Tech-Driven Excellence: Extrusion for Better Kibble, Wet Food & Treats

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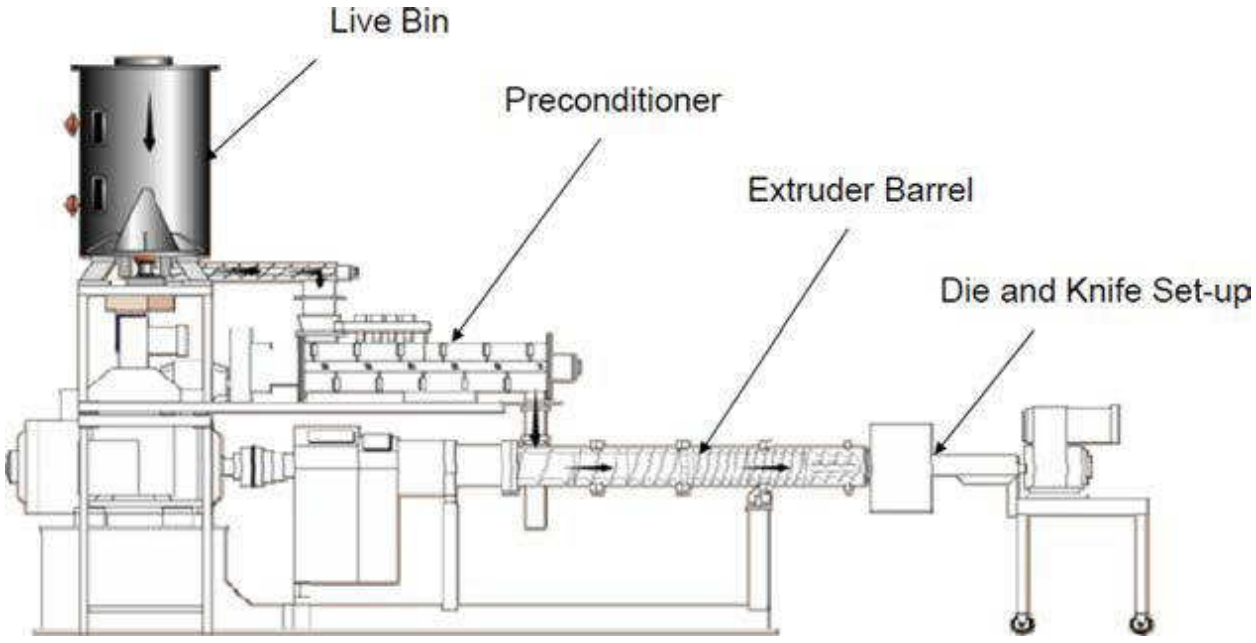
23 July 2025

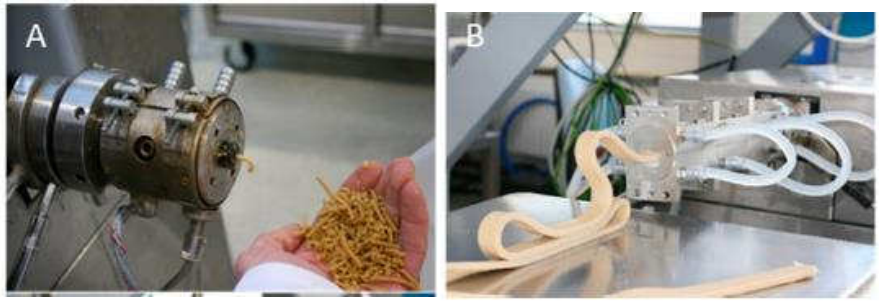
Extrusion process

Extrusion process:
“a process of forcing material through a designed opening”

https://en.wikipedia.org/wiki/Food_extrusion



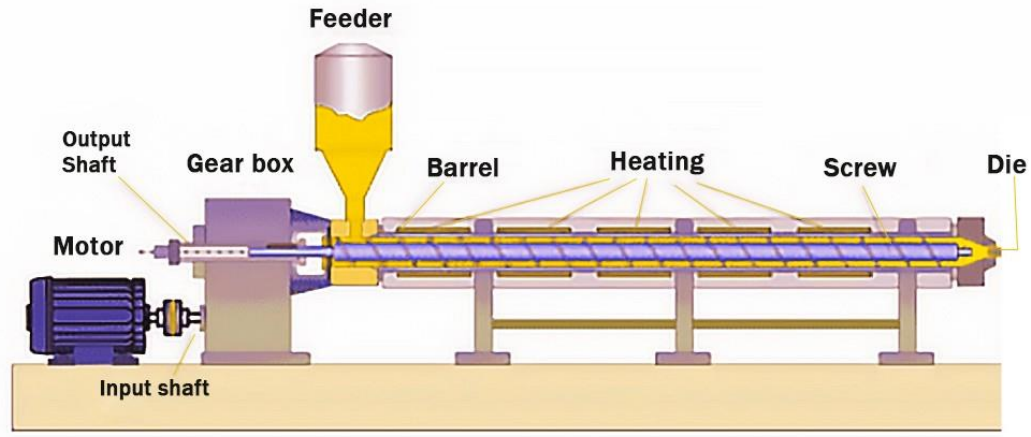
A general schematic of the extrusion processing system
(Courtesy of Wenger Manufacturing Inc.)



Foods **2021**, *10*, 600. https://doi.org/10.3390/foods10030600

Advantages of extrusion technology

One-step/ Continuous/ Versatile Process



Low Processing Costs (labor and energy)

Food Designing (shapes, texture, microstructure, color, appearance)

High Temp & Short time Process (disinfectation & sterilization)

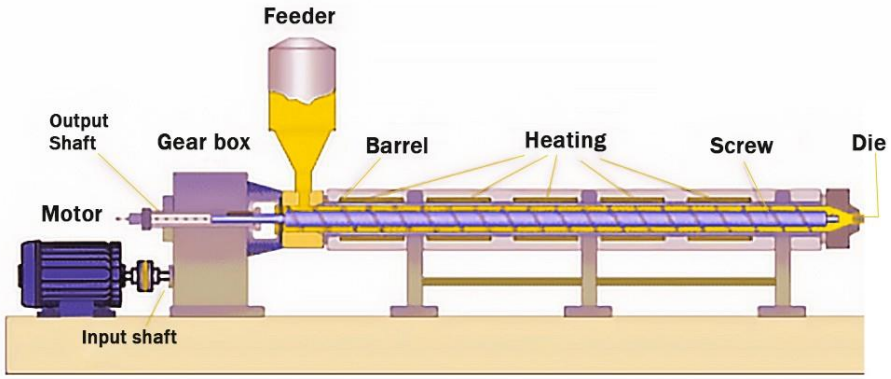
Extrusion cooking

Thermo-Mechanical Process: Clean Label*

Popular in the Global Agro-Food Industry

https://m.loyalfoodmachine.com/sell-detail-3216-single-screw-extruder-food-processing-machine.html

Extrusion in pet food products



https://m.loyalfoodmachine.com/sell-detail-3216-single-screw-extruder-food-processing-machine.html

Pet food products


Dry kibble


Semi-moist

Wet


Dental chew


Twist

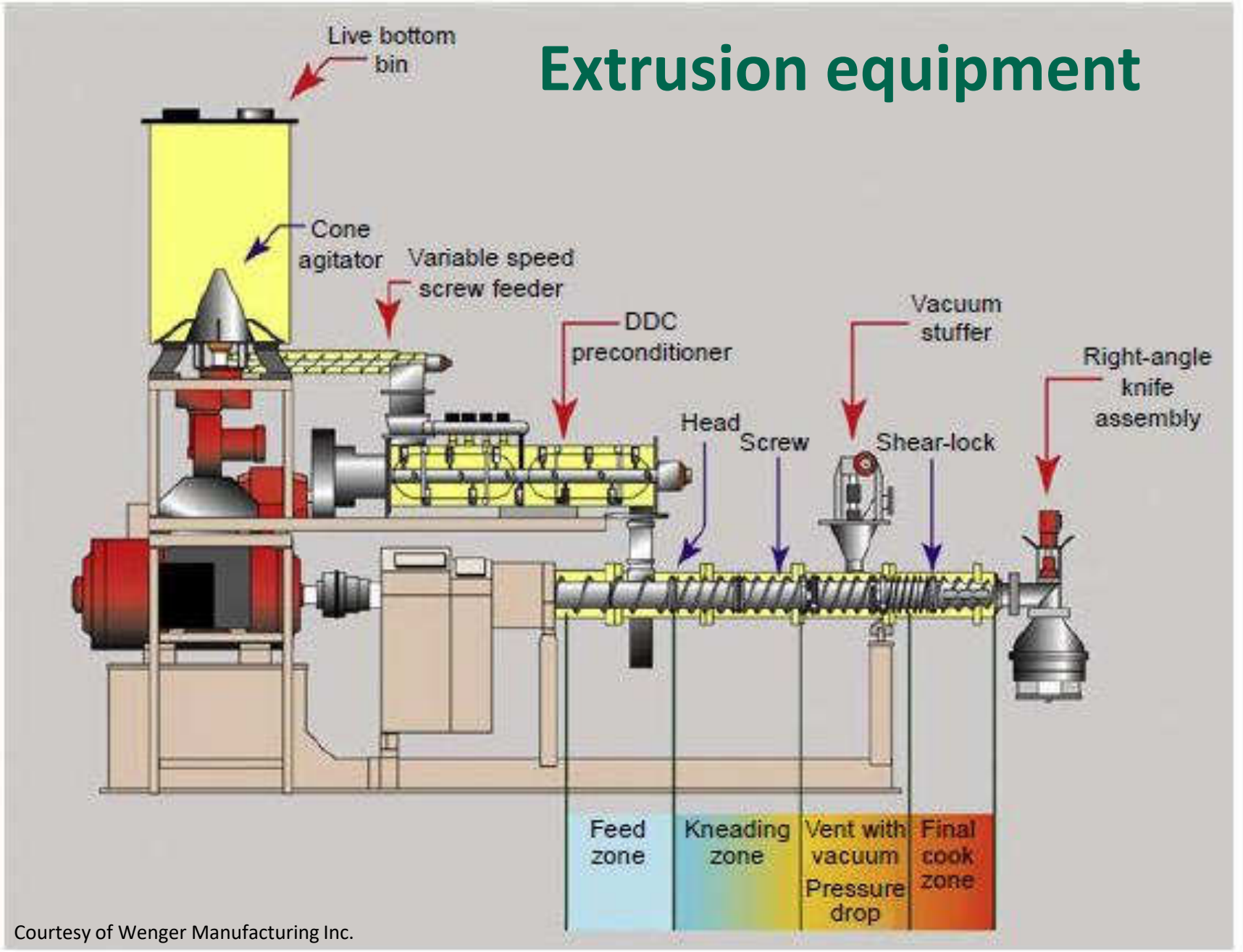

Pillow


strip


Multicolor


stick

Extrusion equipment

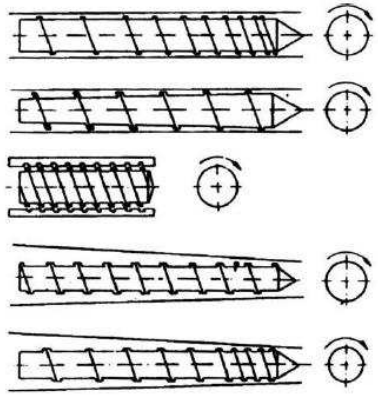


Courtesy of Wenger Manufacturing Inc.

