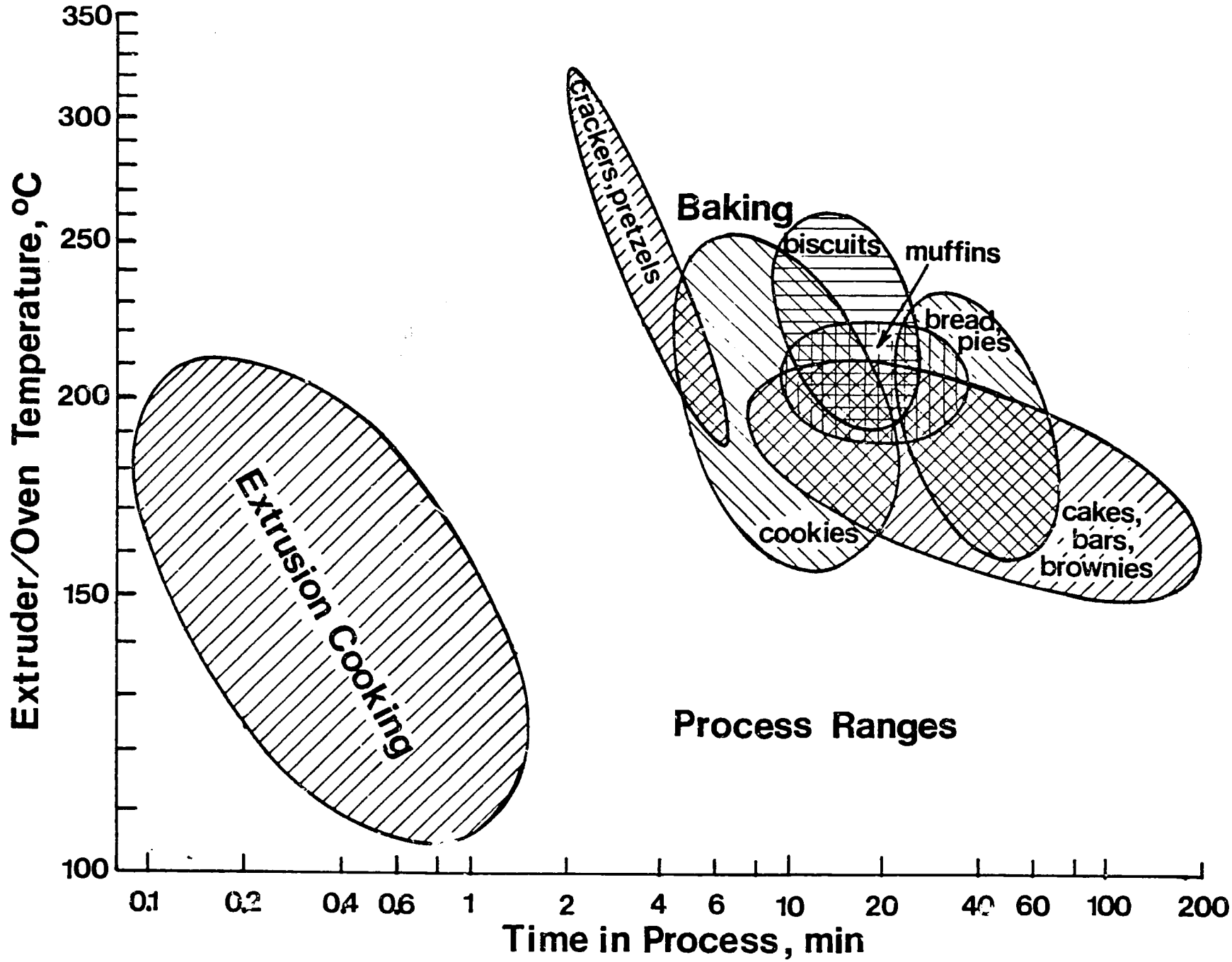

Extruder/Oven Temperature, °C
350
300
250
200
150
100
0.1
0.2
0.4
0.6
1
2
4
6
10
20
40
60
100
200
Time in Process, min
Extrusion Cooking
Baking
crackers, pretzels
biscuits
muffins
bread, pies
cookies
cakes, bars, brownies
Process Ranges

CONSUMER ACCEPTANCE

By Dr. Ross Sheldon
Managing Director-Europe, Universal Flavors, International, Inc.

As consumers, we are making daily choices concerning the products we buy. Our decisions are driven by product performance and efforts to get the best possible value for the money that is available for us to spend.

As manufacturers, it is our task to understand market trends and deliver those products which respond to consumer needs. It is not too difficult to get someone to buy your product once. However, as food manufacturers, our business is based upon repeat sales having an acceptable frequency. We clearly must deliver a product which is relevant to the market and has value to the consumer.

I have been asked to lead this discussion on Consumer Acceptance and, as I do, we all need to recognize that, you and I, are our own best experts for those things we prefer. However, as we begin to consider the preferences of groups, we need to understand that large populations are separated by many differences such as age, environment and experience. Consumer Acceptance is, clearly, very subjective and difficult to measure. As manufacturers, we have to find the right balance in order to deliver the right product, at the right time, and at the right price.

For today's discussion, we are going to assume that our marketing department has pointed us in the right direction. Our task then becomes one of considering the technical aspects of how to deliver the right product quality.

SLIDE 1

In terms of an outline, I would like us to consider, the following areas. First, we need to take a quick inventory of the key product attributes which are important to product acceptance. Next, we need to re-visit some of the unit process considerations discussed by Mr. Miller earlier today and consider how these process parameters impact product quality relative to our ingredient selections. Third, recognizing the significant investments made by our companies in the area of research and development, we need to discuss product modeling. In this context, it is important to ensure our technical efforts are correctly focused on the targets we believe are relevant to the market. Finally, I will close with some brief comments on shelf-life.

What began over 50 years ago as a process to produce macaroni and Ready-To-Eat (RTE) cereals, today's food extrusion has become a High Temperature Short Time (HTST) bio-reactor capable of transforming a wide variety of raw materials into modified

intermediates and finished products.

SLIDE 2

Slide 2 is a brief list of common products in the market produced by extrusion technology. While incomplete, this list is enough to provide some good focus on those key product attributes which are important to consumer acceptance.

SLIDE 3

While the above attributes are somewhat obvious, these product dimensions nonetheless form the basis of our attention in the area of new product development. When my children ask for a certain type of toothpaste, they are not thinking about fluoride additives for to prevent cavities. No, they want a particular product because of the way it tastes. Building on this point, when was the last time you heard somebody talk about a juicy, brown strawberry having a crunchy texture? With foods, all of the attributes have to fit and be fully integrated in order to deliver an overall sensory effect. Unlike a fragrance, we are not dealing with fantasy. With foods, consumers have pre-set opinions as to the product's texture, appearance, aroma, and taste. If the manufacturer does not deliver, the product does not survive.

Process Variables

Returning to an objective we set for ourselves, we need to spend some time looking at unit process considerations relative to their impact upon product quality. Working from Mr. Miller's earlier comments, there are four primary process variables in extrusion cooking.

SLIDE 4

These variables have a major role relative to our list of key product attributes.

