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Sinking & floating aqua feed extrusion – Challenges to manage

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a Nutreco company

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Chapter overview

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01. Introduction

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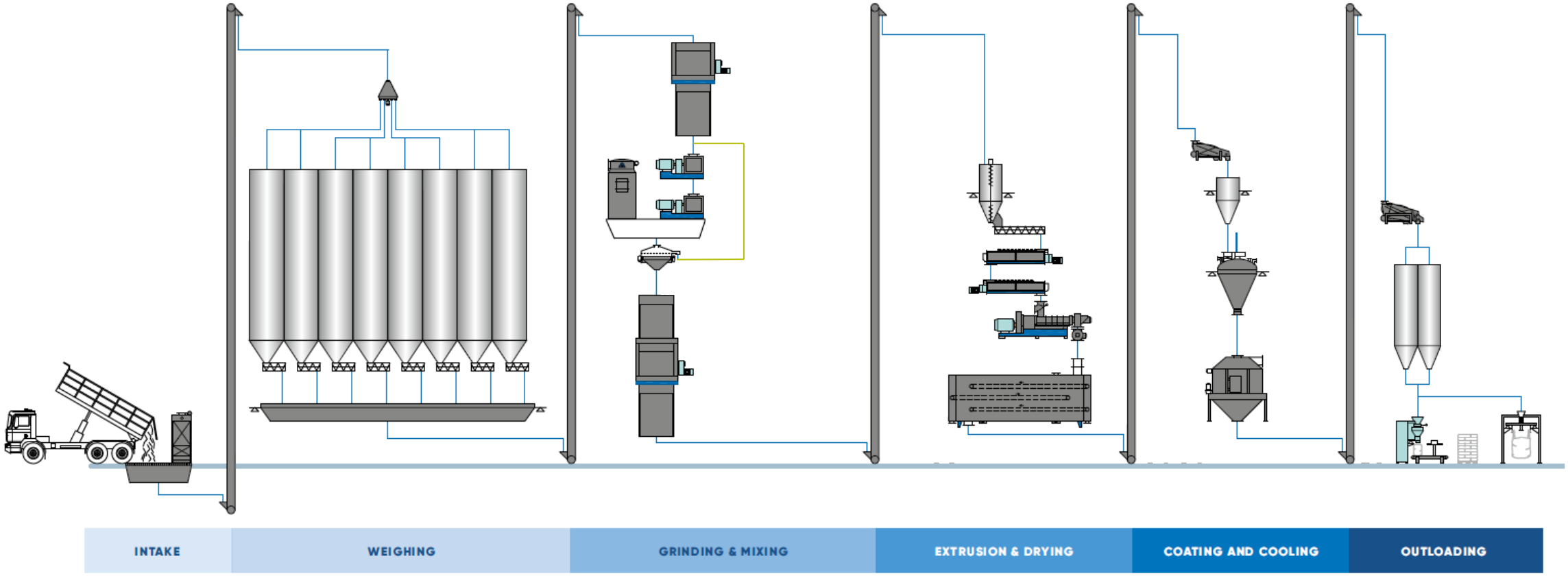
ANDRITZ standard aquafeed line

Simplified Extruded fish feed flow (sinking)

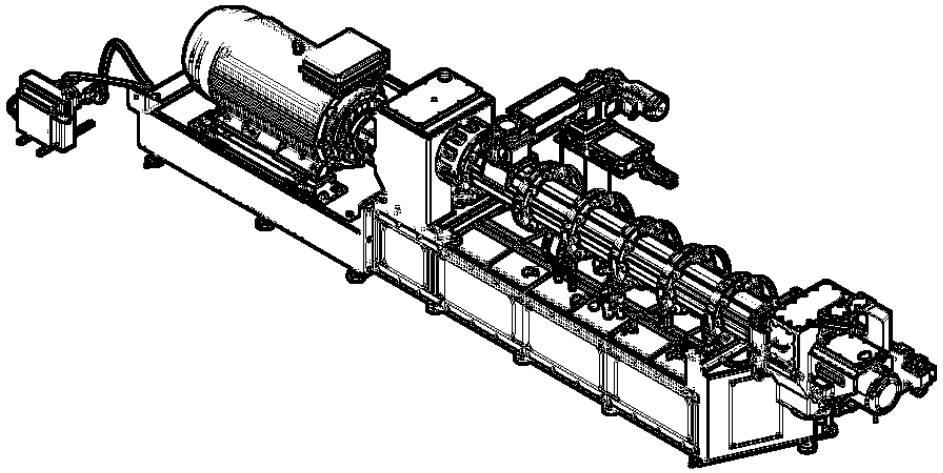


Extrusion for high quality aquafeeds

The added value of extrusion

Advantages:

- Improves the nutritional value of most raw materials
- Produces a product with the right density
- Aqua (floating, slowly sinking or sinking)
- Allows a higher amount of fat/oil to be added post extrusion
- Longer water stability
- Higher mechanical resistance



Disadvantages:

- Higher investments compared to pelleting
- Operators require more specialized skills

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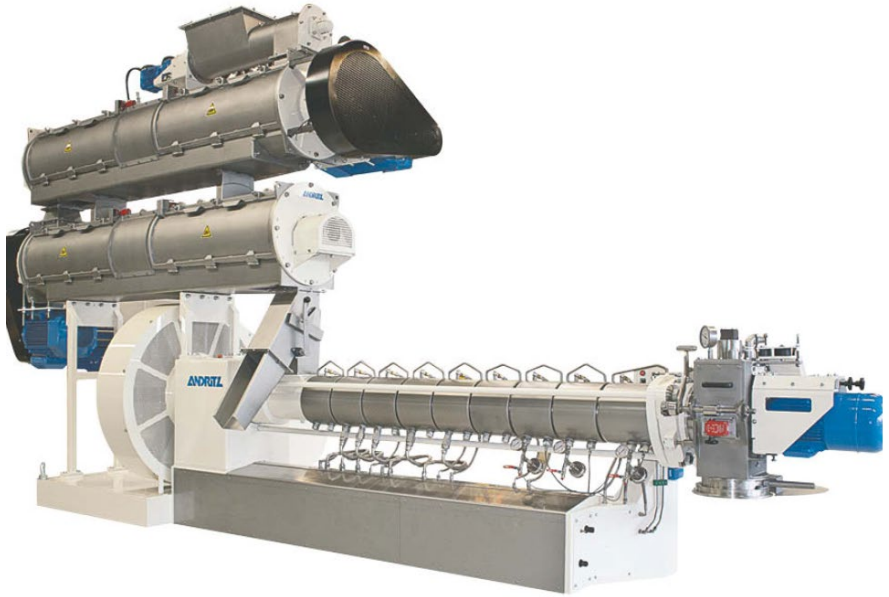
Demands on formulation

Considerations

- Raw material selection / formulation
- Equipment configuration
- Process conditions
- Final product characteristics