- Extrusion drive
- Feed assembly
- Extrusion screw
- Extruder barrel
- Discharge

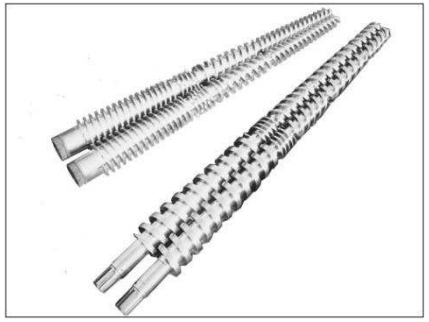
Extruder types

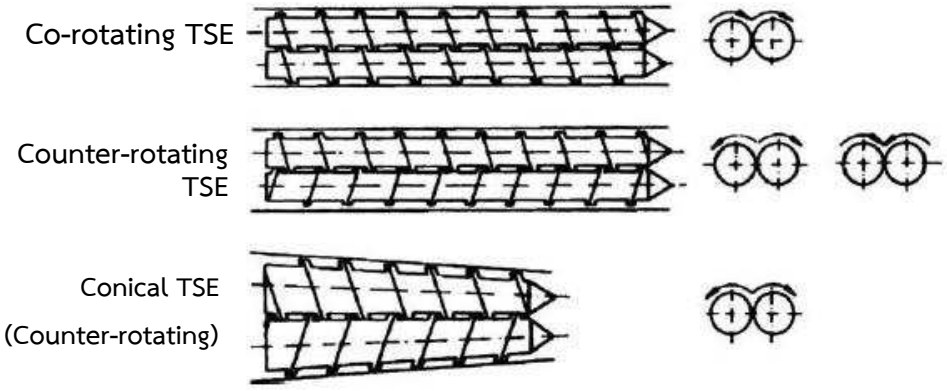
Single Screw Extruder

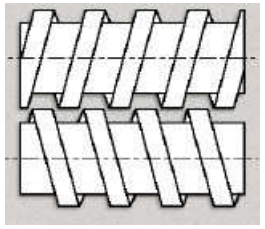


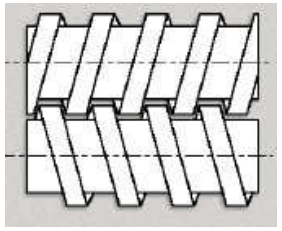
barrel

Twin Screw Extruder






Non-intermeshing screws


Intermeshing screws

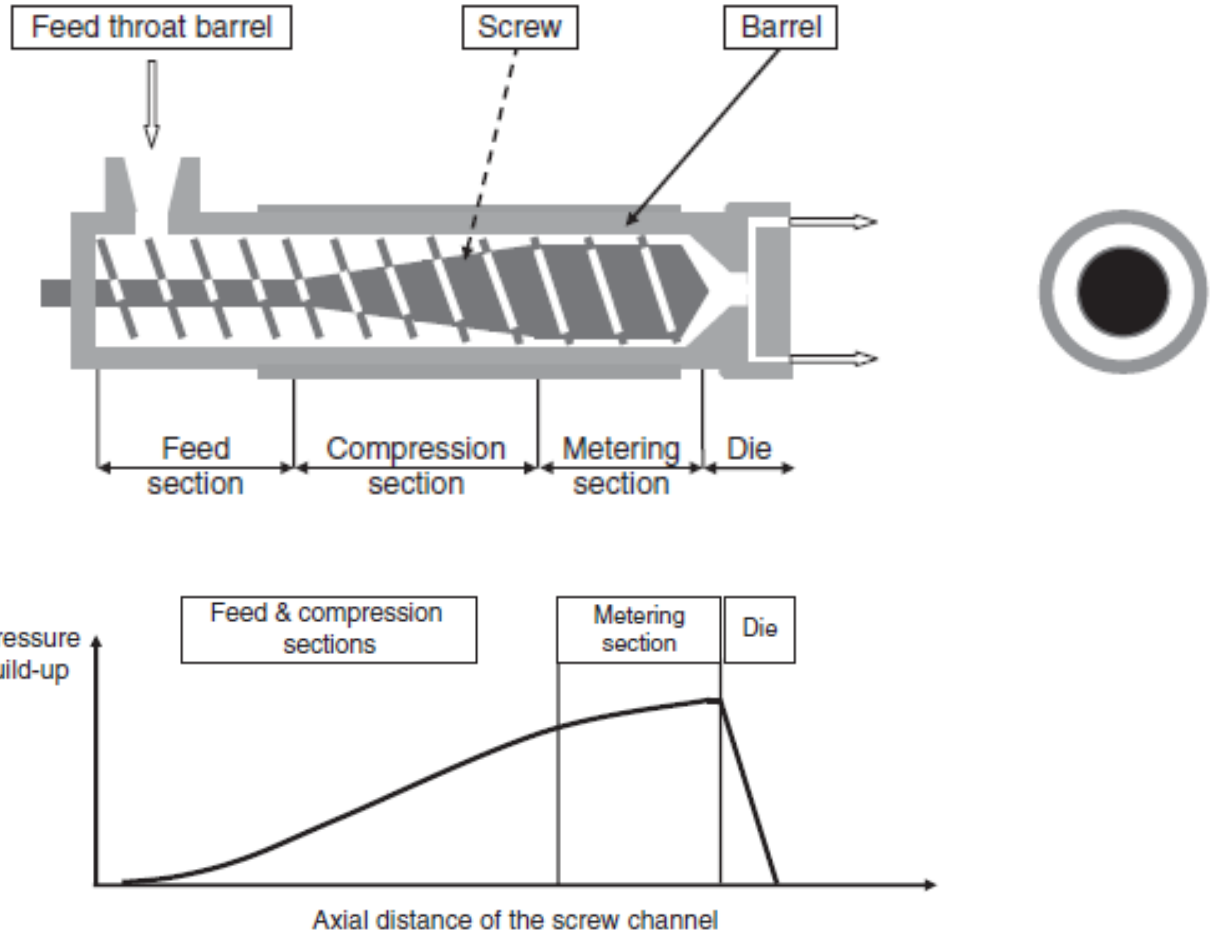
Multiple Screw Extruder


Ring extruder

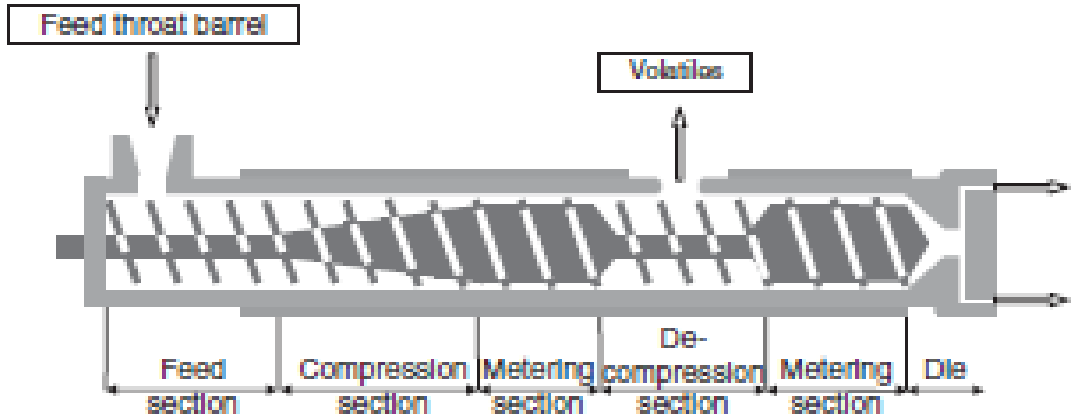
Courtesy of Wenger Manufacturing, Inc.

Single screw extruder

One-stage monobloc screw assembly



Two-stage monobloc screw assembly

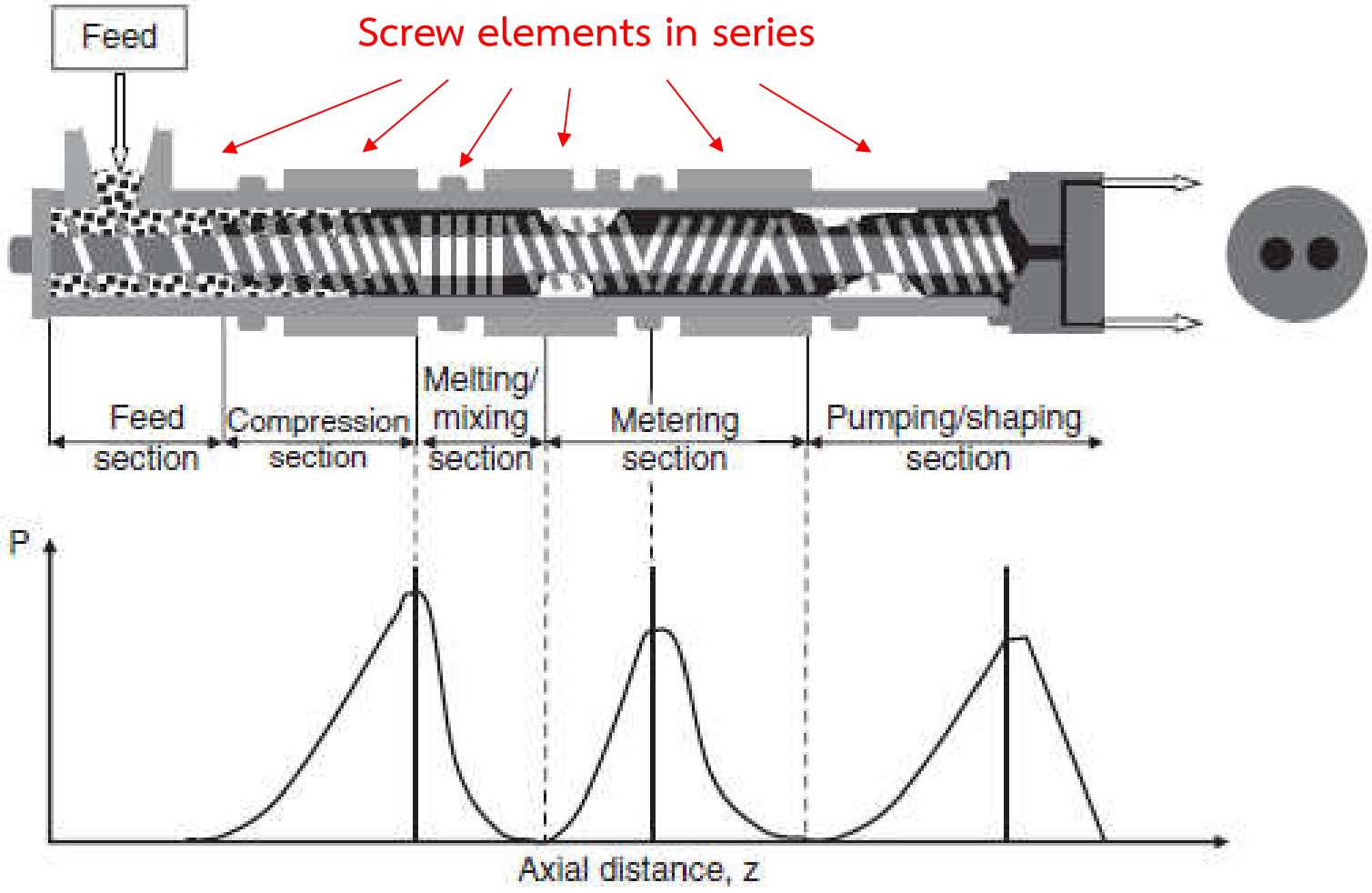


http://www.fusion-plastech.com/news/single-screw-extruder-SJ.html

Bouvier, J-M and Campanella, OH. (2014) Extrusion Processing Technology Food and Non-Food Biomaterials.