Flavor. When thinking about the application of food extrusion for the preparation of RTE cereals or other products for that matter, the extrusion cooking is the preferred technology. The process accepts both starch and protein ingredients, it is able to create highly expanded products, it can produce products having a wide variety of shapes and textures, the process can cook and form in one step and it can process ingredients having low moisture. Nevertheless, what seems to be a process capable of offering a wide range of advantages; for flavors and other ingredients sensitive to rigorous processing, other means of addition have to be pursued.

SLIDE 5

I believe this next slide can be useful in helping us understand the circumstances related to flavor. First, flavorings whether formulated or, as in this case, a natural essential oil, are complex mixtures of organic compounds. The flavor profile is dependent upon a very specific qualitative and quantitive balance of these many ingredients. For this particular essential oil, the early part of the gas chromatogram is dominated by a high level of volatile terpene hydrocarbons. Later, in the run, one observes the elution of some of the higher boiling constituents.

During extrusion cooking, the process operates at elevated temperatures and pressure. If the flavoring were added together with the dry ingredients before extrusion, the result would be a significant loss of material with a corresponding loss of flavor impact. Further, in addition to a loss of intensity, the flavor would become unbalanced because the various constituents would be lost at a different rate. Again, flavor is a function of a unique qualitative and quantitative balance of its various ingredients. In addition to losses due to volatility, processing conditions are often ideal for the flavoring to react with the food mixture with, again, the result being reduced flavor strength.

To further develop this point, let me refer briefly to some work by Dr. Krukar. First, during extrusion, the food product

normally reaches its highest temperature just before it emerges from the die, where elevated pressures prevent flashing and the loss of water. Once the product leaves the die, flashing is immediate due to the pressure drop. The physical effect at the die head is basically a steam flavor distillation process whereby the water is flashed off and the volatile constituents from the finished product co-distill with the water. Recalling earlier work, Krukar noted a 7% level of HVP in a pre-extrusion food mix resulted in a very weak meaty flavor. While increasing the level to 15% yielded an acceptable finished product, the cost made the solution uneconomical.

Understanding the obvious advantages of being able to add the flavoring to the food mixture prior to extrusion, research efforts are in place to address the problem of flavor loss. The next slide lists three areas of research which are being pursued.

SLIDE 6

Briefly, a number of programs are in place to find ways to reduce in-process flavor loss. Encapsulation is clearly one technique which is showing promise. In this case, researchers are encapsulating materials in hard fats so that the release is by heat instead of the traditional means of solubility in water. With entrainment, reference is being made to the use of what

might be described as a "micro-cystalline" sponge. In this case, you have a very porous, micro-crystalline bead. The flavor enters the pores of the particle and, because of its structure, rate of flavor loss is reduced.

Finally, in situ flavor development is nothing more than the application of standard reaction flavor technologies to prepare meat and other savory flavors. With a food extruder, you have a High Temperature Short Time (HTST) bio-reactor. By adding flavor intermediates and precursors to the food mixture and using the heat inherent to the process, flavor develops during processing. Non-enzymatic browning or the Maillard Reaction is a primary example.

Enrobing or surface coating is the most common method for the addition of flavor. A typical enrober is shown on the next slide.

SLIDE 7

The flavor solution is put into the slurry tanks. Liquid solutions are sprayed onto the finished products. Dry flavoring mixes can be topically dusted on the surface. A typical coating formulation is shown on the next slide.

SLIDE 8

Color. Like flavor, color is essential to product acceptance. Unlike flavor, color can be efficiently added to the pre-extrusion food mixture. In some published work conducted by Kinnison of our Warner Jenkinson Division, Certified FD&C Food Colors together with a number of natural and uncertified color additives were evaluated under a number of extrusion parameters. In general, the results were as follows:

1. While fading was noted with some dyes, successful results were obtained across a wide range of color additives and test conditions.

2. Under selected conditions, proteins, reducing sugars and metal ions were shown to react with dyes and cause fading.

In general, with proper testing and ingredient selection, the right combination of conditions can be identified in order to realize a successful result.

Texture. As with the other attributes affecting consumer acceptance, this discussion can only address principles in a general manner. Texture is clearly one of the most important aspects affecting consumer acceptance. Using RTE cereal products and snacks as a point of reference, one can easily see the range of textures which are available in the market. On the one hand,

breakfast cereal manufacturers have products which can remain crunchy even in a bowl of milk. At the same time, one can find snack products with a "melt in your mouth" texture. In the later case, for example, puffed snacks are made by taking low moisture doughs, perhaps less than 15% moisture, and processing them using high steam and high temperature. In this manner, the starch undergoes significant damage thus allowing the structure to literally dissolve in your mouth as the product is consumed.

The full range of textures becomes a function of the ingredients, ingredient treatments, dough modifies and, importantly, the processing conditions. Again, moisture content , mechanical energy in terms of shear we apply, thermal energy and the residence or retention time are vital aspects which impact on the final texture.

While time does not permit an extended discussion of protein, lipid and carbohydrate interactions, I think it would be useful to spend some time discussing starch ingredients and general aspects related to their chemistry. While all dough ingredients are important, the starch additives are clearly the key material in determining the final texture.

During the next few minutes, I would like to outline some basic considerations important to the selection of starch additives.

As I am sure you will appreciate, the subject is complex. As a start, any development process must be prepared to pursue some extensive experimentation so that you can fully understand the full spectrum of ingredient interactions relative to the extrusion operating conditions.

SLIDE 9

The next slide lists the common sources of starch, both from cereal and root crops. The selection depends upon desired properties and, of course, cost and availability.

1. Corn. Commonly used in extrusion because of cost and the ability to expand well under low and high moisture extrusion conditions.

2. Oat. Good source of cereal protein.

3. Rice. Expensive, BUT, low in protein and fat. White color. Good expansion properties.

With starch, we are dealing with two basic types of starch molecules, namely, amylose and amylopectin. Both types are biopolymers of D-glucose. With amylose, one has a linear polymer linked through 1:4 bonds. With amylopectin, we are dealing with

a highly branched, amorphous polymer containing both 1:4 and 1:6 bonds. The 1:6 bonds represent about 4-5% of total. The molecules are large with the exact size depending upon the source and maturity of the plant. For example, with amylose, we could be dealing with a polymer which could contain thousands of glucose units. Amylopectin molecules are known to have molecular weight in excess of 100 million. Amylopectins are the largest molecules known to occur in nature.

Cereal grains tend to have high amylopectin levels, generally 70% with the 30% balance being amylose. Through the selection of your starch raw materials, one can achieve a specific ratio which will impact the textural properties of the finished product. For example, high amylopectin levels promote expansion or "puffing" thus giving a very light and fragile product. Amylose contents tend to make the product harder and contribute to the overall firmness.

Starch chemistry is extremely complex. No doubt you are well familiar with gelatinization procedures. With gelatinization, we are dealing with water absorption by the starch molecule. Gelatinization is a necessary first step before amyloytic enzymes can attack the starch molecule. Importantly, amylopections are difficult to gelatinize and so one must be sensitive to water levels, hydration time and temperature.

A few points . . . .

1. In their raw or native state, the configuration of the starch molecule is held together by internal hydrogen bonds.

2. In water, the granules swell to a size 25-30 times larger than their dry state. When dried, the structure returns to its original state.

3. As more heat and water are added, amylose begins to diffuse from the granule. Once this happens, recrystallization to the original state is no longer possible.

4. When starches re-crystallize to new structure, the process is called retrogradation. Again, such activity will have an effect or the finished product quality.

To summarize, the next slide helps put the question of functionality into perspective.