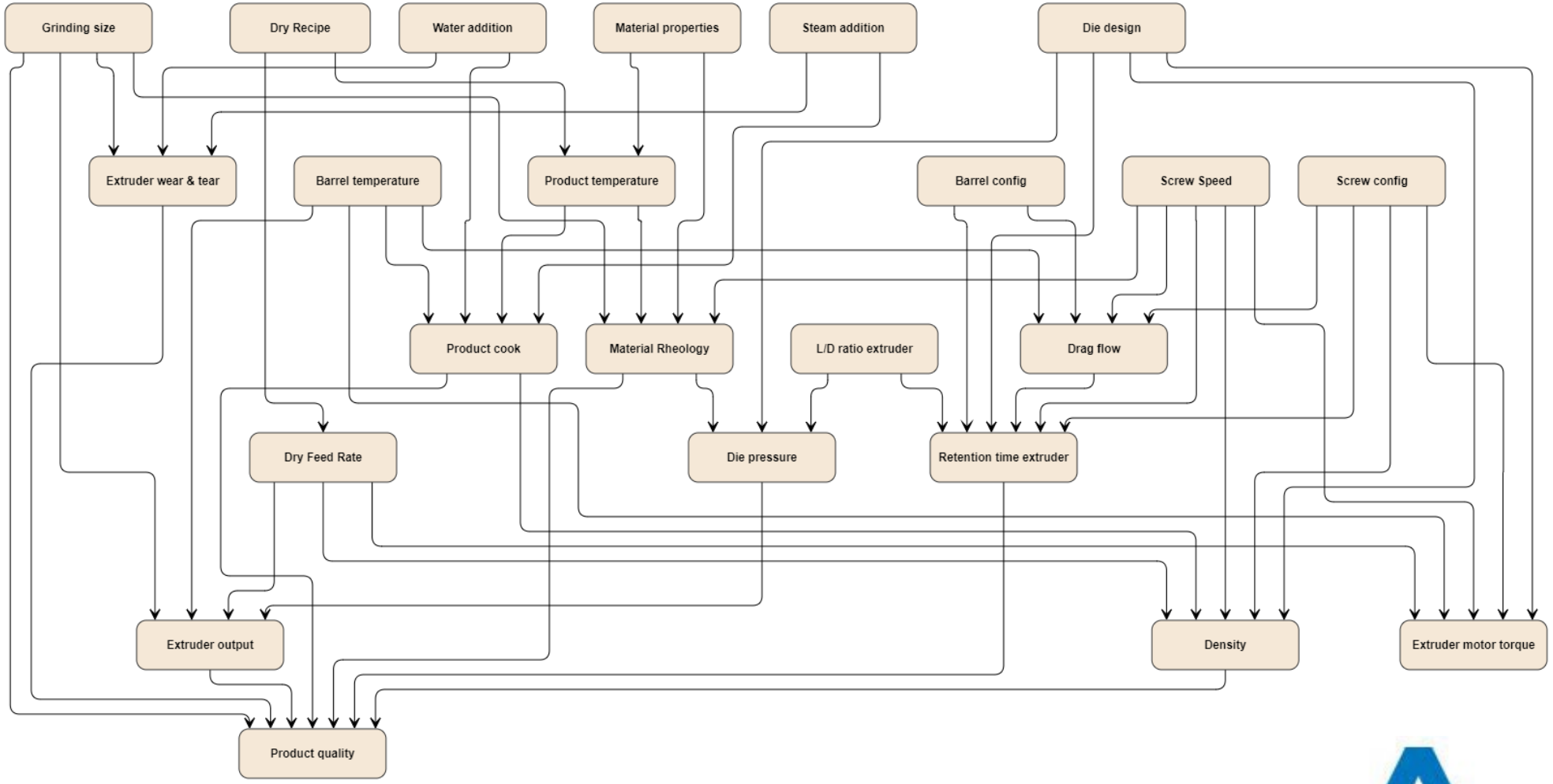


Extrusion process variables dependency

Understanding the process

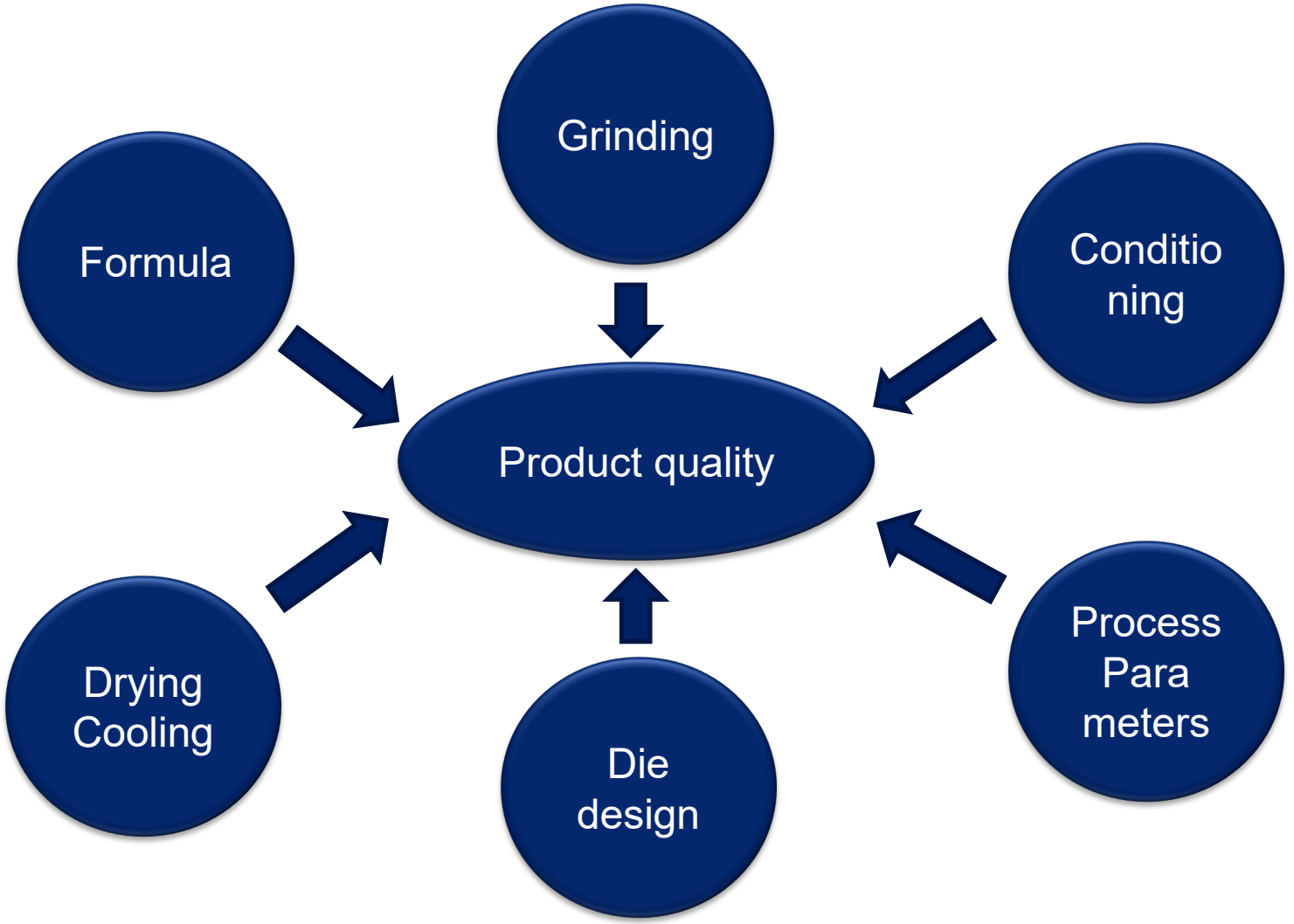
Flow showing various dependencies

Different ways to reach the same result. If one factor changes several others will as well.