Twin screw extruder

- effective mixing and heat transfer, uniform melting, and effective temperature control.
- process flexibility by optimizing screw-barrel configuration for a particular application.



Bouvier, J-M and Campanella, OH. (2014) Extrusion Processing Technology Food and Non-Food Biomaterials.

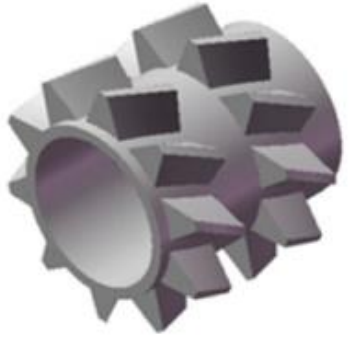
Basic screw elements

(a) conveying element

(b) reverse conveying element

(c) kneading block

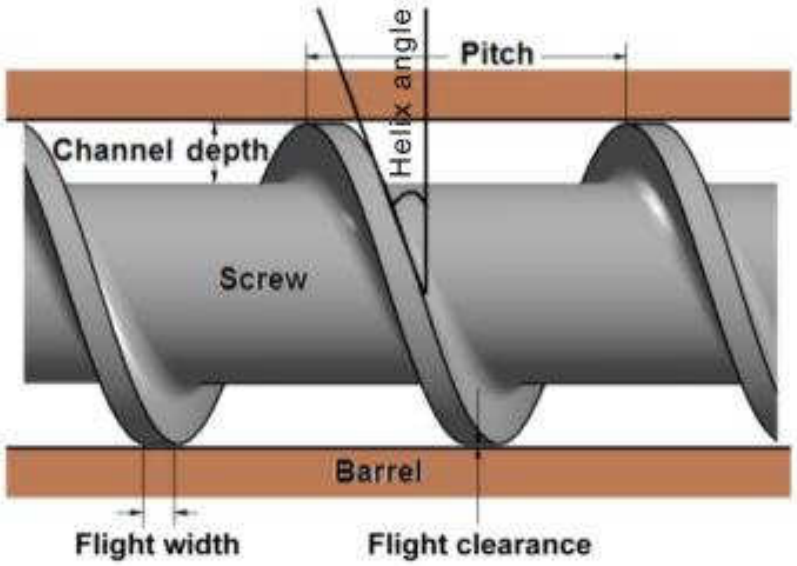
(d) reverse kneading element

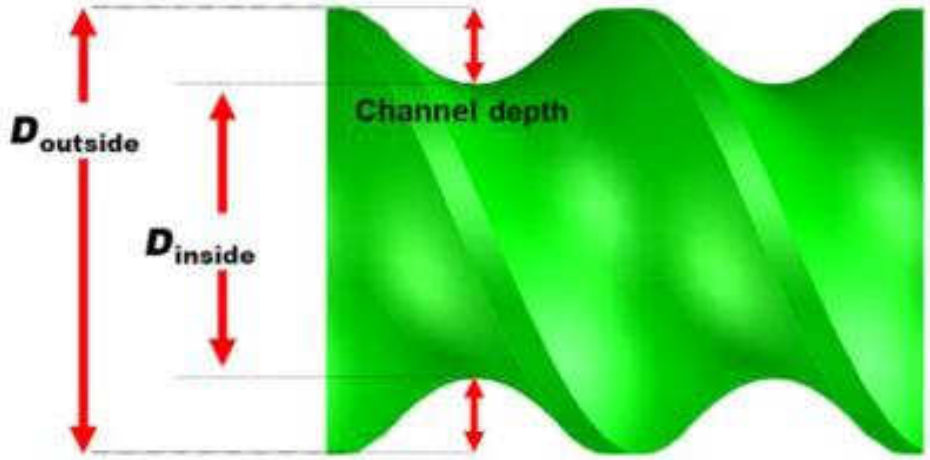


(e) special mixing element

https://pubs.acs.org/doi/10.1021/acs.iecr.0c05078?fig=fig2&ref=pdf

Conveying elements

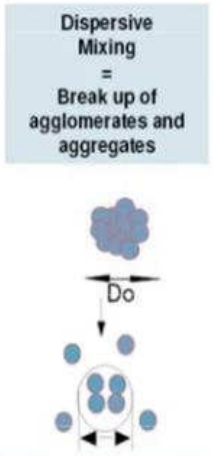


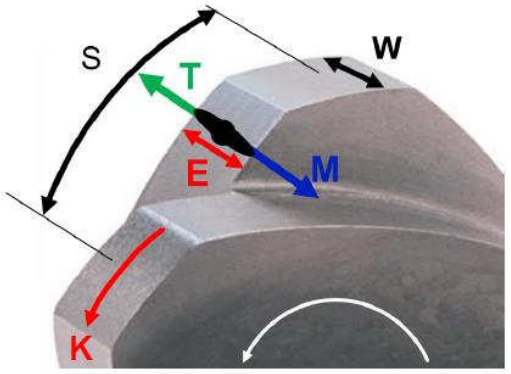


- Transporting solid raw materials and melt to down stream processing section
- Building up pressure at the end of extruder barrel

Process development and scale-up: Twin-screw extrusion. (https://doi.org/10.1016/B978-0-12-802447-8.00031-5)

Kneading elements

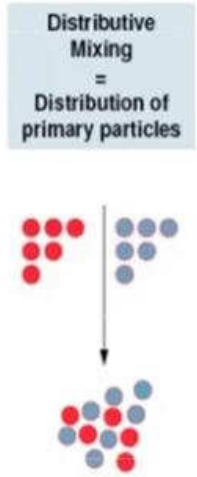




W = disc width
S = stagger angle

- generally used in the melting process.
- Good in dispersive mixing.
- designed as blocks or as individual disks arranged behind each other and cause, if their arrangement is staggered either to the left or right, an additional intensive mixing.

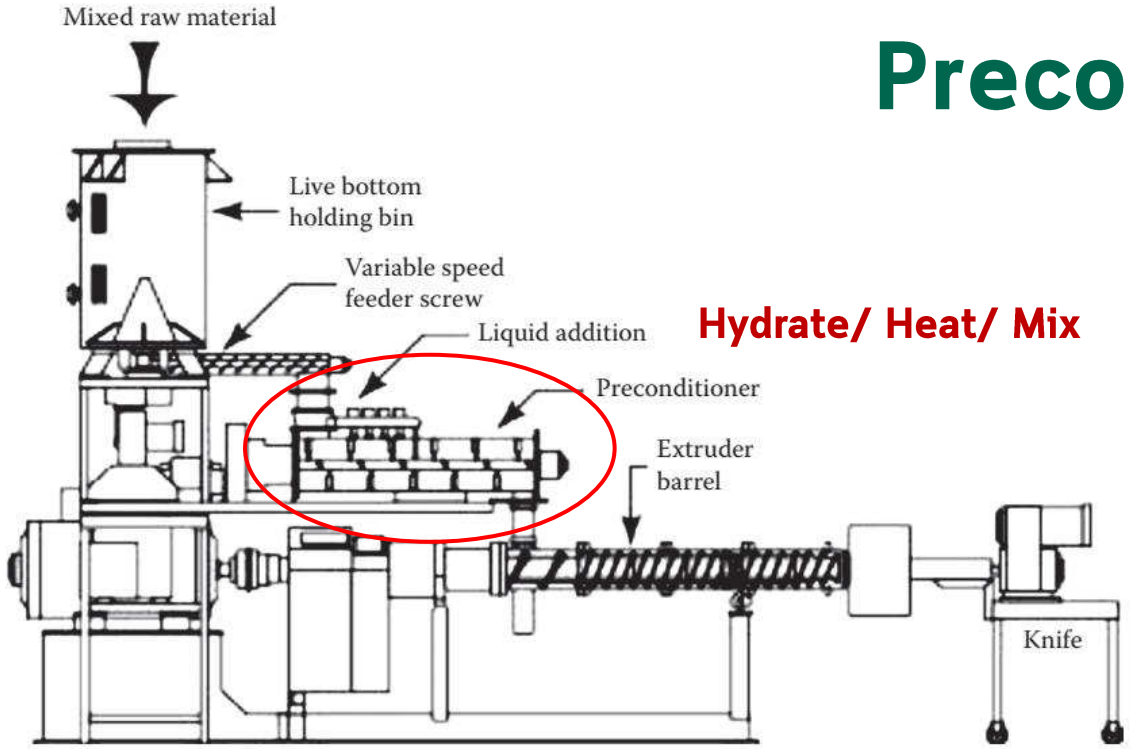
Mixing elements



- applied for mixing liquids, powder or fibrous additives even in smallest concentrations.
- Improved mixing.
- Provided a distributive mixing promoter consisting of a standard screw profile with slots cut across the flight tip to increase leakage flow.

