EXTRUSION APPLICATIONS
Feed and Petfood

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Petfoods Overview

$53 billion total U.S. expenditure on pets

World market: more than double in size (Europe, Latin America, Asia)

$22 billion US market for pet foods
Major Trends

• U.S. sales driven by higher prices rather than volume

• Premium products – health, natural/organic, fortified/functional, weight control, lifestage, gourmet, breed-/size-specific

• Hundreds of new pet food products on the market shelf every year. Innovation is key!
Various Extruded Pet food Products

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Petfood Categories

- Dry expanded
- Semi-moist
- Canned

Product Properties

- Nutritional quality
- Palatability
- Bulk density
- Shelf life
- Owner appeal
Petfood Categories

- **Dry**: < 10% moisture (w.b.); various shapes, sizes and porosity

- **Semi-moist**: 22-35% moisture (w.b.); typical product ~30% moisture (w.b.); requires preservatives

- **Wet**: 65-80% moisture (w.b.); retorted/ refrigerated; cans, pouches, cups, trays, etc.
Why Extrusion for Making Petfood?

- Energy efficient
- Low cost of production
  - Manpower
  - Floor space
- Continuous
- Convenient
- Environmentally friendly
- Different shapes, sizes and colors
- Control of cooking, texture and palatability
Aquatic Feed

Assortment of aquatic feed products
Aquatic Feeds

- Floating
  - Catfish
  - Carp
- Slow Sinking
  - Salmon
  - Trout
- Fast Sinking
  - Shrimp

Product Properties:

- Piece density
- Nutritional quality
- Water stability

Wenger Mfg., Inc.
PETFOOD AND AQUAFEED

EXTRUSION BASICS
Extrusion Cooking

A continuous process by which moistened, starchy, and/or proteinaceous materials are plasticized and cooked by a combination of moisture, pressure, temperature, and mechanical shear.
Extrusion System for Pet Food and Aquatic Feed

- **Raw Materials**
- **Mixer**
- **Extruder**
  - The extruder is considered the heart of the system.
- **Cooler**
- **Coater**
- **Dryer**
- **Finished Product to Packaging**
Extrusion Process for Pet Food and Aquatic Feed

- Moisture = 20 – 35 %
- Temperature = 100 – 150°C or above

Diagram showing:
- Feed entering the extruder
- Heating section
- Screws pushing material forward
- Water/Steam added to the barrel
- Die extruding the product
- Post-processing operations
Raw Materials

Processing Hardware

Processing Conditions And Control

Final Product
Hardware

- Dry Recipe Delivery
- Preconditioning
- Extruding
- Shaping / Cutting
Deliver Uniform Flow Rate of Dry Raw Materials to System

- Volumetric
- Gravimetric
Volumetric

- Operator Sets Feeder Speed to Control Rate
- Actual Feed Rate Affected By Changes in Bulk Density of Raw Material
- Simple Mechanical Design
- Low Cost
- Requires Bin Fill Rate of 5X Extrusion Rate

Gravimetric (L-I-W)

- Operator Sets Feed Rate and System Controls Automatically
- Not Affected By Changes in Bulk Density of Raw Material
- More Complex Design and Control System
- Higher Cost
- Requires Bin Fill Rate of 10X Extrusion Rate
Preconditioning

- Hydrate raw material particles
- Heat raw material particles
- Mix raw materials added in separate streams
Objectives of Preconditioning

Mix
Hydrate
Heat

Results in Partial Cooking of Raw Materials Prior to Extrusion
Preconditioner Designs

1) Single Shaft Cylinder (SC)
2) Double Shaft Cylinder (DC)
3) Dual Diameter Cylinder (DDC)
4) High Intensity Preconditioner (HIP)
Preconditioner Designs

Single Conditioner
Single Cylinder

High Shaft Speed

Low Shaft Speed

Single Cylinder
Preconditioner Designs

Double Conditioner
Intermeshing, Twin Shafted Conditioners
Hydration & Heating

Moisture Addition
- Steam
- Water

Slurry Addition
- Water-based
- Oil-based
Dry Recipe

Water

Other Ingredients

Fat

Steam

80/20 rule
Importance of Proper Nozzle Selection and Installation
Steam Injection on DDC
Benefits of Preconditioning

Increased Capacity
Reduced Screw Wear
Reduced Mechanical Energy Input
Increased Thermal Energy Input
When Should Preconditioning be Considered for Extrusion?