SLIDE 10

When we look at starch, the following properties would apply:

1. Density Control - high amylose levels or the use of chemically modified starches will lead to a more dense product. Starches high in amylopectin can produce highly expanded products.

2. Strength - modified starches can be used to increase the products strength and reduce breakage.

3. Shelf-Life Improvement - modified starches can be used to reduce the rate of moisture uptake.

4. Flavor - High amylopectin starches are generally bland which is an advantage for future flavor addition.

5. Water-Holding Capacity - Highly modified starches can be used to reduce water activity in semi-moist foods.

6. Fat Binding - Modified starches can be used to trap a blind fat in extruded meat products.

In the context of this slide, frequent mention was made concerning the use of chemically modified starch additives. In these cases, starches are treated with different reagents like

phosphorous oxychloride, sodium trimetaphosphate or epichlorohydrin. The result of such treatments involves chemical cross linking within the starch molecule and thereby the creation of different types of functionality.

Vitamins. Many vitamins are heat labile and are therefore denatured during the thermal processing encountered during extrusion. High temperatures increase the rate of vitamin loss. Even though food products are often heated to temperatures in excess of 180°C during processing, the residence time at these elevated temperatures is short, normally less than 10 seconds. Using standard principles from chemical reaction kinetics, one quickly can see that even very heat sensitive products can survive high temperature processing as long as the length of exposure is kept to a minimum.

Good retention is possible with careful processing. Knowing that some losses will occur, the food mixture can be enriched so that desired RDA levels can be obtained in the finished product. Vitamins and minerals can also be added after extrusion in the enrober.

As a way of concluding this section on ingredients and unit process considerations, let me summarize using the following slide:

SLIDE 11

With starch, by varying water levels, shear rates and temperature, one would realize the following effects:

- Starch gelatinization. Increase with high water and high heat.

- As gelatinization occurs, there is increased susceptibility to enzymatic hydrolysis thus improving the nutritive value.

- Minor dextrinization refers to the general hydrolysis of the starch molecule.

With protein,

- The process heat inactivates protease inhibitors present in raw vegetable proteins. These inhibitors would prevent complete protein digestion. Examples would include hemagluttinins in beans or gossypol in cottonseed, etc.

- Protein denaturation with the net result being improved digestibility. The changes would also help texture development.

With lipids, we have an ingredient class which is relatively stable during thermal treatments. Nevertheless, these ingredients can also be altered as well.

- Accelerated oxidation due to heat. Control with antioxidants.

- Isomerization which could affect nutrient value.

In conclusion, the extrusion cooking process has many variables. Experimental designs testing ingredients and process conditions are necessary in order to fully optimize the final result.

Consumer Acceptance.

Our section on consumer acceptance needs to begin with a few assumptions since the discussion will concentrate on product development techniques needed to measure consumer acceptance. Therefore, relying upon the excellence of our sales and marketing departments, we will assume they have properly identified the new opportunity for our company and, second, they have provided us with guidelines covering the market we intend to penetrate.

SLIDE 12

While the slide probably states the obvious, it is surprising how often development programs begin without having the benefit of complete market information. For example, if we are entering an established market, we need to understand how these factors apply.

1. Market Acceptance. How is the market now being served? What is the market share of the existing brands? What is the preference ranking of each product? Note: If we know how the public perceives each product, we can figure why.
2. Unit Cost Objectives. In terms of profitability, we will leave those details to our experts in the marketing area. However, it is their responsibility to determine the selling price and how much they intend to earn in margin per unit. From that, we car calculate our upper limit on ingredient cost. This makes a significant impact on the ingredients available to us to select.

   There is no victory in developing a product our company cannot afford to sell.
3. Label Claims. Are there special label claims that need tc be made? Are there any label restrictions? For example, low sodium, all natural, or no cholesterol. Is there an opportunity to differentiate ourselves from the competition? Again, we may want to make a no cholesterol claim or perhaps, we may want to develop a product which is fortified

with vitamins so that we can make a 100% RDA claim.

4. Product Variations - Line Extensions. This later point, anticipates the possibility of making new line extensions. Perhaps, the introduction of new flavors, new shapes, or maybe even new textures or combinations of each.

Let's consider an example of how some standard techniques can be applied in support of a product development program. Remembering an earlier claim, if our marketing department can rank the various products in order of market acceptance, we should be able to understand the reasons why.

Using a potato snack as an example, let us work through a product development exercise which is intended to give our technologists the necessary information to complete the development project satisfactorily. The process can begin in many ways. The more complex the task; the more the need to do an effective job of Product Modeling. In this context, one way to approach Product Modeling is to follow the steps summarized on the next slide.

SLIDE 13

In this process, consumer panels or focus groups representative of the market are selected in order to develop an understanding of the target product. We do not want to be using individuals

who are over 50 years old, if we are producing a product intended for children or young adults. Next, we want these individuals to describe the product using words which are meaningful to them. While one should not force our own terminology on the focus group, it is essential that the group leader understand exactly what the consumer panel is meaning when a certain term is used. While the process may be perceived as very subjective, as you work with your focus group, it is not too difficult to properly characterize a product with a reasonable degree of thoroughness.

Once the group has completed it's task, the marketing and technical staffs begin their work. Let's suppose, the focus group identified 20 different attributes which could be used to describe the product. Get them to talk about what is really important. If only 6 to 8 were regarded as important, keep the process simple and work only with these criteria.

Returning to our potato snack example, let's suppose our focus group has determined that the following six product attributes are essential in order to properly characterize our target product.

SLIDE 14

The attributes are relatively straight-forward and, certainly, there may be more that we could use at a later date. As you will note, there will be some important relationships existing between the various criteria. For example, products exhibiting high levels of hardness would be expected to exhibit a correspondingly high tendency to fracture. Such products would be in direct contrast to samples which would be soft and, even, rubbery in texture. Additionally, experiments evaluating extended cook time might be expected to yield products having high levels of color, flavor and, even, oiliness.

Having selected the attributes consumers consider important, the laboratory must internalize these parameters and use them throughout the course of their development work. The focus group was dealing with a subjective characterization of the product. The laboratory must now take these descriptive measures and use them quantitatively. One useful technique is called Quantitative Descriptive Analysis or QDA. This procedure was developed by Drs. Joel Sidel and Herb Stone of the Tragon Corporation. In general, the technique is applied in the following manner.

First, all product evaluation is done using the key product attributes selected by the focus group as the frame of reference. A sample evaluation form similar to the one shown on the slide could be developed for all product measurements.

SLIDE 15

Next, the laboratory needs to organize a trained panel. Since we are trying to quantify our product measurements and understand differences, the product training phase is critical. In practice, the panelists work together and they look at products which would have a broad range of saltiness, hardness, etc. They agree on what would be a reasonable ranking of such samples. These product standards are held or periodically re-made so that the panel can continually re-train itself and have a constant reminder of criteria which has been established. Once the training has been completed, the panelists are able to evaluate market samples and, importantly, internal samples generated during the course of the development work. (Further discuss how form can be used.)

As data are generated, the following kinds of profiles can be developed.

SLIDE 16

In the case shown, three competitive products within our target market have been profiled using the attributes our focus group said were key product measures. The differences are obvious. In terms of development, our product development scientists can

either work to match a particular parameter or adjust it to another level which may be preferred by the consumer. Importantly, this work is descriptive and quantitative in nature. It does not measure consumer acceptance. Therefore, at selected times, consumer preference tests need to be conducted so that we can measure our progress.