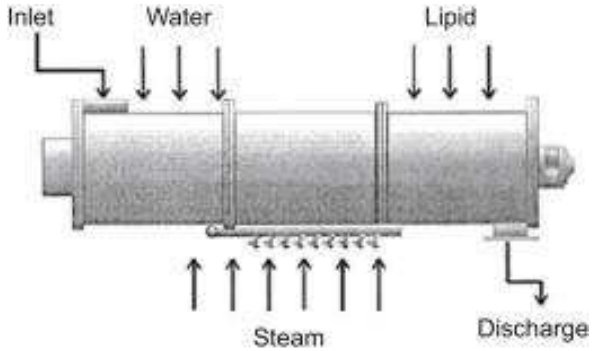
https://spe-stx.org/newsletters/SPE18NovemberExtruder/pdfs/FUNDAMENTALS-OF-TWIN-SCREW-COMPOUNDING-KNEADING-BLOCK-PERFORMANCE-CHARACTERISTICS.pdf

Preconditioning



Hydrate/ Heat/ Mix

Sun D-W (2012) Advances in food extrusion technology, p 366



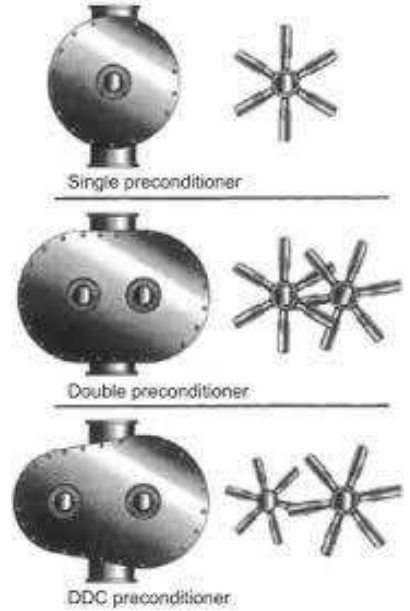
Preconditioner

Benefits of preconditioning

- Improve moisture penetration
- Improve heat transfer
- Improved mixing of wet and dry ingredients
- Decreased friction and wear of extruder components
- Higher extruder capacities

Design of preconditioner

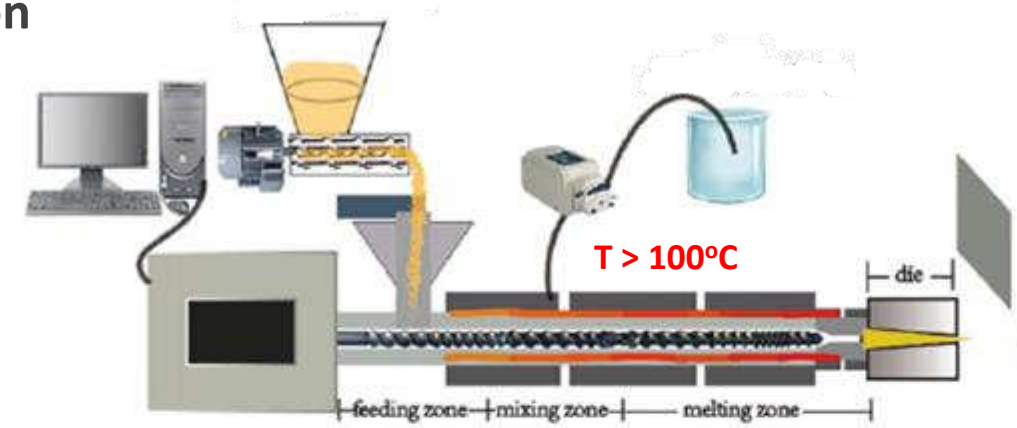
- Single-shaft
- Double-shaft
  - Intermeshing Counter-rotating
  - Same/ different speed
  - Same/ different diameter



Perdon AA, Schonaue, SL, Poutanen K (2020) Breakfast Cereals and How They Are Made, 3rd ed., p 203-248

Extrusion

Low moisture extrusion



T_{die} > 100°C

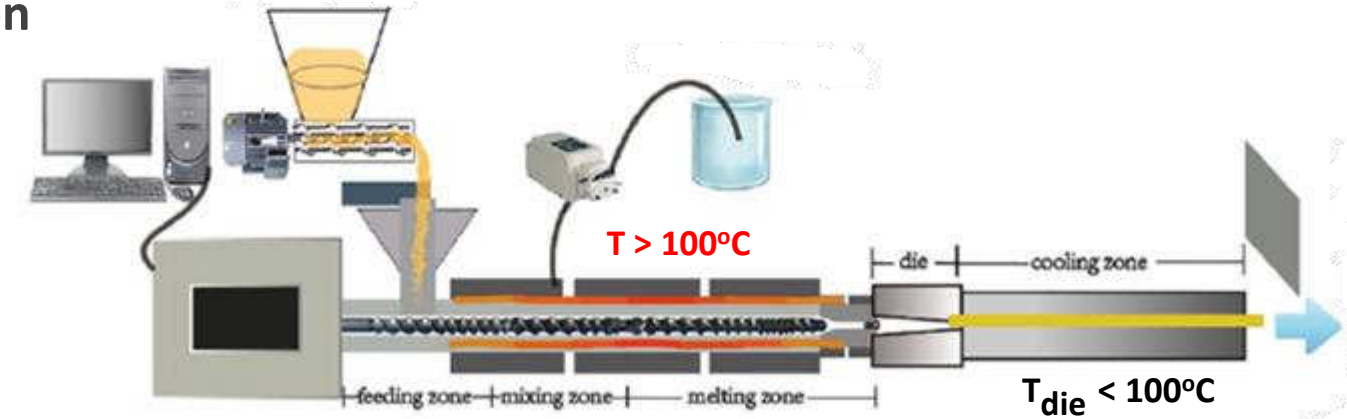
Texturized Vegetable Protein (TVP)

- ❑ Expanded, Porous
- ❑ Oven dry for storage
- ❑ Low moisture product

Breakfast cereal

Dry kibble

High moisture extrusion



T_{die} < 100°C

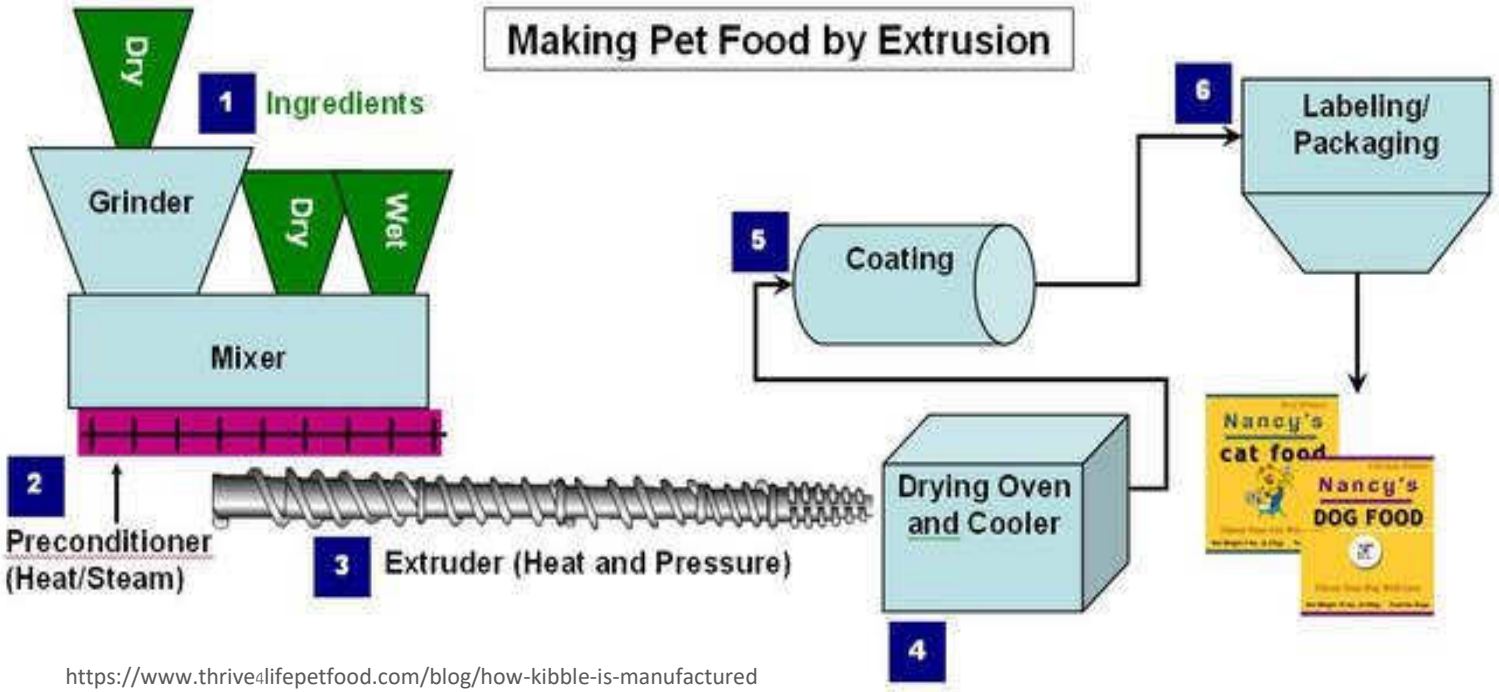
High Moisture Meat Analogue (HMMA)

- ❑ Fibrous or layer structure
- ❑ High moisture product
- ❑ Keep frozen

Modified from Zhang et al. (2019) Crit Rev Food Sci Nutr, 59, 3267-3280.

Dry pet food

More than 95% of kibble is manufactured using extrusion technology.



https://www.thrive4lifepetfood.com/blog/how-kibble-is-manufactured

Kibble

Characteristics

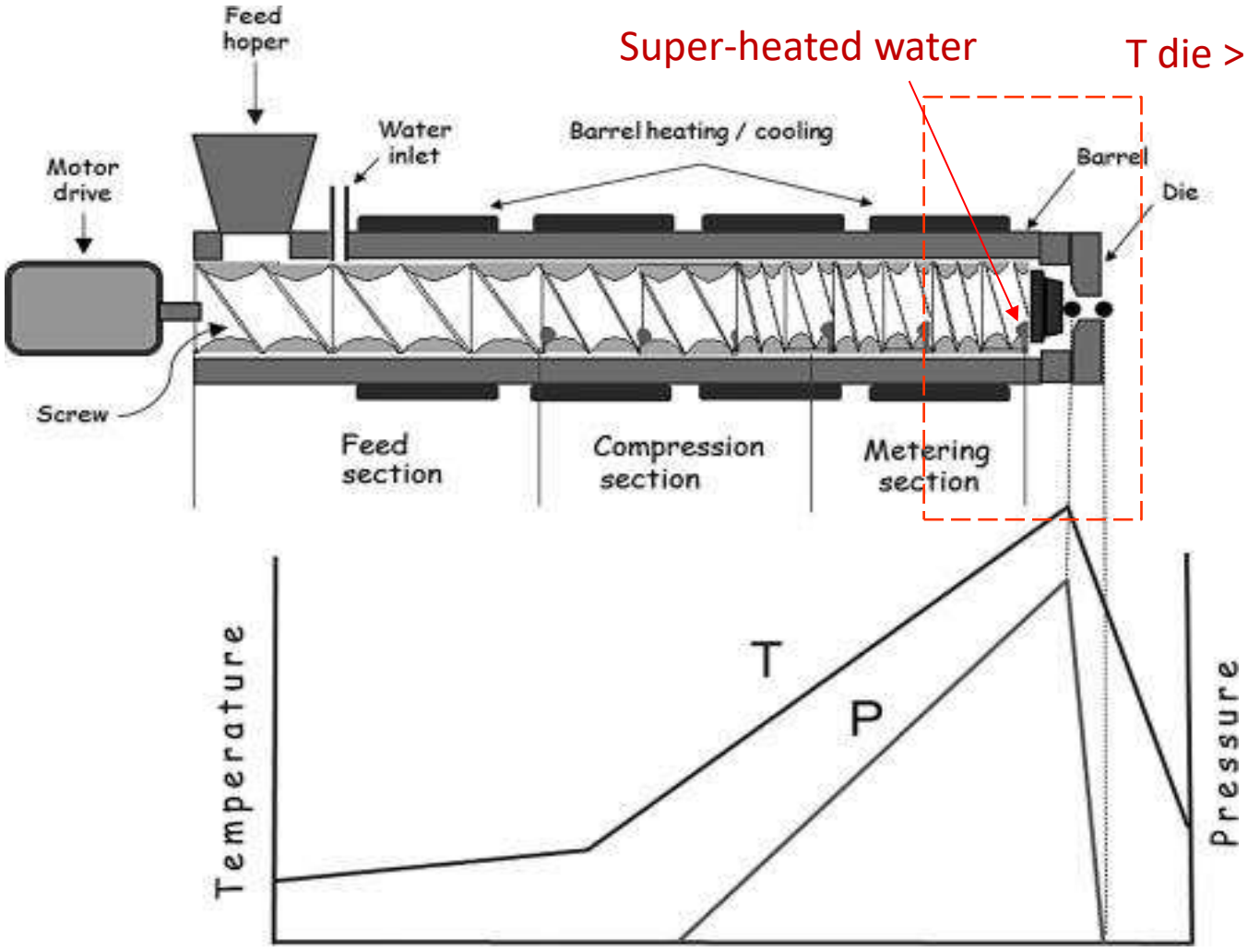
- Expansion index
- Bulk density
- Size
- Hardness