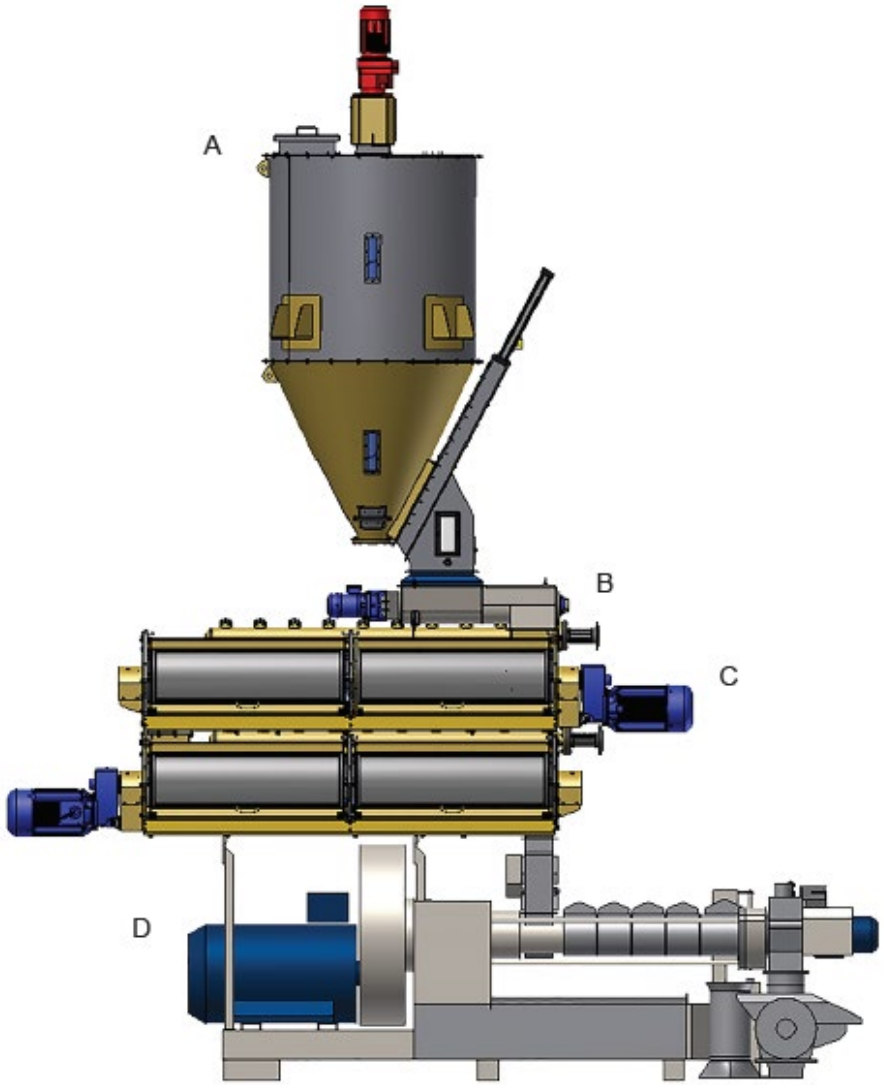
Factors influencing the feed quality

Simplified overview



Extrusion stack

Setup



A – Live bin

B – Screw feeder

C – Conditioners

D - Extruder

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02. Raw materials

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Demands on formulation

Considerations

- Contribution to nutritional objectives
- Impact on final flavor, palatability and / or color
- Impact on feed pellet physical properties – binding / durability / water stability / density
- Expansion – floating / sinking / slowly sinking
- Impact on process

Groups of raw materials

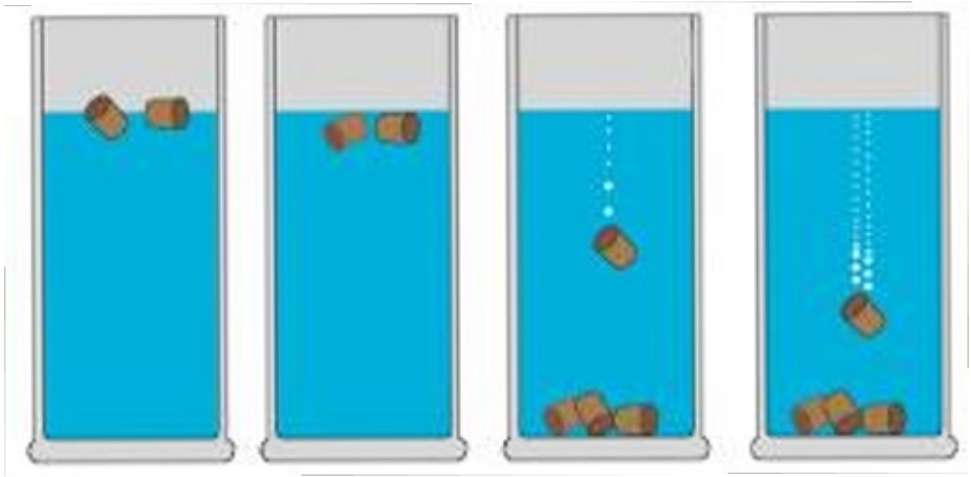
Considerations

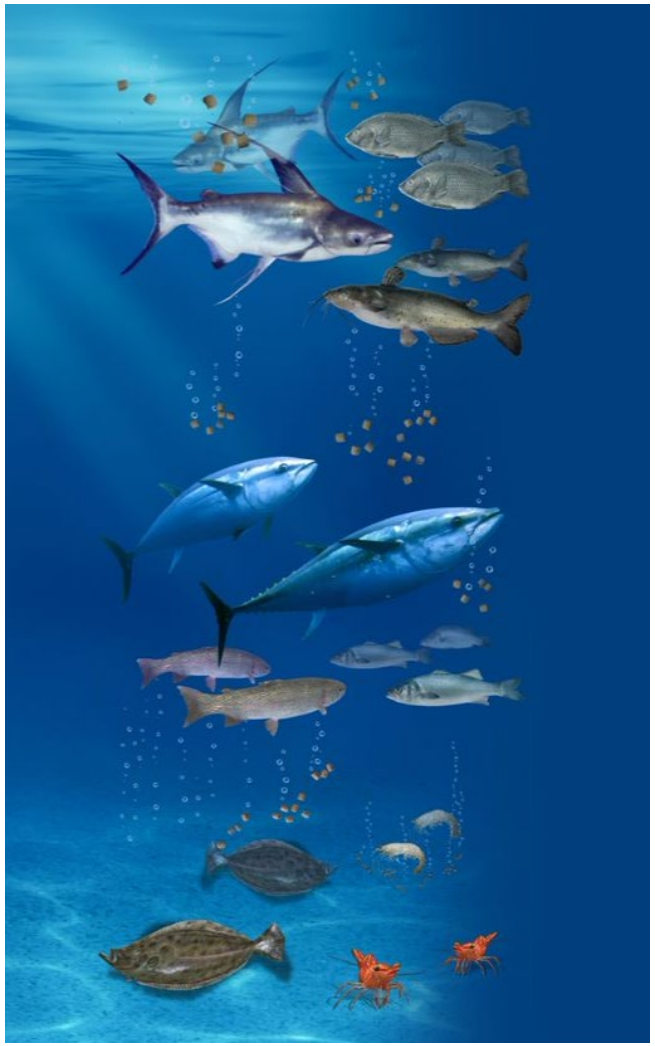
	Function
1. Starches – rice, potatoes, wheat, maize	Gelatinization
2. Proteins – meat & fish meal, fresh meat, vegetable proteins	Nutritional value
3. Lipids - Oils and fats (lubricants, influence expansion)	Nutritional value
4. Moisture – water / steam	Rheological properties /aids cooking
5. Coloring substances	Species meat color
6. Additives and Flavoring substances (can be added in extrusion or during coating)	Processing / nutritional value

01. Starch (carbohydrates)

Expansion due to starch

- Floating fish feed – min. 20% → expansion
- Sinking fish feed – approx. 10% starch → binder



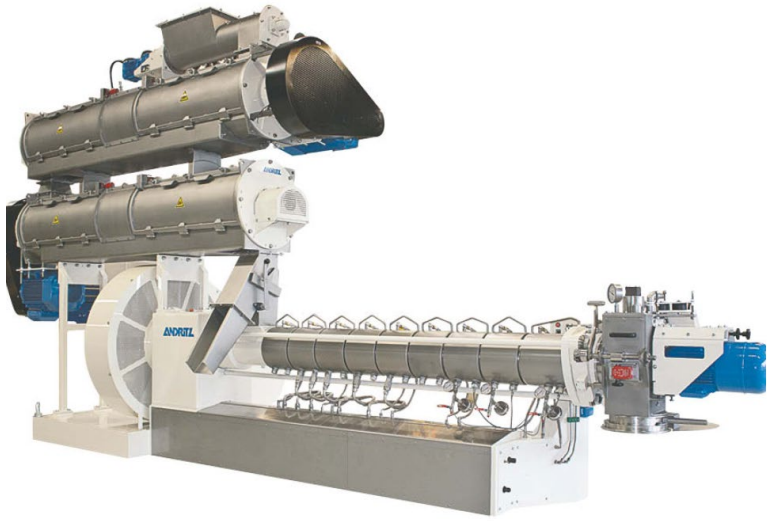


01. Starch (carbohydrates)

Expansion due to starch

Extruder functions:

- Increase in barrel temperature
- Screw configuration – increase in SME (FlexTex)
- Die length / Diameter



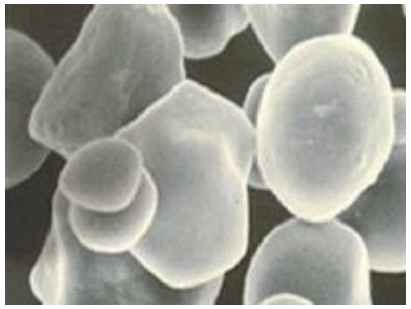
Formulation:

- Reduction in fibers, protein, lipid (fat) content
- Increase in starch => increase in Amylose content (amylose – 10-35% in starch responsible for expansion)

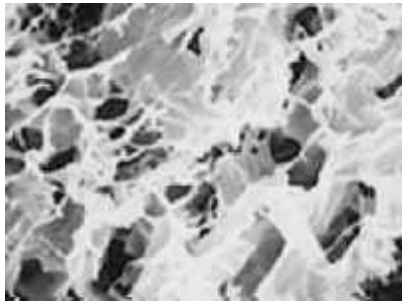
01. Starch (carbohydrates)

Considerations

Cereals	Starch % (dry basis)
Rice 10% protein	75%
Maize/corn 10% protein	71%
Wheat 14% protein	66%
Peas 24% protein	42%
Wheat gluten 75% protein	15 %
Soya meal 48% protein	6%
Fish meal 70% protein	0%
Blood meal 84% protein	0%



Starch molecules before extrusion



Starch molecules after extrusion

- Starch is a major source of energy
- In fish feed diets starch content is normally low (5 - 10%) because most fish species are carnivores – starch only acts as binder
- During pre-conditioning and extrusion, the starch granules lose their organized structure (gelatinization/melting occurs)

02. Protein

Nutritional ingredient to the formula

Functional protein (in connection with the extrusion process)

- Proteins which are soluable in water
- Contribute to expansion or binding
- Increase elasticity of the melt
- Enhance the gas-holding properties
- Soluble proteins tend to be better digested
- Amino acid needs to be supplemented

Examples are plant proteins, milk proteins, gelantine, some blood and plasma proteins and raw /"fresh" animal / marine proteins added to the process.

02. Protein

Nutritional ingredient to the formula

Non-functional protein (in connection with the extrusion process)

- Proteins not soluable in water => inert during the process.
- Do not contribute to the process
- Temperatures help with the digestion of these proteins.
- Good amino acid profile

Examples are Animal meat meals (due to the way they are processed under high temperatures)

Proteins typically loose their functionality at typically around 55-65°C → **less contribution to expansion, binding and durability of the pellets.**

Cooking at +130°C typically generates loss in nutritional values !

Key protein sources

Approximate figures [%]

	Fish oil	Fish meal	Meat & bone meal	Poultry meal	Soy	Lupin	Corn Gluten
Starch	0	0	0.5	0.5	10 – 12	20 – 30	10 – 15
Protein	0.5 – 1.0	65 – 75	45 – 50	60 – 65	50 – 55	30 – 35	55 – 60
Fat	97.5	8 – 10	8 – 12	10 – 12	12 – 14	4 – 6	0
Moisture	0	4 – 5	6 – 8	6 – 8	9 – 11	7 – 10	5 – 11
Fibre	0	1 – 2	2.5 – 3.5	2 – 3	4 – 6	2 – 7	2.5 – 3.5
Ash	0.5 – 1.0	2.5 – 3.5	25 - 30	12 - 16	8 - 10	2 - 5	1 - 2

03. Lipids – fat and oils

Reasons to add fat – due to nutrition

- Energy source
- Building blocks for cell membranes (phosholipids)
- Energy source for celluar functions
- Energy transport among various tissues
- Supply essential fatty acids for normal function and growth
- Source of phospholipids
- Increase palatability
- Provides essential fatty acids
- Carrier for fat soluable vitamins

- Animal fat
- Poultry fat
- Marine oils – fish oil
- Blended vegetable and animal fats
- Feed grade vegtable oils

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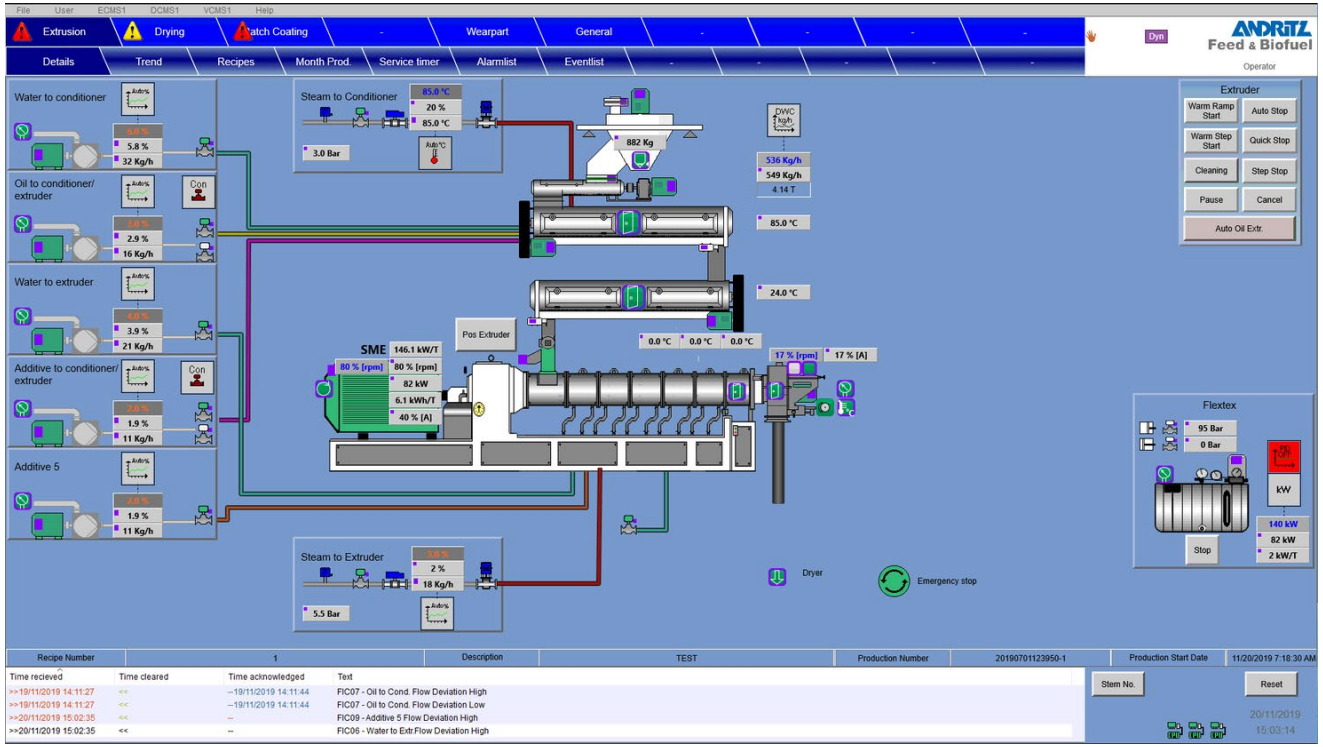
03. Vitamins

Extrusion conditions which will increase vitamin destruction

- Increase in barrel and product temperature
- Increase screw speed
- Increase in Specific Mechanical Energy (SME)

- Decrease in feed moisture
- Decrease in die diameter
- Decrease in throughput



04. Flavors

Considerations

- Added flavors are often heat dependant
- Should be added post extrusion in the coater
- Low feed moisture help retain flavors