Key Questions

1. Have we matched the market leader so that there is no significant difference in consumer acceptance? Or

2. Have we been able to optimize an important attribute giving a level of acceptance superior to the market leader?

While a gross over-simplification, the development process is an exercise to understand what is important and, then, to develop a product which will match or, hopefully, surpass the competition.

In summary, the necessary steps can be viewed in the following manner. (Discuss Slide)

SLIDE 17

Shelf-Life.

Shelf-life is a final area of consideration. First, when we consider shelf-life limitations or the causes of product failure, we are dealing with degradation which is either microbial or chemical in nature. With extruded foods, the incidence of bacterial spoilage is insignificant because of two very basic reasons. First, the normal HTST thermal treatments inherent to the process are sufficient to properly process the food mixture and eliminate unwanted micro-organisms. Second, the water activity or free water content typical of extruded foods is generally very low. The combination of both factors makes bacterial spoilage an insignificant problem.

In general, shelf-life issues will develop because of some form of chemical or physical degradation. Either we encounter a problem related to oxidative rancidity or perhaps we are dealing with a product which is hygroscopic and has a tendency for moisture pick-up. In each of these cases, the approach is the same because the answer will come as we address the barrier properties of the package. Importantly, depending on the product, we will need to build-in barrier properties which protect against light, oxygen and moisture. If we are dealing with a high fat product, one can also pack the product using an inert gas headspace.

Typical film options are shown on the next slide.

SLIDE 18

Packaging converter experts can literally take your requirements and develop a special film suitable to the product's needs. For such work the following parameters would be important.

- Distribution time and conditions
- Cost objective
- Barrier property
- Printability
- Process compatible etc.

(Closing remarks)

Discussion Outline

- Consumer Acceptance Attributes
- Unit Process Considerations
- Product Modeling
- Shelf-Life Overview

Extruded Food Products

- Ready-To-Eat Cereals
- Snack Foods
- Croutons
- Pet Foods
- Textured Vegetable Protein
- Pasta Products

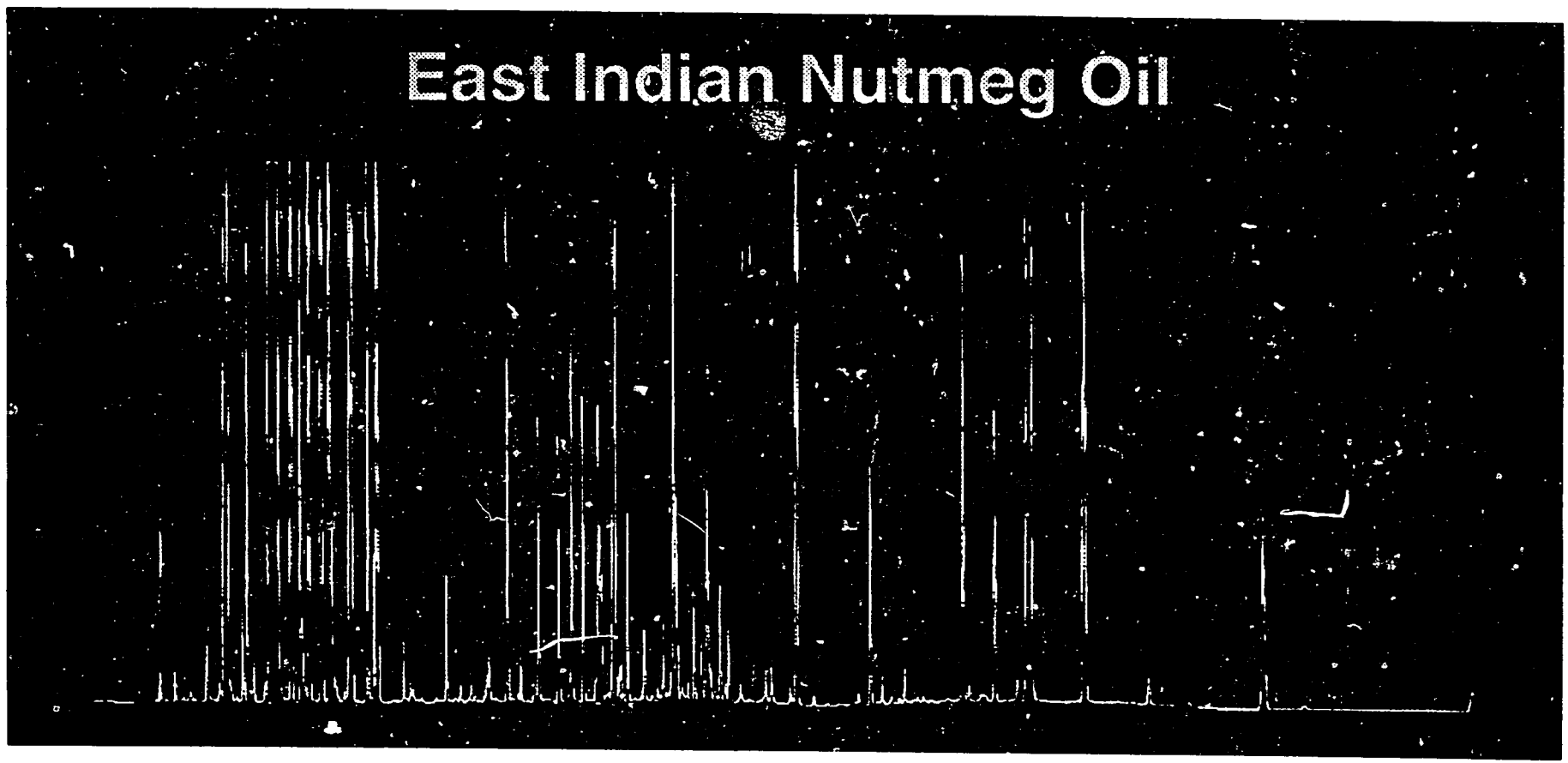
Primary Product Attributes Affecting Consumer Acceptance