Concerns

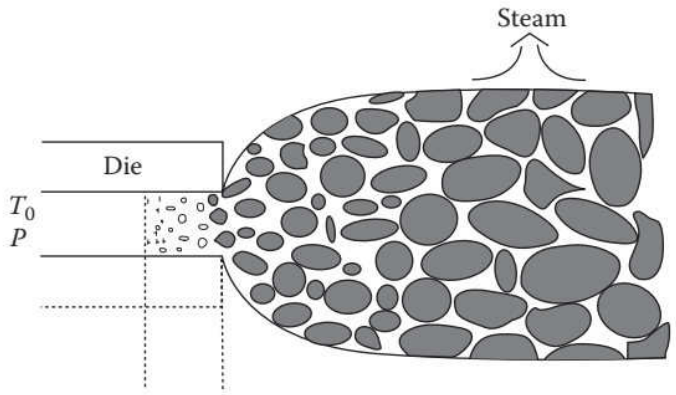
Multiple times processing at high temperatures, effectively killing many vitamins and enzymes.

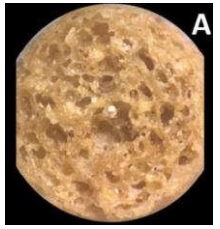
Spear and Fahey (2004) J.AOAC Int., 87, 787-791.

Expansion process in low-moisture extrusion



Ganjyal, GM (2020) Extrusion Cooking Cereal Grain and Processing, 2nd ed., p 31





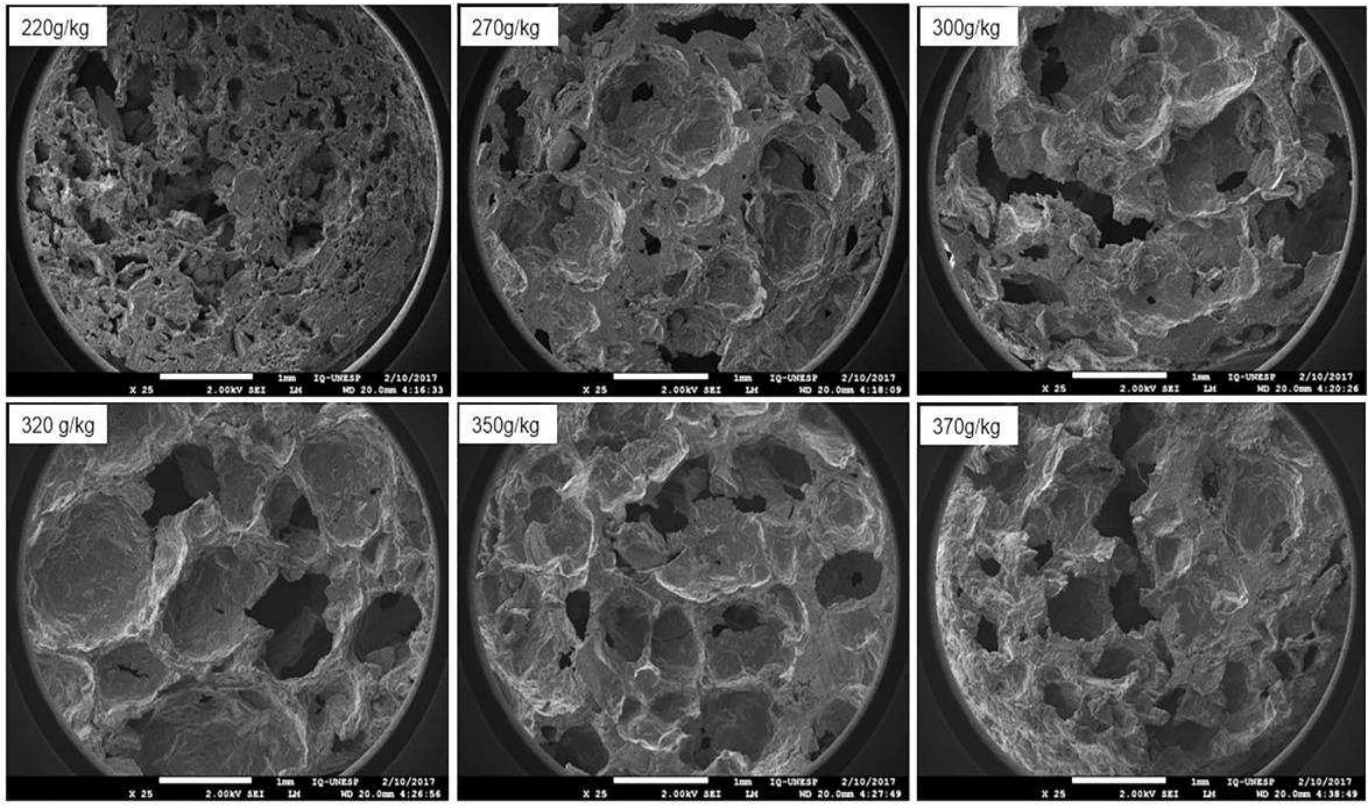
Foods **2021**, *10*, 2526

Product expansion after exiting the die due to vapor pressure and temperature difference

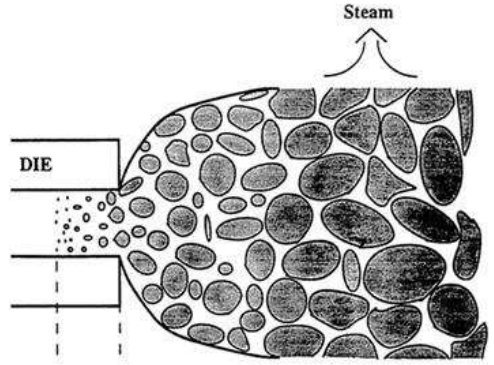
Sun D-W (2012) Advances in food extrusion technology, p 44

Kibble expansion

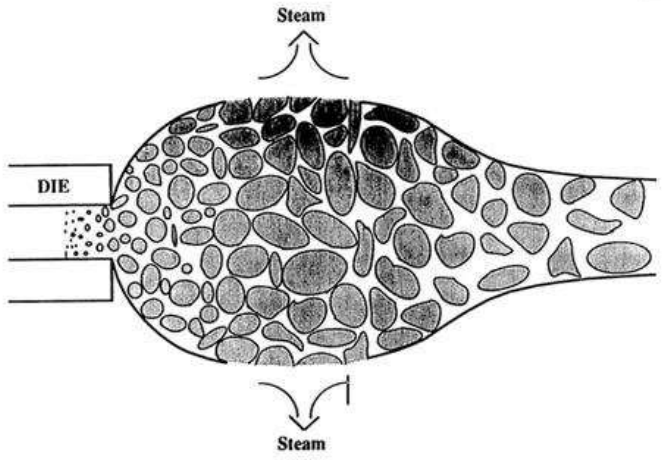
Effect of feed moisture content



Animal Feed Science and Technology 246 (2018) 82–90



low water levels



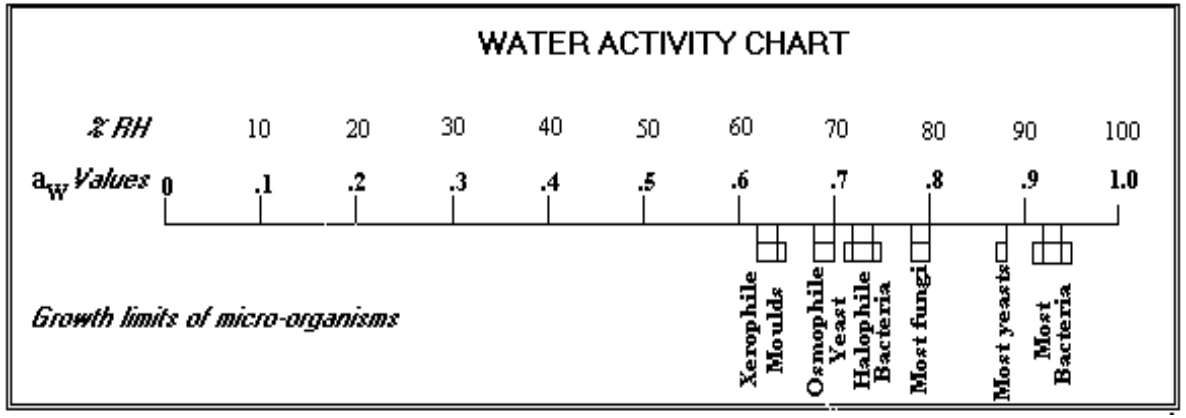
high water levels

Modified from https://www.globalseafood.org/advocate/extrusion-cooking-aquafeeds/

Drying

Water activity value (a_w):