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Extrusion process for floating/sinking high quality aquafeeds

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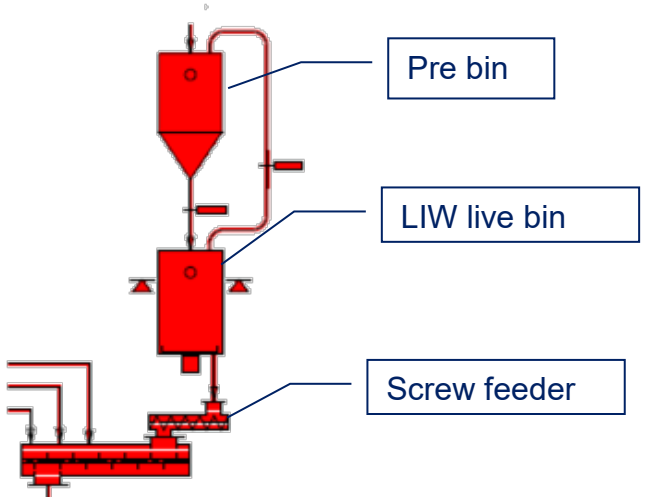
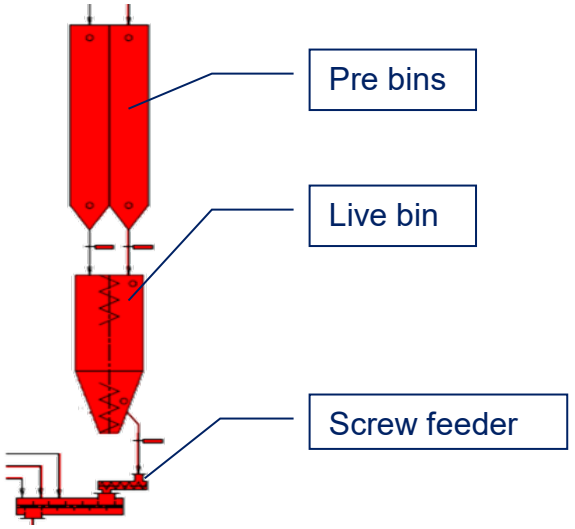
Live bin and Extruder feed system

Loss-in-weight



Gravimetric system



Volumetric system

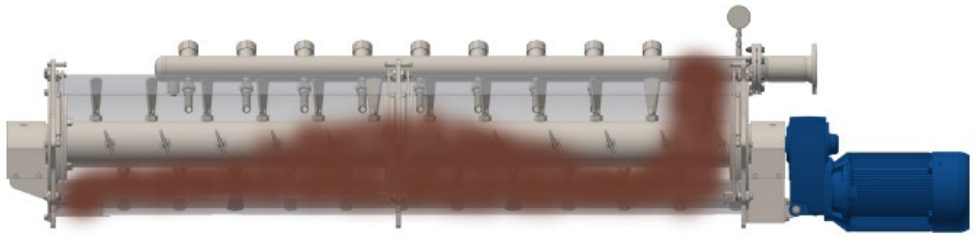
Extruder live bin must have agitation to ensure constant product flow to extruder. Aspiration of dust/air must not cause disturbance of weighing

Gravimetric loss-in-weight (LIW) system	Volumetric System
Accuracy in feeding: +/- 1.0 – 2.0%	Accuracy depends on changes in bulk density (+/- 10%)
Feed rate controlled by weight kg/h (automatically controlled)	Feed rate controlled by speed rate of feed screw (operator controlled)
Not affected by fluctuating meal bulk density	Actual feed rate in kg/hr affected by changes in meal bulk density
Requires pre bin feed rate of 5 – 8 times screw feeder capacity	Requires pre bin feed rate of 2 – 4 times screw feeder capacity
Higher capital and maintenance costs	Lower

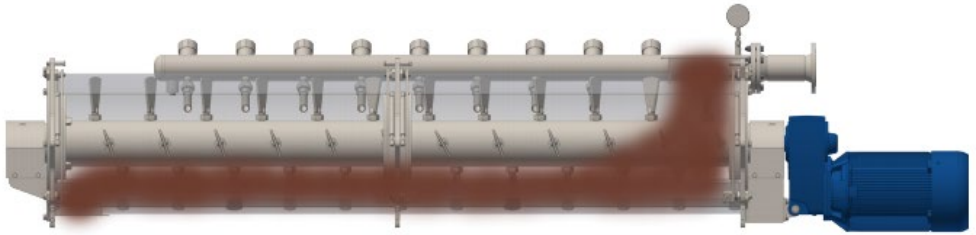
Conditioning

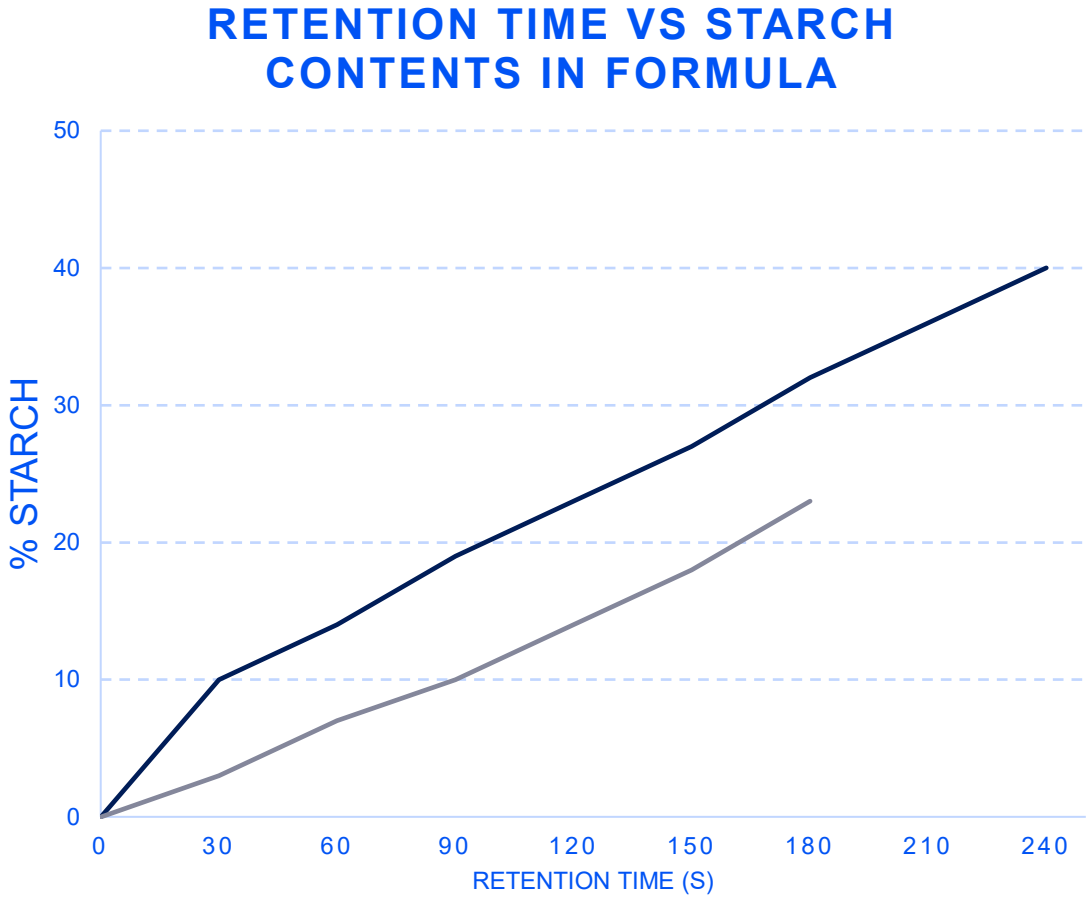
Preconditioner

DISTRIBUTION OF THE MATERIAL WITH CORRECT PADDLE SETTING.