- Flavor
- Color
- Texture
- Size and Shape
- Nutrition

Key Process Variables Having an Impact on Product Quality

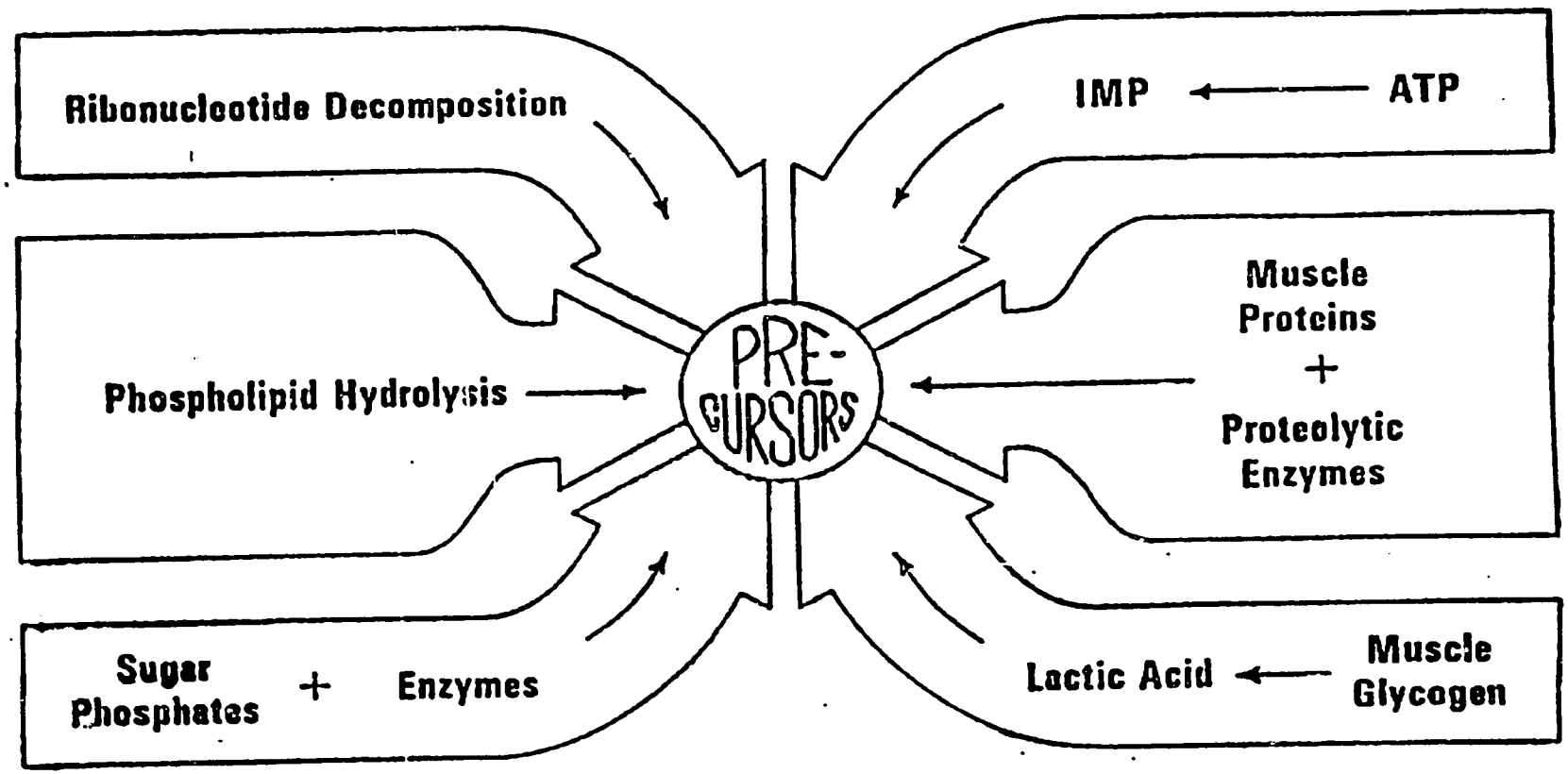
- Moisture
- Mechanical Energy
- Thermal Energy
- Retention Time

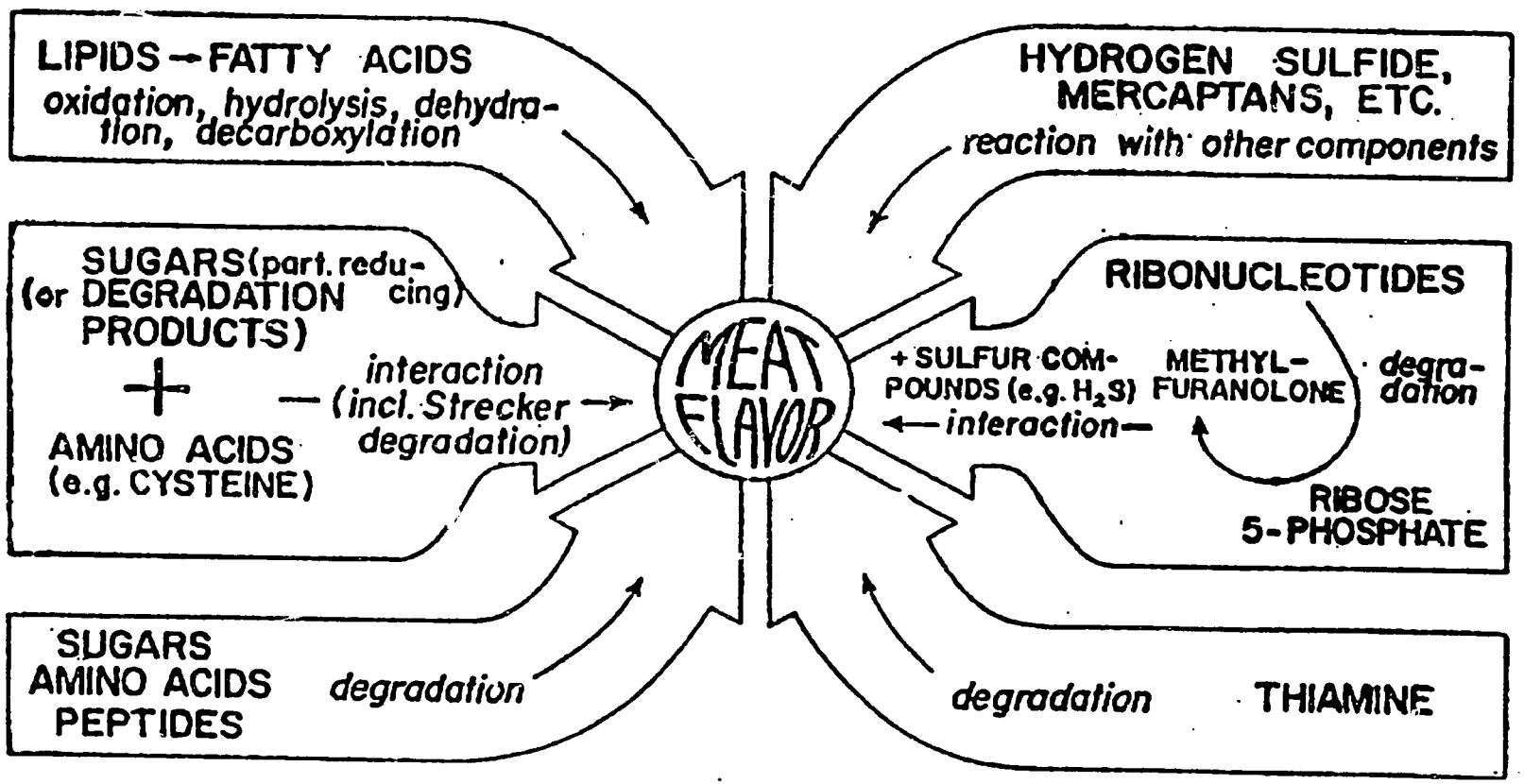
East Indian Nutmeg Oil



New Flavor Technologies for Extrusion Cooking

- Encapsulation
- Entrainment
- *In Situ* Flavor Development


Ribonucleotide Decomposition
IMP
ATP
Phospholipid Hydrolysis
PRE-CURSORS
Muscle Proteins
+
Proteolytic Enzymes
Sugar Phosphates
+
Enzymes
Lactic Acid
Muscle Glycogen