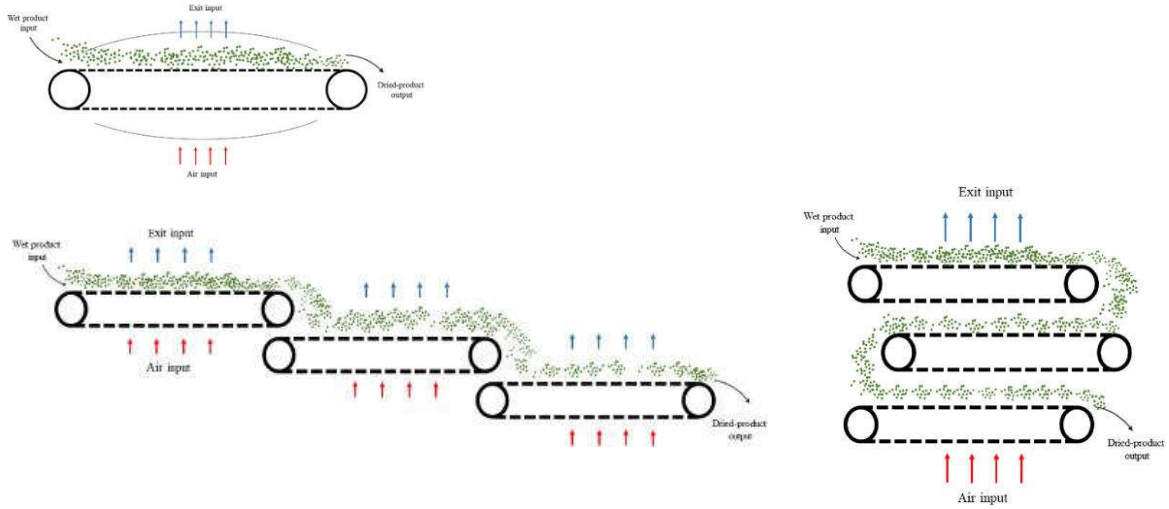
- a_w represents the amount of unbound water available in a product.
- a_W of pure water = 1
- The higher a_w, the higher risk of spoilage.
- a_W < 0.6: No microbial proliferation



https://pmp.errc.ars.usda.gov/wateractivity.aspx

Dryer:

- Belt dryer (single belt, multi-stage belt)



Drying technology in food processing (2023), p33-46
https://doi.org/10.1016/B978-0-12-819895-7.00011-0

- Microwave dryer
- Infrared dryer

Enhancing the palatability of kibble

Fat/ Oil

- Fat/oil content and type contribute to food's mouthfeel and palatability.
- Fat/oil can be added within kibble and as a surface coating.
- Oxidation of fat/oil decreases palatability.

Palatant

- Palatants enhance smell, flavor, and texture of food.
- Common palatants include proteins, yeasts, salts, sugars, and amino acids.
- Palatants are often coated on a kibble surface.

Kibble size, shape and texture

- Kibble shape and size can significantly impact palatability.
- Large kibble has less surface area for palatants.

Nutrient content

- Moisture content can affect kibble texture and palatability.
- Different types of protein affect palatability.

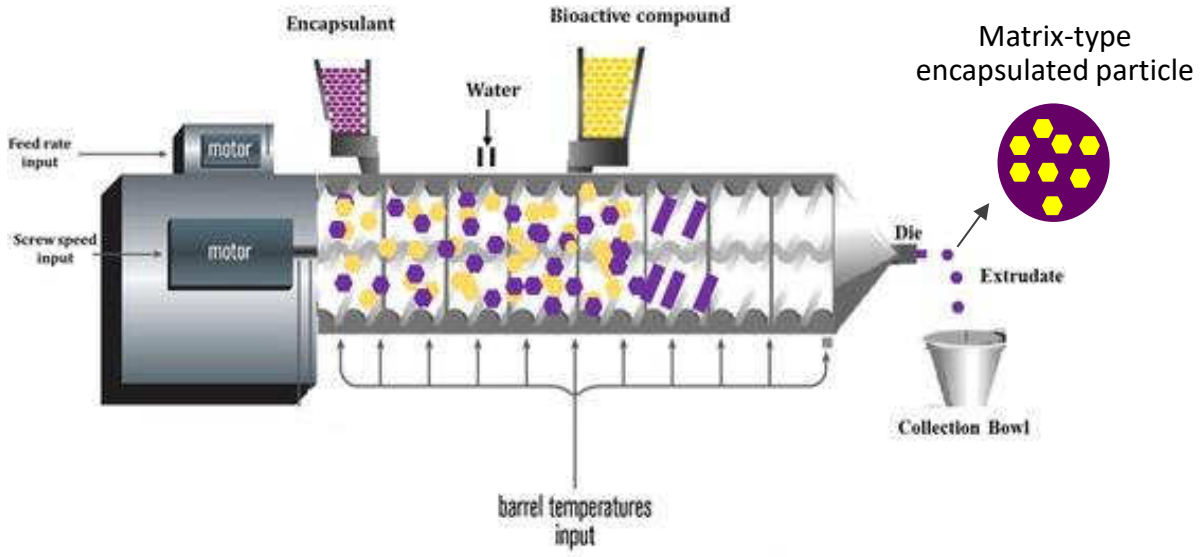
https://www.petfoodprocessing.net/articles/18894-palatable-preferences
https://www.kemin.com/na/en-us/blog/petfood-rendering/enhancing-palatability
https://www.petfoodprocessing.net/articles/18390-cracking-the-cat-code-how-to-create-nutritional-palatable-cat-foods

Advance in palatability: Encapsulation

Encapsulation

- can be achieved by extrusion process.
- enhances thermal and oxidative stability of some sensitive ingredients, i.e., vitamins, flavors.
- aids in controlled release of key ingredients under predetermined conditions.

Extrusion encapsulation



Bamidele and Emmambux (2021) Crit.Rve.Food Sci.Nutr., 61(18), 3100-3118.

Encapsulated particles

- easy to incorporate into pet food during manufacturing
- minimizes waste and requires less added nutrients
- benefits in pet nutrition

Meat-free kibble

Sustainability

https://www.iqi-petfood.com/sustainability/#

Alternative proteins: Pulse proteins/ Insect proteins/ Cultured proteins

Product: V-Dog (US), Wild Earth (US), Benevo (UK), Yora (US), Bond Pet Foods (US), MicroBell (UK)

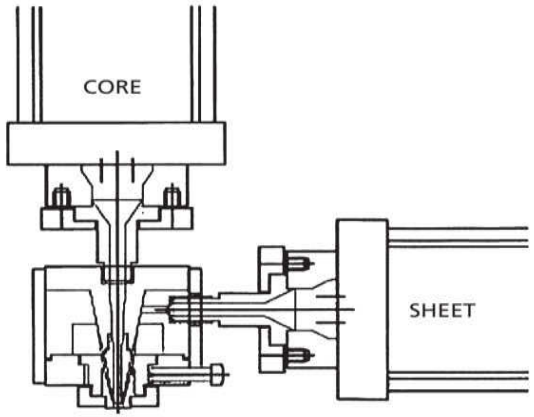
Semi-moist pet food

Semi-moist pet food

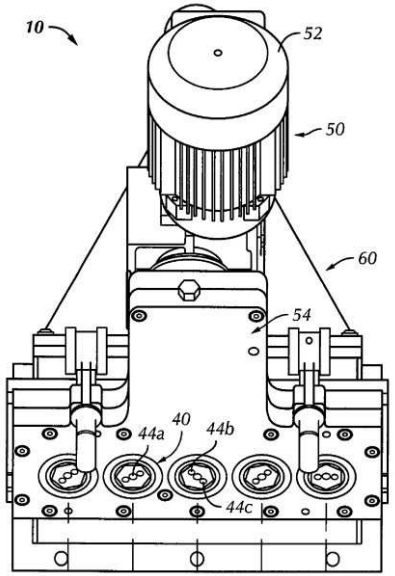
- Typically contains 20-65% moisture content
- Softer texture than dry kibble
- Water activity (a_w) < 0.60 by
  - Adding humectants (glycerol, polypropylene glycol, sugars, syrups, etc.)
  - Adjusting pH levels to 4.0 to 5.5
  - Adding preservatives

Soft treats

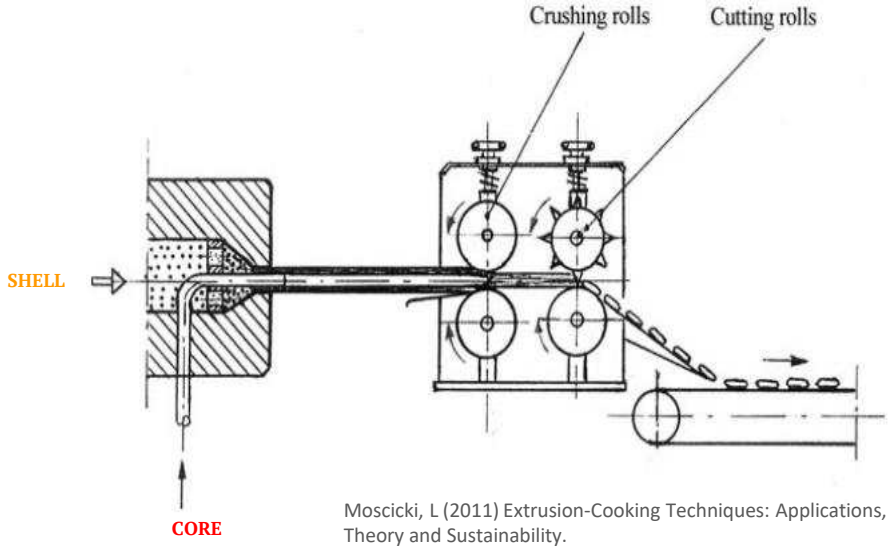
Co-extrusion in pet food



Journal of Pharmacy and Pharmacology, **66**, pp. 167–179



US8177542B2



Moscicki, L (2011) Extrusion-Cooking Techniques: Applications, Theory and Sustainability.

Filled snacks

Dental treats

Soft treats

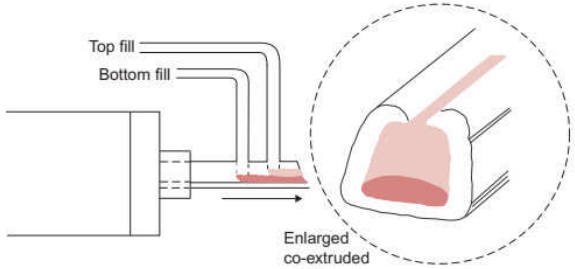


Figure 14.2 Filled products using co-extrusion. (Adapted from Moore, 1994)

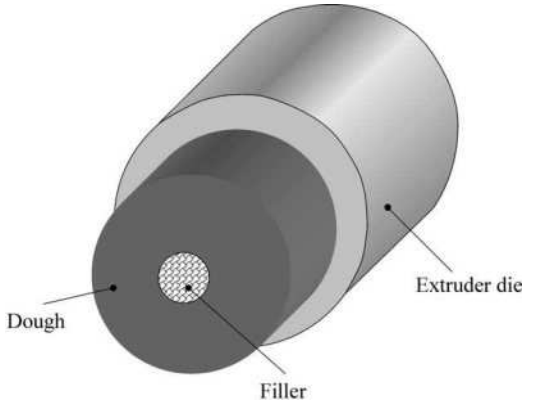
Co-extrusion in pet food

Advantages

- Provide products with diverse textures, shapes, colors, flavors, and nutritional profiles.
- Enhance palatability and visual appeal.