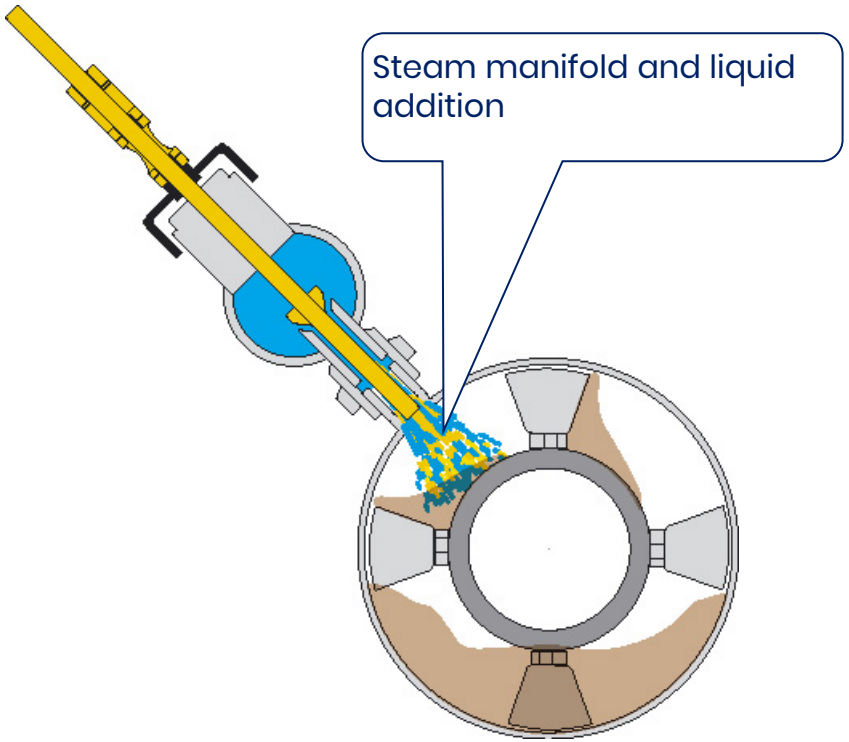
DISTRIBUTION OF THE MATERIAL WITH AN INCORRECT PADDLE SETTING.

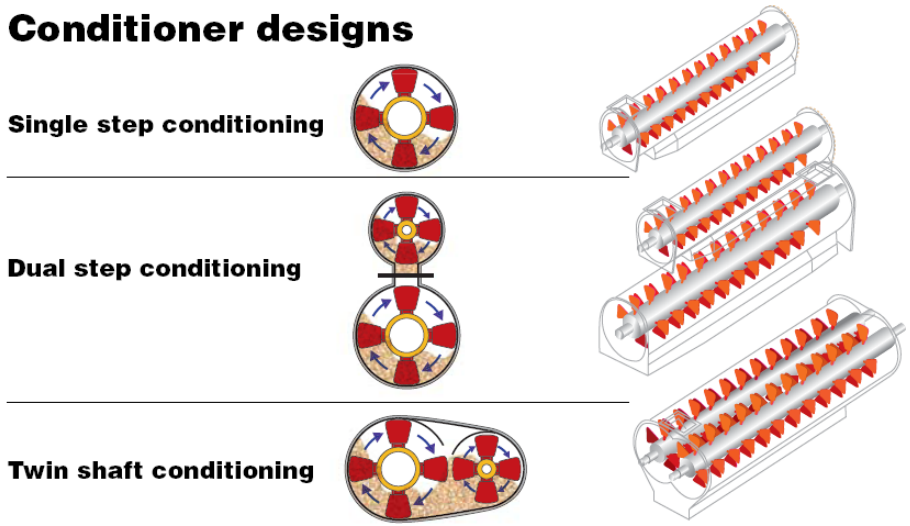




Conditioning

Preconditioner

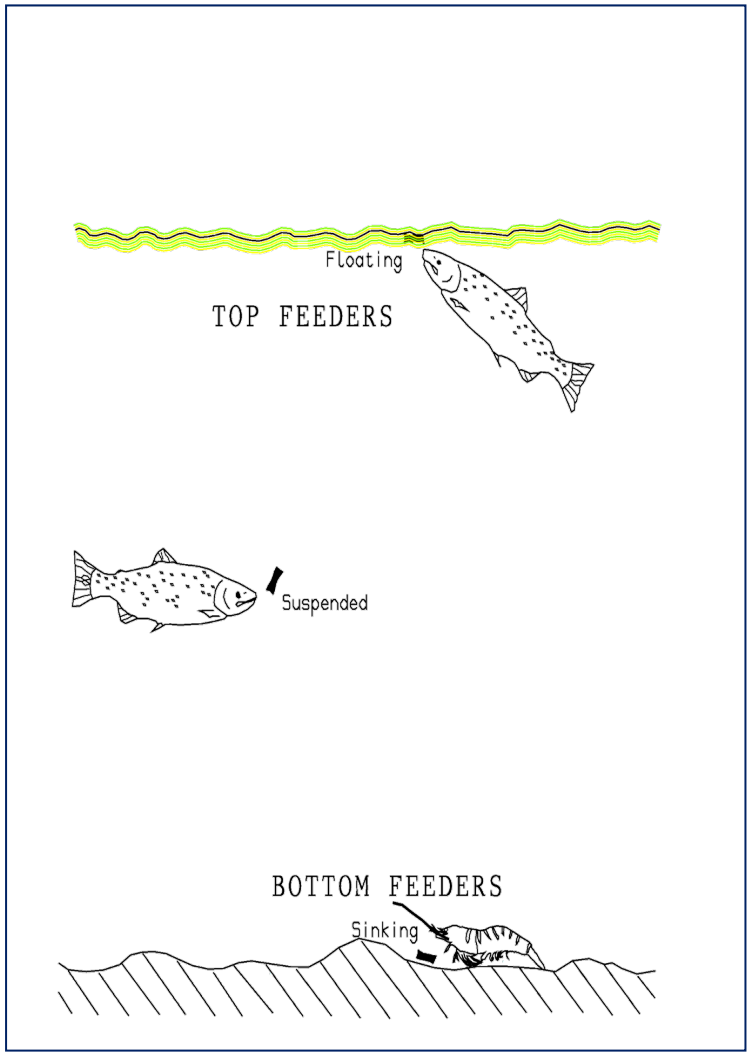




Typical recommended degree of filling in all types of conditioners = 40-45%
More than 40-45% degree filling will have a negative effect to mixing efficiency.

Bulk density: fish/shrimp feed

Preconditioner



Feed Types	Saltwater@20°C 3%salt	Freshwater@20°C	Expansion factor (%)
Fast sinking	> 640 g/l	> 600 g/l	10
Slow sinking	580 - 600 g/l	540 – 560 g/l	15
Neutral	520 – 540 g/l	460 – 500 g/l	20
Float feed	< 460 g/l	< 420 g/l	> 30

Bulk density: fish/shrimp feed

Conventional parameters for density control

- Screw speed
- Steam addition
- Water addition
- Oil addition
- Feed rate
- Temperature control of barrel
- Die plate design
- Venting head
- Screw/Barrel configuration
- Formulation

Water stability

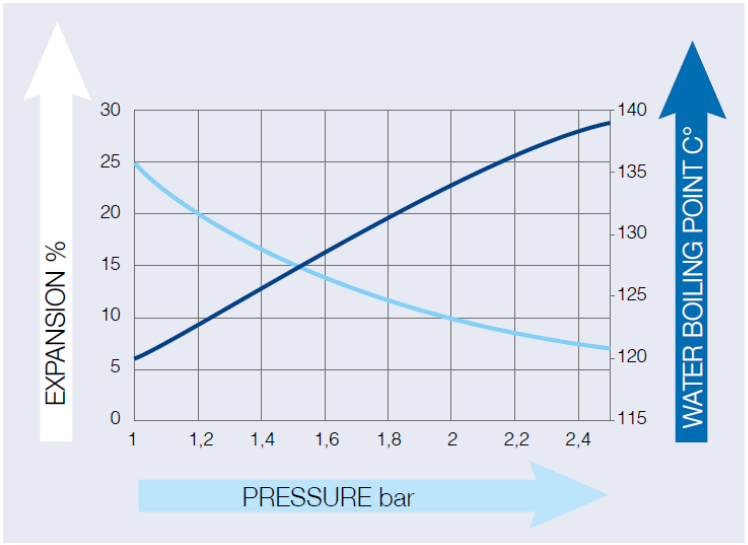
- A water stable pellet is necessary to reduce feed waste and to maintain water quality in aquaculture farming
- Extruded feed has a water stability of above 24 hours as compared to pelleted feeds from 10 min to 2 hours
- Shrimp feed should not disintegrate in water for min 2 hours because the shrimp is a slow eater