LIPIDS → FATTY ACIDS
oxidation, hydrolysis, dehydration, decarboxylation
SUGARS (part. reducing)
(or DEGRADATION PRODUCTS)
+
AMINO ACIDS
(e.g. CYSTEINE)
interaction
(incl. Strecker degradation)
SUGARS
AMINO ACIDS
PEPTIDES
degradation
MEAT FLAVOR
HYDROGEN SULFIDE, MERCAPTANS, ETC.
reaction with other components
RIBONUCLEOTIDES
+ SULFUR COMPOUNDS (e.g. H_2S)
METHYL-FURANOLONE
degradation
interaction
RIBOSE 5-PHOSPHATE
degradation
THIAMINE

Starch Sources

Cereal Crops

- Barley
- Corn
- Oat
- Rice
- Rye
- Sorghum
- Triticale
- Wheat

Root Crops

- Tapioca
- Potato

Starch Functionality

- Density Control
- Strength
- Shelf-Life Improvement
- Moisture Uptake
- Flavor
- Water-Holding Capacity
- Fat Binding

C. Feldburg, 1969
P. Smith, 1971

Extrusion Effects on Formulation Ingredients

Ingredient:	Starch	Protein	Lipid
Effect:	Gelatinization	Control of Protease Inhibitors	Starch/Protein Complexes
	Susceptibility to Enzymatic Hydrolysis	Denaturation of Protein	Enzymatic Control
	Viscosity Development	Increased Digestibility	Oxidative Rancidity
	Water Solubility and Absorption	Texturization	Isomerization
	Minor Dextrinization	Rearrangement of Polymer Bonds	
	Increased Digestibility	Protein - Lipid Complexing	
	Starch - Lipid Complexing		

G. J. Rokey, 1990

Market Information

- Market Practice and Trends
- Unit Cost Objectives
- Label Claims
- New Product Opportunities

Product Modeling

Focus Groups	• Untrained consumer panels • Panels representative of target consumer • Descriptive analysis - qualitative
Internal Development	• Trained panels • Characterize target market • Descriptive analysis - quantitative
Preference Testing	• Untrained consumer panels • Measure product acceptability

Key Product Attributes

- Saltiness
- Oiliness
- Hardness
- Potato flavor
- Yellow color
- Fracturability

Product Evaluation Worksheet

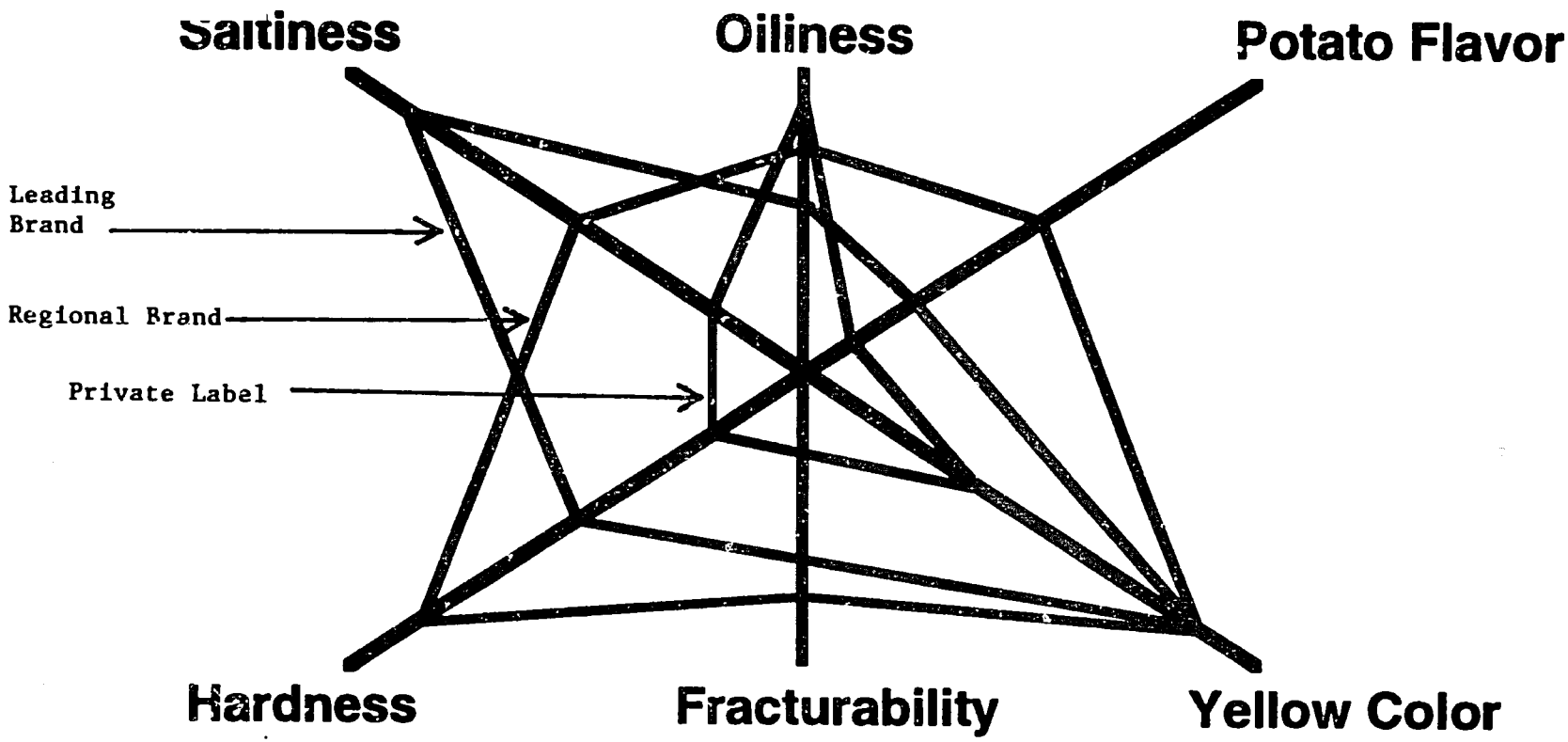
Product: _____

Reference: _____

Date: _____

	Low	High
Saltiness		
Oiliness		
Potato flavor		
Yellow color		
Fracturability		
Hardness		

Descriptive Analysis



Leading Brand
Regional Brand
Private Label

Product Development Program

Market Research	Understand how the market is being served. Identify market needs and future opportunities.
Focus Groups	Characterize product attributes important to product acceptance.
Descriptive Analysis	Using trained panels, apply a descriptive sensory terminology to characterize market and development samples.
Acceptance Testing	Monitor development process through the use of an Acceptance Testing Program with consumers.

Packaging Materials
Key Performance Parameters

- Gauge
- Slip
- Water vapor transmission
- Oxygen transmission
- Haze
- Gloss
- Opacity
- Tensile strength
- Tear strength
- Seal strength
- Impact strength
- Heat seal range

Packaging Film Options*

- Cellophane
- Celluose Acetate
- Nitriles
- Nylon
- Polybutylene
- Polyester
- Polyethylene
- Polypropylene

*Partial listing

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SEMINARIO EN TECNOLOGIA DE EXTRUSION Y SABORIZANTES EN LA PRODUCCION DE ALIMENTOS

VALOR NUTRICIONAL

DESARROLLO DE ALIMENTOS NUTRICIONALMENTE MEJORADOS

Dr. Luiz G. Elías, Jefe División Ciencias Agrícolas y de Alimentos, Instituto de Nutrición de Centro América y Panamá (INCAP)

RESUMEN

El desarrollo de alimentos nutricionalmente mejorados data de hace más de 30 años, y el propósito inicial de su fabricación en los países en desarrollo, fue principalmente el de suministrar la cantidad y calidad proteínica de los alimentos de origen animal como la carne, la leche y los huevos que no eran accesibles a estas poblaciones. Para la elaboración de estos alimentos se emplearon proteínas de origen vegetal, como las oleaginosas, leguminosas, cereales, tubérculos y raíces que combinadas dan como resultado alimentos de alto valor nutritivo.