Challenges

- Moisture migration between core and shell could affect texture and stability.
- Comparable rheological properties of core and shell materials is crucial for achieving a cohesive and well-developed product.



Journal of Food Engineering 52 (2002) 67–74

Wet pet food

General types of wet pet food

loaf chunks-in-gravy chunks-in-loaf

Animals **2023**, *13*, 1134

Characteristics

- High moisture content > 65%
- Typically contains meat protein, and mixes with gelling agents or gravy
- Soft texture
- More palatable than dry and semi-moist
- Shelf-stable (sterilization)

Wet pet food processing

Meat, Meat by-products

Other ingredients (i.e., fats/oils, vitamins, minerals, cereals, vegetables)

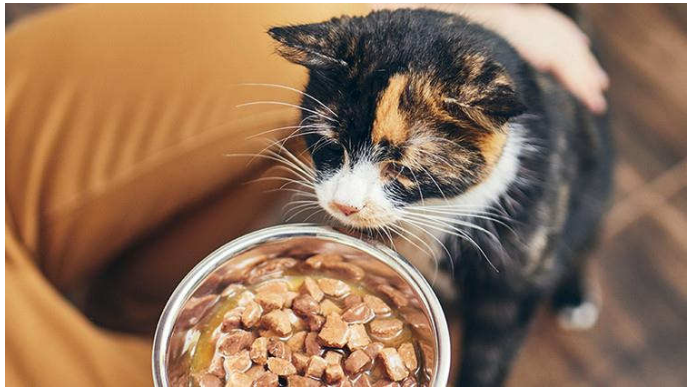
Grinding → Mixing → Cooking (Sterilization)

Gelling/ Thickening agents

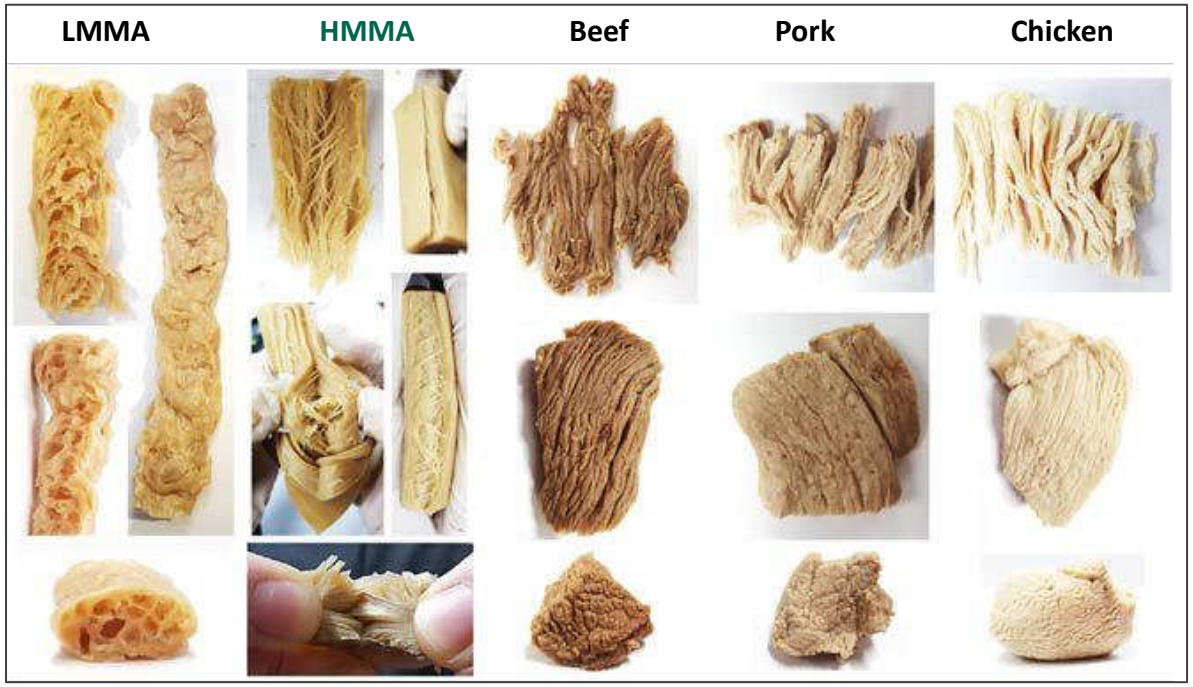
Meat analogue in wet pet food

Meat analogue

- Made from plant proteins (i.e., soy, pea, wheat, etc.) as a major ingredient
- Provided meat-like chunks in wet pet food
- Gave chewy texture
- Retained shape and color better than real meat during retort



https://www.kerry.com/markets/animal-applications/pet-food-nutrition/plant-based-pet-food-trends



Samard, 2019

LMMA (low moisture meat analogue) or TVP (Texturized vegetable protein)

- Prepared from low moisture extrusion
- Spongy appearance
- Need rehydration

High moisture meat analogue (HMMA)

- Prepared from high moisture extrusion
- Gave fibrous appearance and texture

Low-moisture extrusion for wet pet food

Texturized vegetable protein (TVP)

- Low moisture extrusion is used to prepare TVP.
- Many canned and pouched pet foods contain considerable amounts of TVP.

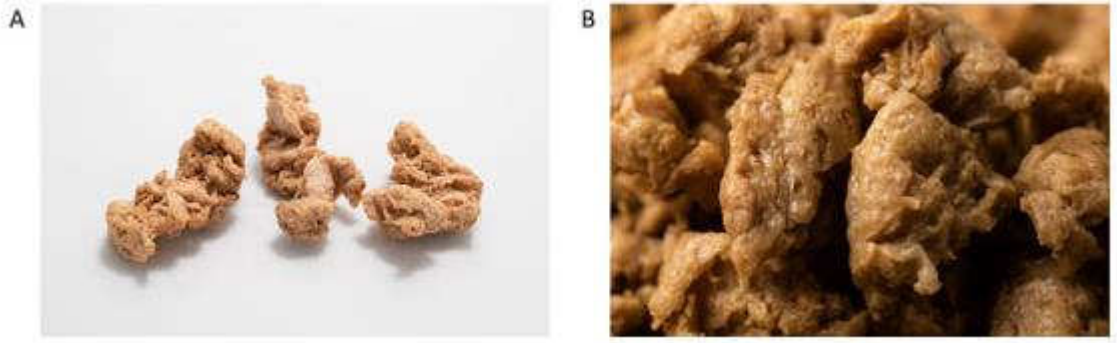


Fig. 1. Low moisture textured vegetable proteins (e.g., blend of corn/soy protein). A: dry. B: hydrated. Copyright: ClonBio group Ltd.

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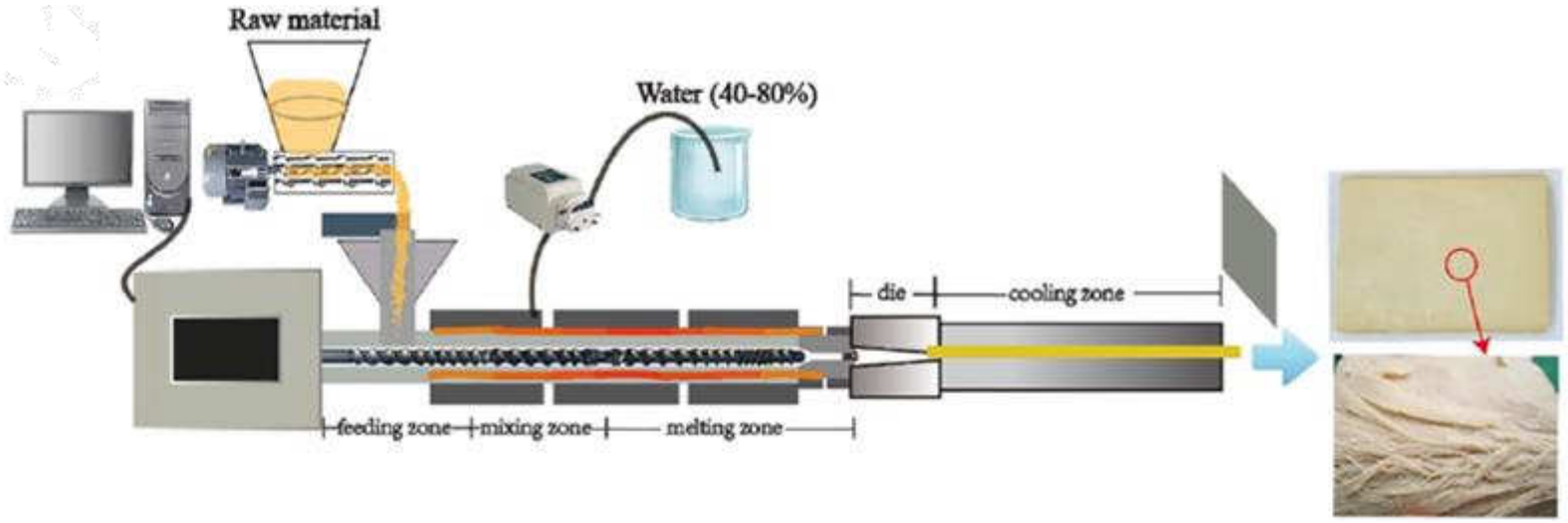
Picture 1. Vestkorn´s textured pea protein mince in tapioca and carrot gravy.