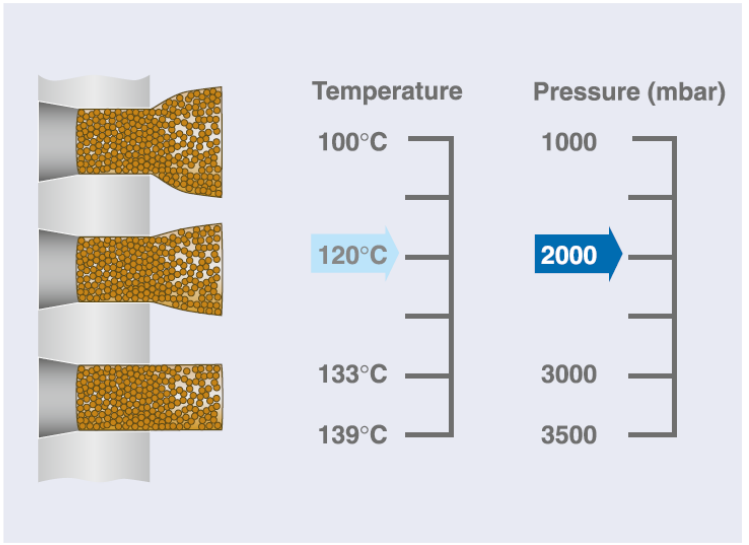
ECS – Expansion Control System

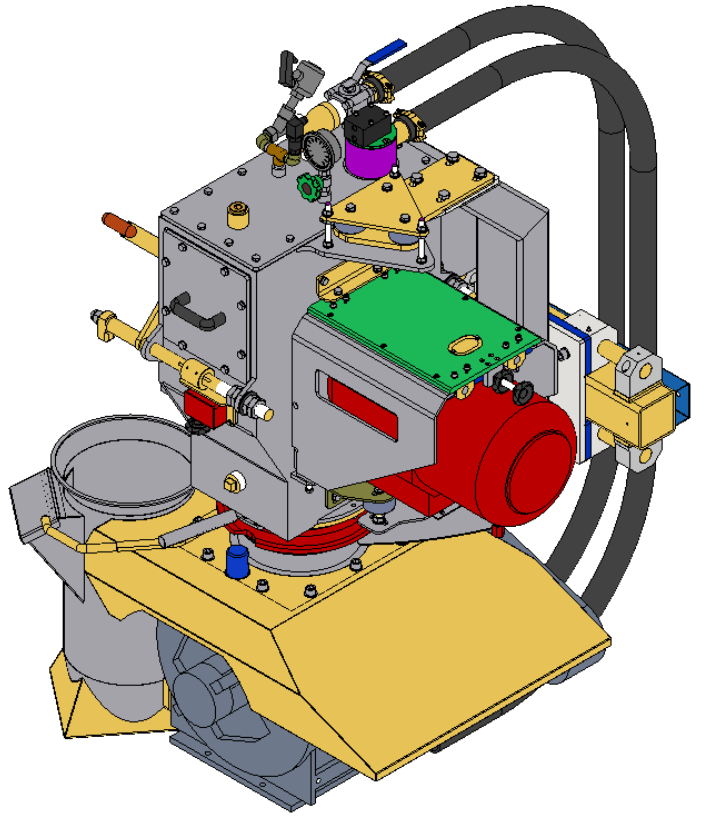
Compressed air to control expansion saves energy

Preventing expansion by means of compressed air is the key (counter pressure)

- Pressurized knife house
- Continuous supply of compressed air



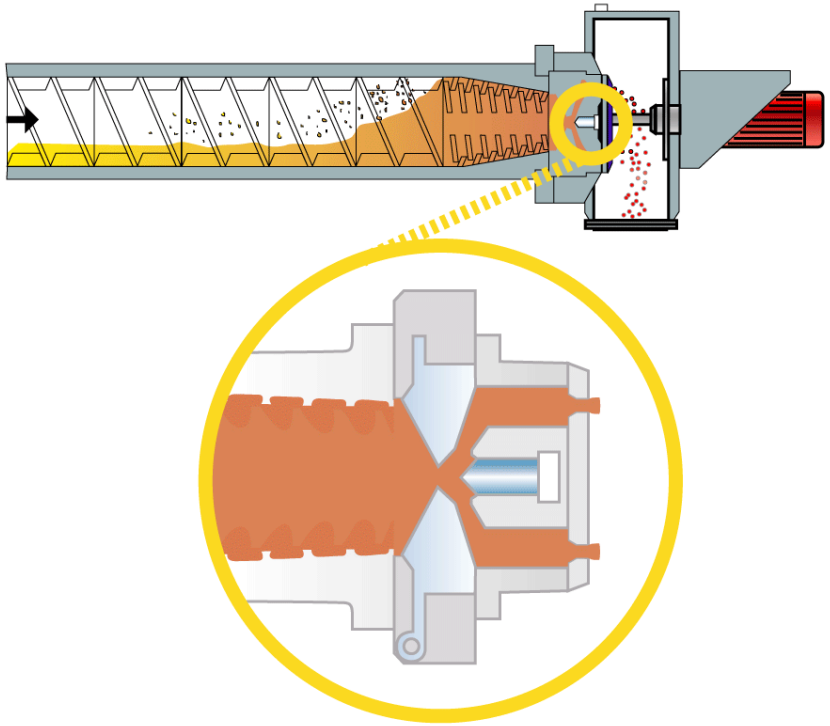


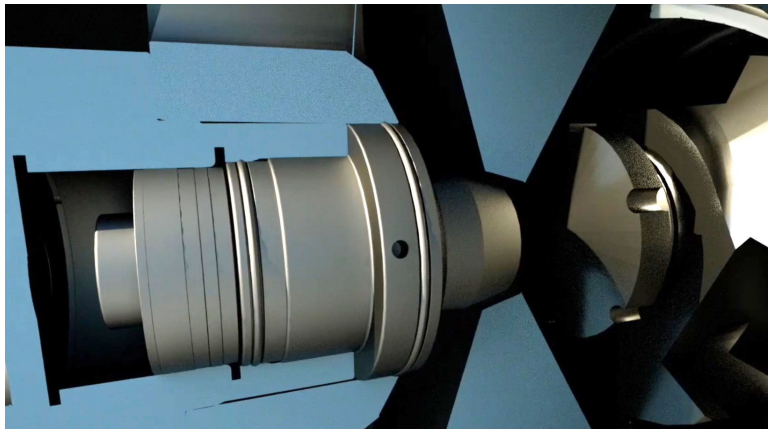


Flextex

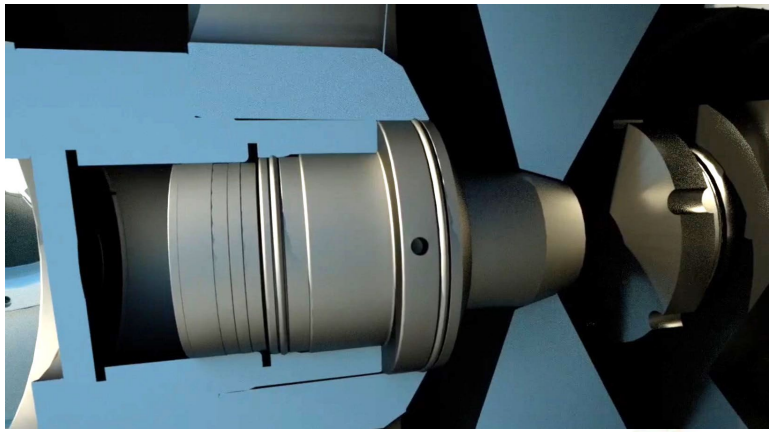
Increasing the SME to produce floating fish feed with low starch content