Posteriormente se determinó la necesidad de agregar otros nutrientes como las calorías, las vitaminas y los minerales, con el propósito de contribuir a un mejor estado nutricional de grupos prioritarios de estas mismas poblaciones. Actualmente, el interés por el uso de alimentos formulados a base de productos de origen vegetal ha aumentado notablemente no solo por su rol en los aspectos nutricionales, sino también por la asociación de la dieta con la salud. El desarrollo de estas formulaciones, tiene que considerar los siguientes aspectos: a. La disponibilidad de la materia prima, que de preferencia sea local y de buena calidad; b. Con respecto a la formulación de estos alimentos hay que definir el

propósito de su uso; puede ser utilizado como un único alimento, como suplemento a la dieta, dirigida a grupos específicos, o a la población en general. Relacionado a esto está la calidad nutritiva del producto así como también aspectos físicos y organolépticos. c. La evaluación de la calidad involucra aspectos de naturaleza nutricional, tecnológica y sanitaria del producto. d. Finalmente, aspectos de procesamiento que involucran estudios de factibilidad técnica-económica; así como de comercialización, como forma de presentación, distribución, propaganda y otros. Con respecto al procesamiento, especial atención se dará al proceso de cocción-extrusión, principalmente en lo que se refiere a las ventajas de este proceso en la inactivación de factores antinutricionales presentes principalmente en las oleaginosas y las leguminosas, así como su efecto beneficioso sobre la calidad de la proteína y un mínimo daño en el contenido de las vitaminas.

On-site Visits by Drs. Miller and Sheldon

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- Provide technical and managerial assistance to food and feed processors, food equipment manufacturers, engineering companies and legal firms in Europe, Asia and the United States, including several Fortune 500 companies

- Client services include plant start-up supervision, equipment design and selection, market analysis, process/product development and improvement, process analysis and problem solving, training of plant and technical personnel, presentation of technical seminars, and expert testimony.

- Areas of expertise include snacks, cereals, bread, pet food, gasohol, TVP, cocoa, and general food equipment applications with emphasis on extrusion technology.

- My independent research has led to the development and sale of innovative equipment designs and new techniques for food process analysis.

Faculty 1985-Present
American Association of Cereal Chemists, St. Paul, MN
The Center for Professional Advancement, East Brunswick, NJ
Advisor 1985-Present
Institute of Food Science, Cornell University, Ithaca, NY
Center for Advanced Food Technology, Rutgers University, New Brunswick, NJ

Project Leader - Borden Foods Research Centre, Syracuse, NY 1977-80
- Managed corporate R&D Program for snacks and related products

Research Specialist - NY State Agricultural Experiment Station, Cornell University, Geneva, NY 1974-77
- Researched fruit and vegetable processes
- Managed food science pilot plant operations

Consulting Engineer - Lotte Ltd., Tokyo, Japan 1976

Senior Engineer - Nabisco, Inc. Research Center, Fair Lawn, NJ 1967-74
- Managed breakfast cereal and snack R&D groups
- Conducted engineering study of baking process
- Researched confectionery processes

Project Engineer - American Chicle Co. Div. Warner-Lambert, New York, NY 1965-67

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"Continuous Cooking of Breakfast Cereals," Cereal Foods World 33(3):284, 1988

"Extrusion Cooking: Process Analysis by Transient Response to Lipid Injection," IFT Paper 124, 45th Annual Meeting, June 10, 1985

"Extrusion Cooking of Pet Foods," Cereal Foods World 30(5):323, 1985

"Low Moisture Extrusion: Effects of Cooking Moisture on Product Characteristics," Journal of Food Science 50(1):249, 1985

"Effect of Wear on Twin-Screw Extruder Performance," Food Technology 38(2):56, 1984

"Some Factors Affecting the Extraction of Apple Juice in a Screw Press," Special Report 27, Cornell University, 1978

"Centrifugal Clarification of Apple Juice," Special Report 27, Cornell University, 1978

"The Effect of Steam Stripping of Grape Juice Prior to Fermentation," American Journal of Enology & Viticulture 28(4):231, 1977

"Food Extrusion," Food Technology 27(8):46, 1973

In Progress

"Fluid Flow in Variable, Tapered, Annular Cross-sections, and Rheology of Apple Pomace"

"Food Extrusion: Discovery and Development"

"Twin-Screw Extrusion at Cornell University"

Advances In Baking Technology (Contributing Author), Blackie & Son.

Presentations

"The Extruder: Cornerstone of Western Civilization," Institute of Food Technologists -- Regional Chapters: Long Island, February 2, 1987; Central NY, April 16, 1987

"Recent Developments in Food Extrusion," Cornell University Seminar, October 7, 1986

"Effect of Wear on Twin-Screw Extruder Performance," BDL-Kongress, Mönchengladbach, F.R.G., November 4, 1983 (See Lebensmitteltechnik, December, 1983)

U.S. Patents

3,851,084 - Method of Producing Laminated Comestible Products

3,861,844 - Apparatus for Producing Irregularly Shaped Expanded Food Products

4,022,918 - Method for Producing Irregularly Shaped Expanded Food Products

Education

Newark College of Engineering (NJIT), Newark, NJ - B.S. Chemical Engineering, 1965

Graduate Studies - Newark College of Engineering, 1969-70

AIChE Professional Development Certificate, 1985 & 1990

Professional Memberships

American Institute of Chemical Engineers

Institute of Food Technologists

American Society of Agricultural Engineers

R&D Associates for Military Food & Packaging Systems

Volunteers in Technical Assistance

Technology Club of Syracuse

References

Available on Request

UNIVERSAL FLAVORS
A UNIVERSAL Foods COMPANY

FAX CORRESPONDENCE
FAX NO.: 1-202-628-5726

TO: Dr. Elizabeth Turner
Program Director
Project SUSTAIN

FROM: Dr. Ross M. Sheldon

DATE: 4 June 1992

Dear Dr. Turner:

As requested, I believe the following notes should be enough in order to construct a short paragraph.

Education

BS 1965 University of California - Davis
MS 1967 Oregon State University
PhD 1969 Oregon State University

Food Science was the major for each of the above degrees. Heavy emphasis in Organic Chemistry, Research Interest: Natural product chemistry; Flavor research; Instrumental analysis techniques on a micro-scale.

Work Experience

1969-1975; 1978-1983 SCM Organic Chemicals, Jacksonville, FL

Position Held: Senior Scientist, R & D Manager - Essential Oils, Business Manager - Essential Oils, Director of Marketing

1975-1978 The Pillsbury Company, Minneapolis, MN

Position Held: Section Head - Flavor & Sensory

Primary Activity: Managed the applied flavor and the sensory evaluation laboratories in support of product development activities.

91

1983-Present	Universal Flavor Corporation, Indianapolis, IN
Positions Held:	Vice President - Sales & Marketing; Managing Director - Asia Pacific; Managing Director - Europe
Current Activity:	Manage Universal Flavors four European companies. Locations In: England, Belgium, Italy, and France. Responsibility covers all commercial activities for Europe and the Middle East.