- Preconditioning **NOT** Necessary for All Extrusion Processes
- Any Process Benefitting From Higher Moistures and Longer Retention Times Benefits From Preconditioning
- As a Guideline, Consider Adding Preconditioning to Any Process Running at Greater Than 18% In-Barrel Moisture Content
Extruder Barrel

- Heads
- Screws
Extruder Barrel

Twin Screw
- Segmented (Heads)
- Jacketed
- Rigid
- Replaceable Liners

Single Screw
Extruder Barrel Components

- Barrel Sections
- Screws (Conveying & Restriction)
- Restriction Elements (Lobe & Round Locks)
Barrel Wall Configurations

- Smooth Bore
- Longitudinal Grooves
- Spiral Grooves
Single Screw Barrel Liners

• Spiral Ribbed Liner

• Straight Ribbed Liner
Round Shear Locks

Small Diameter = Low Restriction

Large Diameter = High Restriction

Commonly Used in Single Screw Extruder
Configuring the Extruder
Configuring the Extruder

- Conveying
- Restriction
- Venting
- Material Addition
Configuring the Extruder

- Shearlocks
- Cone Screws
- Conveying Screws
Single Screw System

- Single shaft
- Replaceable components
- Variable speed
- Temperature controlled heads
- Robust bearing design (up to 1000 kW)
- High capacities (up to 22 ton/hr)
- Lower maintenance and operations cost
Twin Screw System

- Co-rotating
- Parallel shafts
- Wider ingredient flexibility
- Ultra high levels of internal fat (above 17%)
- Very uniform size and shape
- Ultra small product sizes (less than 1.5 mm)
- Pushing product long distances
- Difficult to convey products
- High SME products (>45 kW-hr/mton)
Extruder Comparison

Single Screw Extruder

Twin Screw Extruder

Operating Ranges

- Moisture
- Internal Fat
- Mechanical Energy Input
- Product Size
# Extrusion System Comparison

<table>
<thead>
<tr>
<th>System</th>
<th>Single Screw</th>
<th>Twin Screw</th>
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<tbody>
<tr>
<td>Capital Investment</td>
<td>1</td>
<td>1.75</td>
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<tr>
<td>Operating Costs</td>
<td>1</td>
<td>1.75</td>
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<tr>
<td>Ingredient Flexibility</td>
<td>Good</td>
<td>Very good</td>
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<tr>
<td>Requires Extruder Configuration Changes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>System Complexity</td>
<td>Medium</td>
<td>High</td>
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<tr>
<td>Turn-Down Ratio</td>
<td>2:1</td>
<td>2.5:1</td>
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Principles of Die Design
Product Shaping
Die Terminology

[Diagram showing various parts:
- SPACER
- DIE PLATE
- KNIFE STUB
- BULLET
- INLET RELIEF
- LAND]
Insert Holder

- Flexibility – Change Number of Inserts
- Good For > 4mm & Shapes
Drilled Dies

- Preferred for < 3mm Dia
- Maximized Space Between Holes
- Increases Permissible Open Area
Spacers / Adaptors

SINGLE DIE WITH SPACER

HORIZONTAL DIE ADAPTOR

VERTICAL DIE ADAPTOR
Extrudate Expansion
Extrudate Expansion

- Influenced By:
  - Die Design
  - Processing Conditions (Temperature – Moisture)

- Controlled by:
  - Knife Speed
Extrudate Expansion

- Influenced By:
  - Die Design
  - Processing Conditions (Temperature – Moisture)

- Controlled By:
  - Die Opening Size
Co-Extruded / Filled Products
Co-Extrusion Die

- **FILLING**
  - PRODUCT ENTRANCE
  - PRODUCT ENTRANCE
  - FILLING
  - FILLING
  - FILLING
  - FILLING
- **PASTRY TUBE**
- **FILLED TUBE DIE**
Product Cutting
Ridged – Thin Knife

Good for:
• 2mm – 10mm sized products
• Shapes
Flex Knife Blades

- 0.8 – 3.0 mm sized pellets
- Sticky – Difficult to cut products
Knife Sharpening / Adjustment
Cutting of 3D Shapes
EXTRUSION OPERATION AND PROCESS VARIABLES
System Variables

Independent
Dependent
  ⊲ Critical Parameters
Product Responses
Independent Variables

- Dry Recipe
- Dry Recipe Rate
- Water Injected into Preconditioner
- Steam Injected into Preconditioner
- Preconditioner Speed
- Preconditioner Configuration
- Water Injected into Extruder
- Steam Injected into Extruder
- Extruder Configuration
- Extruder Speed
- Extruder Barrel Configuration
- Die Configuration
Dependent Variables

Retention Time in Preconditioner
Temperature in Preconditioner
Moisture in Preconditioner
Retention Time in Extruder
Temperature in Extruder
Moisture in Extruder
Pressure in Extruder
Mechanical Energy input via Extruder
Critical Parameters

- Moisture
- Thermal Energy Input
- Mechanical Energy Input
- Retention Time
Product Responses

- Water Absorption
- Stickiness
- Bulk Density
- Piece Density
- Solubility
- Oil Absorption
- Hardness
- Digestibility
- Texture
RAW MATERIALS

CRITICAL PARAMETERS

INDEPENDENT PROCESS VARIABLES

PRODUCT CHARACTERISTICS
Extrusion Cooking...

A VERY FLEXIBLE PROCESS THAT USING THE PROPER RAW MATERIALS, HARDWARE, AND PROCESSING TECHNIQUES, CAN PRODUCE A WIDE RANGE OF FOOD, FEED, AND INDUSTRIAL PRODUCTS
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