- Online control of SME and pressure
- Starch cook
- Product expansion
- Product density
- Increased output





FLEXTEX in neutral position – no additional SME applied

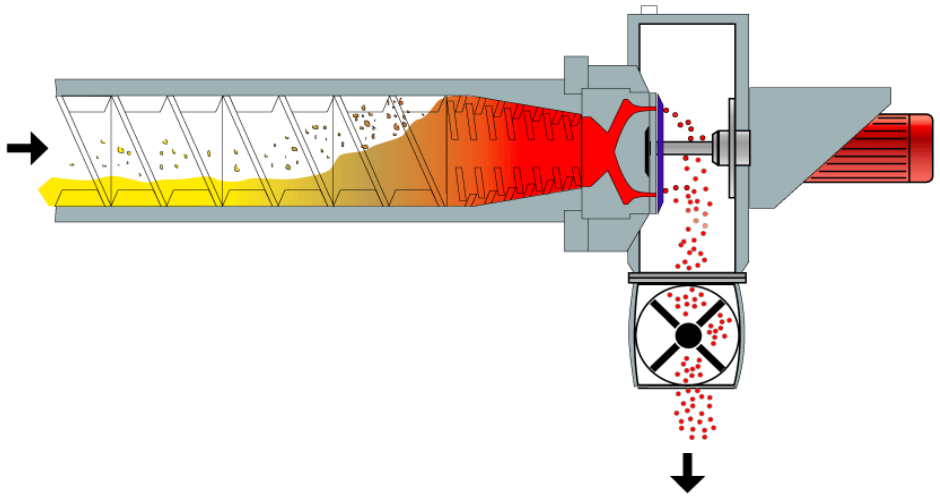


FLEXTEX in closed position – additional SME applied

ECS + Flextex

Extruder configurations for both sinking and floating fish feed

- ECS controls expansion (density) accurately.
- ECS provides up to 50% increase in capacity.
- No oil is required for controlling density as density is controlled by ECS.



Over pressure in Bar G	Boiling point water	Increase in product density
0 bar	100.0°C	0%
0.5 bar	111.4°C	8-12%
1.0 bar	120.2°C	16-20%
1.5 bar	127.4°C	23-27%
2.0 bar	133.5°C	25-30%

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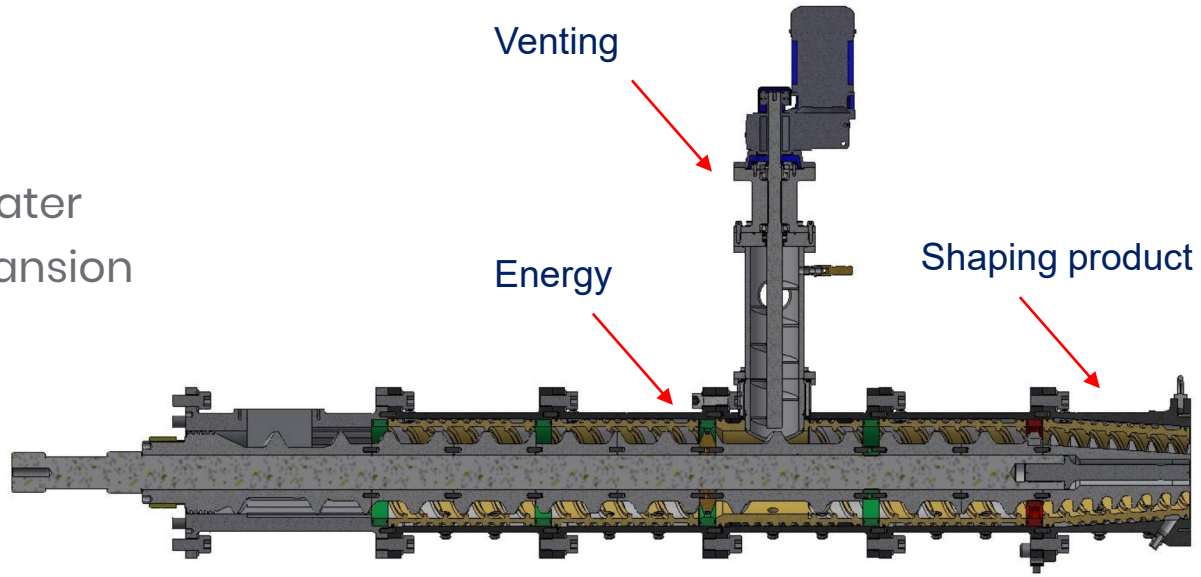
The venting unity

High quality sinking pellets, higher throughput on extruder, less energy

The Vent Stuffer is used to reduce the product temperature, moisture and expansion to produce a heavier sinking product.



High quality sinking feed

- increased gelatinization of starch and increased water stability of pellets without increasing the pellet expansion and product density.

Energy saving

- Less humidity, less energy to dry

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Single screw vs twin screw extruders

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Single vs Twin screw extruders

How to choose the right equipment – some of these questions you need to consider

- Main ingredients and formula
  - High / low starch content in the formula (aqua)
  - Fat content in the formula
- Change in raw materials or seasonal raw material fluctuations
- Physical nature of main materials – texture, size, uniformity, nutritional quality etc.
- Type of feed / food produced
  - Sinking, floating fish feed
  - Std. dry kibbles, semi-moist, high energy etc.
- Target bulk densities
- Capacities

Single vs Twin screw extruders

Then to use a twin screw extruder

The main question:

What kind of products to be extruded?

If you have answered Yes to any of the questions, the twin screw extruder is a good option.

Are you looking for:

- Fish feed with low starch;
- Flexibility to deal with raw material variations;
- High oil content products (>17%);
- Micro extruding (Aqua) Ø0,6 mm

Single vs Twin screw extruders

The right equipment for the right purpose

Single Screw:

- Cheaper to buy
- Cheaper to maintain
- Less complexity
- Lower operating cost
- Unique dependence on performance and screw speed.
- Majority of products can be manufactured on a single screw extruder

Twin Screw:

- Wider range of operating moisture
- Higher level of fat or fresh meat inclusion
- Low starch products
- Better heat transfer
- Higher operating pressure
- More uniform product flow and product appearance
- Less sensitive to changes in raw materials
- Less wear on the screws
- Easier to clean due to “self-wiping” of the 2 screws.

Single vs Twin screw extruders

	Single Screw	Twin Screw
Moisture content	20-28%	>40%
Cooking control	Good	Excellent
Mixing in barrel	Good	Excellent
Density control	High - ECS or Flextex	High - ECS or Flextex
Hygiene	More difficult to keep clean	To some extent self cleaning
Raw material flexibility	Good	Excellent
Fresh meat inclusion	Medium (up to 30%)	High (>30%)
Formulas with high fat *	Medium (typically up to 12%)	High (>17%)
Process flexibility	Good	Excellent
Dependency performance / screw speed	Yes	No
Small die holes > Ø 0.6 mm	Good	Excellent

Single vs Twin screw extruder

Between a single screw and twin screw extruder

	Single Screw	Twin Screw
Capacity tons per hour	12-18 tph	12-18 tph
Power requirements (SME)	15-35kWh/t	15-35 kWh/t
Length/diameter	11.5	20
Screw speed typical	335 rpm	608 rpm
Investment in extruder (machine only)	100%	140%
Wearing costs (barrel + screw)	0.5-1.25 €/ton	1.5-2.25 €/ton

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