I hope the above is sufficient.

Regarding yesterday's discussion and your fax, I have given your 14 July matter some serious thought. Regratfully, I must decline. First, the Panelist Slots for your Session #4 (Group 1 & 4) are not applicable to my background or our company's interests. Returning to the Policy Reform presentation for Session #3, I must confess to some interest. At the same time, what I would have to say would require far less time than 90 minutes. Briefly, in my opinion, your audience needs to consider some sort of industrial model and the business/logistical elements which are needed in order to make the exercise successful (profitable!). The proposed policy reforms would then be the means by which the barriers to profitability are removed: For example, some possibilities would include:

- Tax credit policy to encourage investment.
- Duty/customs provisions to facilitate the import of raw materials.
- Financial policies which would permit the repatriation of profits.
- Access to hard currency in order to purchase needed materials not available in the local market.
- Local logistics and services necessary to support a local enterprise.

The above list could go on. On balance, the participants need to understand that business seeking to invest will be held accountable for some favorable level of return. The question needing to be answered is: What policies could be developed which would provide the necessary incentives to encourage outside participation?

Thank you for the consideration I have received. I will be looking forward the August program in Central America.

Sincerely,

Ross Sheldon

Ross M. Sheldon
Managing Director - Europe

RMS/md
MIS92227.RMS

El Instituto de Nutrición de Centro América y Panamá INCAP

La Asociación Guatemalteca de Tecnólogos en Alimentos AGTA

El Proyecto SUSTAIN

Hacen constar que:

ELIZABETH TURNER

Participó en el seminario " Tecnología de Extrusión y Saborizantes en la Producción de Alimentos " realizado en la Ciudad de Guatemala el día cuatro de agosto de mil novecientos noventa y dos.

Dado en la Ciudad de Guatemala a los cuatro días del mes de agosto de mil novecientos noventa y dos.

Dr. Luis G. Elías, Jefe
División de Ciencias Agrícolas y de Alimentos
INCAP

Elizabeth Turner
Directora
Proyecto SUSTAIN

Lic. Clark McDonald
Presidente
AGTA

EL INSTITUTO DE NUTRICION DE CENTRO AMERICA Y PANAMA
(INCAP/OPS)

LA ASOCIACION GUATEMALTECA DE TECNOLOGOS EN ALIMENTOS
(AGTA)

Y, EL PROYECTO SUSTAIN

Presentan el Seminario:

TECNOLOGIA DE EXTRUSION Y SABORIZA[illegible]
EN LA PRODUCCION DE ALIMENTOS

TEMAS Y EXPOSITORES

TECNOLOGÍA DE EXTRUSIÓN:
Dr. Robert Miller
Catedrático de la American Association of Cereal Chemists, St. Paul, MN y Asesor del Institue of Food Science, Cornel University, Ithaca, NY
Gerente de Robert C. Miller Consulting Services

ACEPTACION DEL CONSUMIDOR-SABOR, TEXTURA, ETC.;
Dr. Ross Sheldon
Vicepresidente de Ventas y Mercadeo,
Director Ejecutivo de Europa y Asia de Universal Flavors Corporation.

VALOR NUTRICIONAL:
Dr. Luis G. Elías
Jefe de la División de Ciencias Agrícolas y de Alimentos del INCAP/OPS

DISPONIBILIDAD DE MATERIAS PRIMAS EN LA PRODUCCION DE ALIMENTOS NUTRITIVOS:
Ing. Billy Estrada
Consultor en el Area de Ciencias Agrícolas de INCAP/OPS

FECHA: [illegible] Marzo [illegible] 92

LUGAR: Hotel [illegible] de Guatemala, Guatemala

HORA: 8:30 a 18:00 [illegible]

INVERSIÓN: [illegible]
Socios AGTA [illegible] 00
No Socio [illegible] 00
Estudiantes [illegible]
Extranjero [illegible]

PREINSCRIPCION:
OSMOSIS
[illegible] 19 calle [illegible]
Tel: 33 53 3[illegible]
Fax: 33 53 53

BEST AVAILABLE COPY

CONFERENCISTAS INVITADOS

Dr. Robert Miller *

Catedrático de la American Association of Cereal Chemists, St. Paul, MN y Asesor del Institute of Food Science, Cornel University, Ithaca, NY
Gerente de Robert C. Miller Consulting Services

Dr. Ross Sheldon*

Vicepresidente de Ventas y Mercadeo,
Director Ejecutivo de Europa y Asia de Universal Flavors Corporation.

Dr. Luiz G. Elías

Jefe de la División de Ciencias Agrícolas y de Alimentos del INCAP/OPS

Ing. Billy Estrada

Consultor en el Area de Ciencias Agrícolas de INCAP/OPS

* Los Dres. Sheldon y Miller ofrecerán consultorías gratuitas a empresas interesadas el día lunes 3 de agosto en las áreas de extrusión y saborizantes. Información Ing. Luis Eduardo Reyes/ INCAP Tels.: 723762 al 7, extensión 326

NOTA:
Las consultorías estarán limitadas por el tiempo y el número de empresas solicitantes.

AQUI VA ETIQUETA DE CORREO

101

EL INSTITUTO DE NUTRICION DE CENTRO AMERICA Y PANAMA (INCAP/OPS)

LA ASOCIACION GUATEMALTECA DE TECNOLOGOS EN ALIMENTOS (AGTA)

Y EL PROYECTO SUSTAIN

Presentan el Seminario:

TECNOLOGIA DE EXTRUSION Y SABORIZANTES EN LA PRODUCCION DE ALIMENTOS

Project SUSTAIN

AGTA

TECNOLOGIA DE EXTRUSION Y SABORIZANTES EN LA PRODUCCION DE ALIMENTOS

PROGRAMA

Tecnología de Extrusión: Dr. Robert Miller

- ¿Qué es? y ¿Cómo trabaja?
- Protección del producto
- Costo del proceso / Capital de inversión
- Tipos de extrusores disponibles

Valor Nutricional: Dr. Luiz G. Elias

- Concepto
- Impacto del proceso en el valor nutricional de los ingredientes
- Fortificación
- Formulaciones

Disponibilidad de materias primas en la producción de alimentos nutritivos: Ing. Billy Estrada

Aceptación del Consumidor: Dr. Ross Sheldon

- Sabor, textura y apariencia
- Vida de anaquel
- Evaluación sensorial

Pánel: Conferencistas Invitados/INCAP/AGTA

- Retos en el Mercadeo de Alimentos Nutritivos

FECHA: Martes 4 de agosto de 1,992

LUGAR: Hotel Camino Real, Ciudad de Guatemala, Guatemala, C.A.

HORA: 8:30 a 18:00 horas

INVERSIÓN:

Socios AGTA	Q. 300.00
No Socios	Q. 350.00
Estudiantes	Q. 275.00
Extranjeros	$. 80.00

PREINSCRIPCIÓN:

OSMOSIS
Sra. Vivian de García
19 calle 12-52, zona 10
Tel.: 33 53 35 y 68 14 93
Fax: 33 53 56

Este mismo seminario se llevará a cabo en San Pedro Sula, Honduras, el día 6 de agosto de 1,992. Para más información comunicarse con la Sra. Ana Katán de Medina / INTERCHAM Tel.: (504) 57-4994 Fax: (504) 32-2483

102