Picture 2. Vestkorn´s textured pea protein chunks in banana and carrot gravy.

https://www.petfoodindustry.com/ingredient-issues/proteins/article/15448627/textured-vegetable-protein-all-about-appearance

High-moisture extrusion for wet pet food

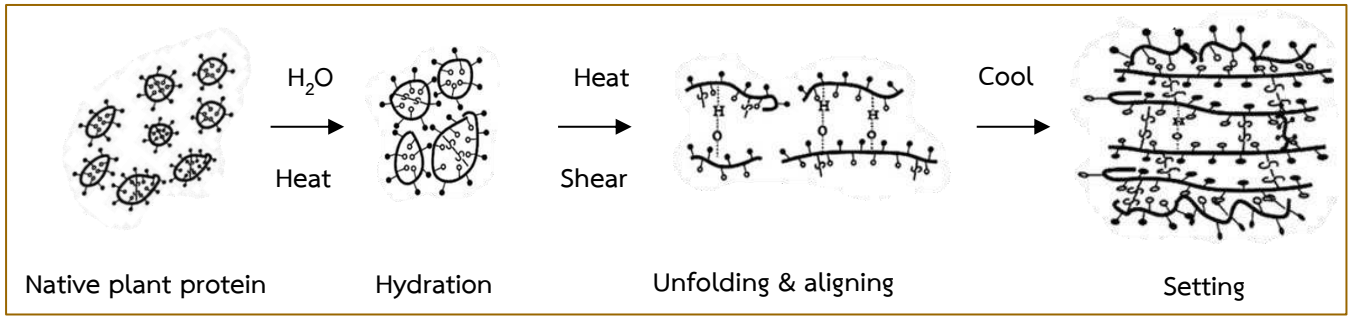
Fiber formation in high-moisture extrusion



Raw materials

- Protein
  - plant-based (soy, wheat, pea, etc.)
  - animal-based (meat meal, insect, whey, etc.)
- Starch
- Fiber

Conformational change of plant protein during HME



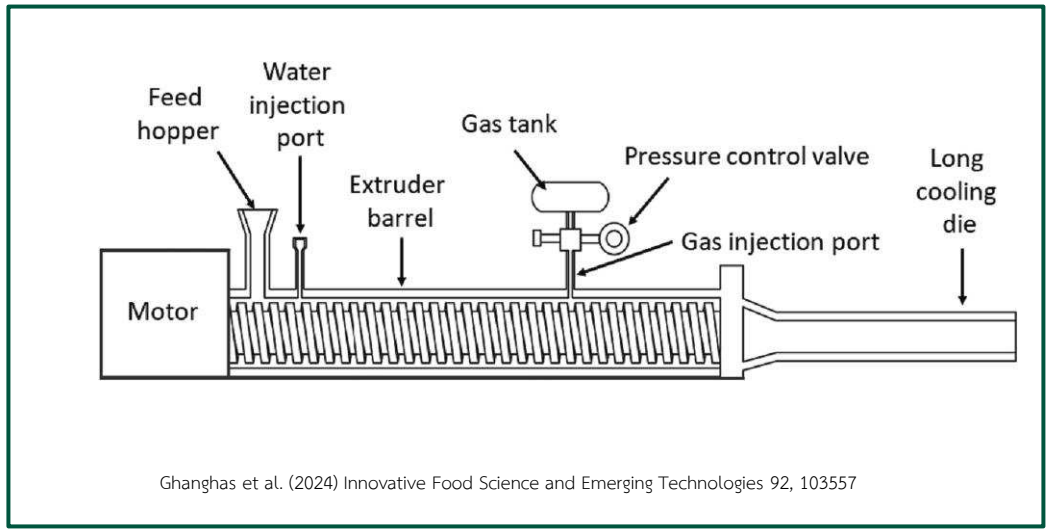
Modified from Zhang et al. (2019) Crit Rev Food Sci Nutr, 59, 3267-3280.

High-moisture extrusion for wet pet food

High-moisture extrusion unlocks new possibilities for wet pet food innovation

- combines with aeration technology and breaker plates
- improves texture, appearance, and palatability, meeting the growing demand for premium-quality wet pet foods.

Breaker plate



Ghanghas et al. (2024) Innovative Food Science and Emerging Technologies 92, 103557

Pore can be generated by

- Introducing gas in the extruder (i.e., CO_2, N_2)
- Adding a gas-releasing compound (i.e., $NaHCO_3$, Na_2CO_3)

https://www.petfoodindustry.com/news-newsletters/petfood-forum-news/article/15740271/highmoisture-extrusion-unlocks-new-possibilities-for-wet-pet-food-innovation

Extrusion process parameters

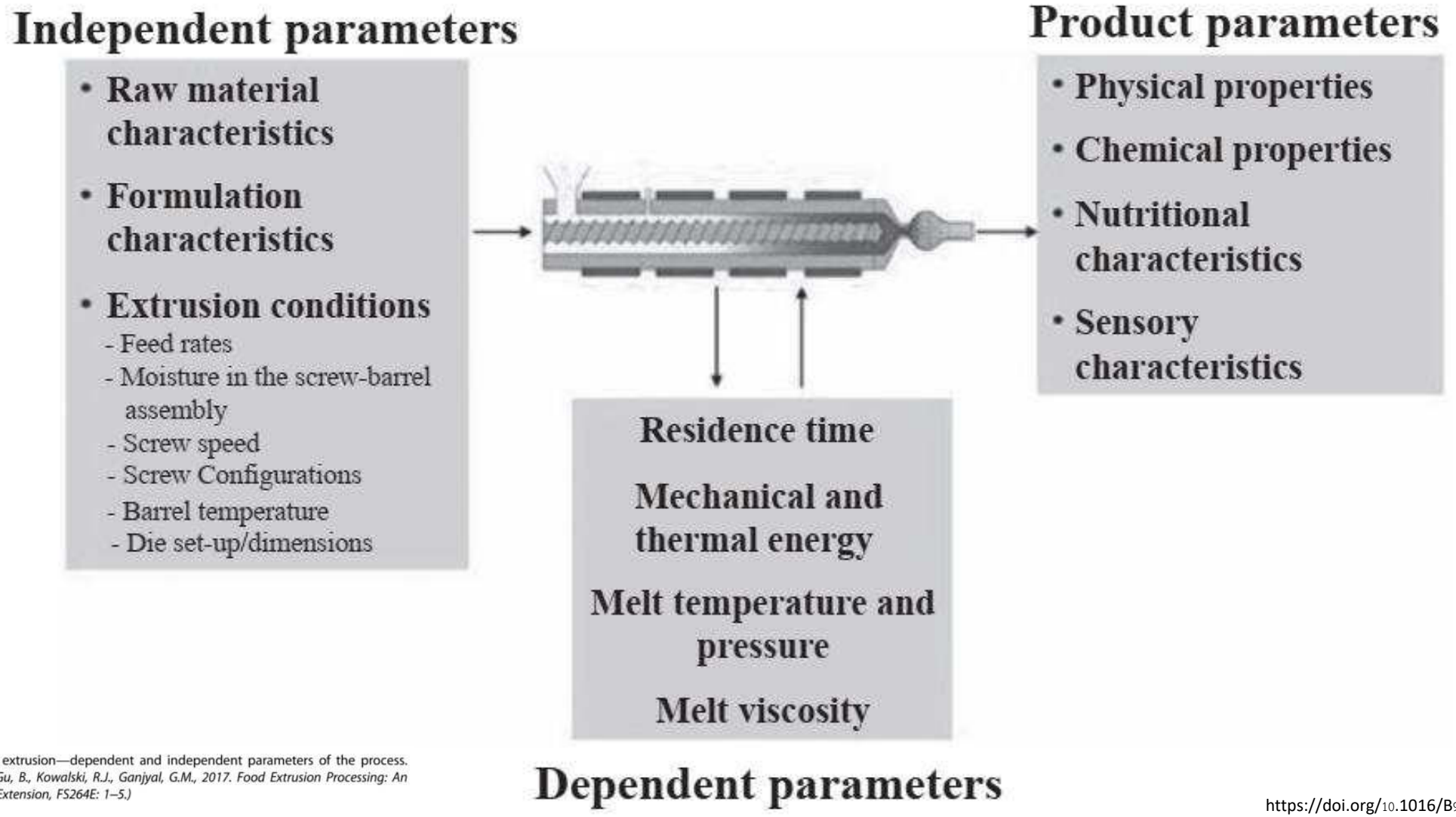


Fig. 3 Cooking extrusion—dependent and independent parameters of the process. *(Adapted from Gu, B., Kowalski, R.J., Ganjyal, G.M., 2017. Food Extrusion Processing: An Overview. WSU Extension, FS264E: 1–5.)*

https://doi.org/10.1016/B978-0-12-815360-4.00002-X

FOMT facility
Twin Screw Extruder

Co-rotating Twin Screw Extruder
(ZSK 18MEGAlab, Coperion, Germany)

ZSK 18MEGAlab

9 segmented barrels & Vent port at B8
Screw diameter: 18 mm (L/D: 36)
Barrel length: 72 mm
Max. temp: 315°C
Max. screw speed: 1200 rpm
Max. throughput: 40 kg/h

Gravimetric solid feeder (K-tron, Niederlenz, Switzerland)

Gravimetric liquid feeder (K-tron, Niederlenz, Switzerland)

Liquid feeder (Volumetric pump, Watson Marlow, UK)

A variety of screw elements

Long cooling die:

Rectangular (die opening)
Dimension: 50 x 15 x 800 mm &
45 x 10 x 750 mm (W x H x L)
Temp. :30-60°C

Other dies

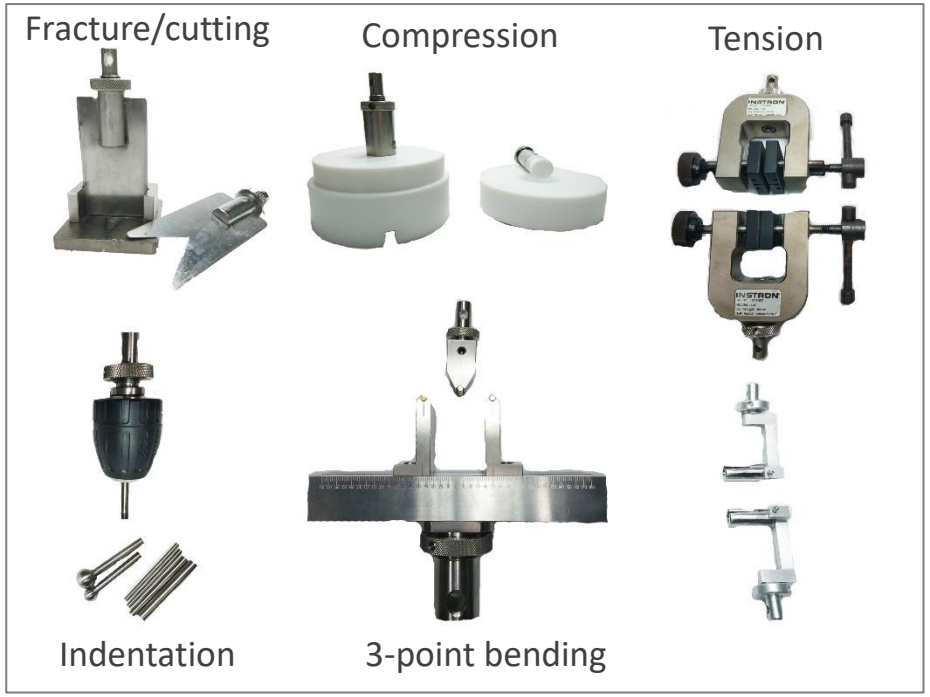
Circle : 2, 3, 4, 5 mm (diameter)
Square : 10 x 10 mm

Concentric pelletizer (ZGF30, Coperion, Germany)

Belt conveyor

FOMT facility
Texture Analyzer

Universal Testing Machine (Instron 5943)
Load capacity: 1, 100, 1,000 N load cells



Thank You

https://sunsetviewpets.com/articles/966732-april-newsletter-the-benefits-of-dental-chews-for-dogs

https://www.smurfitkappa.com/sectors/pet-food

ติดต่อ **นายชนิต วานิกานุกูล** นักวิเคราะห์อาวุโส
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