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Application manual

TwinLab-F 20/40 D

Application Manual TwinLab-F 20/40 D

Edition 1020

Contents

1 Introduction

1.1 Extrusion

The process of extrusion represents a long known and widely spread form of technology that has developed over the past centuries and is nowadays used in different industrial sectors. The underlying principle of extrusion (lat. “extrudere” (to) press out) is a simple one. Under controlled conditions, the material to be processed is pressed through a die of variable configuration. Due to acting forces, the material undergoes a transformation, thus becoming an extrudate.

1.2 TwinLab-F 20/40 D

The Brabender TwinLab-F 20/40 D is a twin screw extruder enabling the extrusion of products on a laboratory scale, the development of recipes, and the investigation and evaluation of extrusion processes with different test parameters. The extruder stands out for its compact design, its two-part liner the upper half of which can fold away, and a high flexibility of process design.

The present application manual of the Brabender TwinLab-F 20/40 D provides an overview of the extruder functions and possible applications. The first part introduces the features of the extruder and up- and downstream equipment like die heads, pumps, and feeders. The second part sets out examples and pictures of the manifold application possibilities of the machine system.

If you have any questions or need further information, please do not hesitate to contact the Brabender food laboratory team:

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We hope you enjoy reading and browsing through this application manual.

The Brabender food laboratory team

2 Equipment

2.1 TwinLab-F 20/40 D

2.1.1 Features

Fig. 1: TwinLab-F 20/40 D

The TwinLab-F 20/40 D is a food processing twin screw extruder with co-rotating intermeshing screws used for the production of food and feed products. All product wetted parts such as case and processing unit of the TwinLab-F 20/40 D are made of food grade steel. The processing unit consists of a horizontally divided liner that can be opened up in a vertical level. Consequent advantages are the facilitated cleaning of the extruder as well as the easy removal of the twin screws. Furthermore, the filling level of the individual screw elements like kneading blocks, conveying and re-conveying elements and further more with different raw materials can be visually assessed during as well as after the extrusion process.

WIth a screw diameter of Ø 20 mm and a processing length of 40 D, raw materials pass through a maximal length of 800 mm. In addition to the main feed openings at 0 D, 10 D, 20 D and 30 D on the upper side of the liner, there are two additional side feed openings at 12 D and 22 D. Due to these 6 openings, the extruder provides a huge variety of possibilities to introduce raw materials or liquids into the extrusion process on different positions. To reduce the processing length and therefore shorten the residence time in the extruder, raw materials can additionally be dosed into the extruder at 20 D or even 30 D. Inside the liner, there are 4 heating zones that are electrically heated and cooled by water, ensuring temperatures are kept at a constant level and heat caused by shear energy of the screws is dissipated easily.

2.1.2 Safety devices

2.1.2.1 Bursting pin

The TwinLab-F 20/40 D has a bursting pin on the die adapter that will break as soon as pressure in the screw tip within the adapter is exceeding 350 bar, thus causing an immediate pressure drop. Apart from this, the MetaBridge as well as factory-made alarm settings will already inform the user in advance of a pressure rise so that a further increase can be prevented.

Fig. 2: Bursting pin

2.1.2.2 Emergency motor stop button

On the upper side of the TwinLab-F 20/40 D is an emergency motor stop button that will cause an immediate stop of the extruder drive upon pressing and will immediately reduce pressure on the screw tip.

2.1.2.3 *Slip clutch*

A slip clutch between the drive motor and the gear unit, activated at a torque value over 80 Nm is intended to prevent potential damage to the twin screws in case of overload. As soon as the load, i.e. the percentage engine power exceeds 90 %, an alarm signal sounds and the torque value is reduced automaticallly as set in the factory-made alarm settings to protect the motor.

2.1.2.4 *Software temperature limit*

For temperatures exceeding 400 °C, software causes a blockage of the four heating zones to protect the liner and the twin screws from damage due to wrong temperature parameters.

2.1.3 Technical data

Table 1: Technical data of the TwinLab F20/40

Technical data of the TwinLab-F 20/40 D	
Drive power	9.5 kW
Max. screw speed	1200 min
Screw diameter	20 mm
Da/Di	1.60
Processing length	40 D
Max. torque value per screw	40 Nm
Max. pressure	300 bar
Throughput*	0.5 - 20 kg/h*
Max. operating temperature	400 °C
Dimensions (L x W x H)	2013 x 569 x 1566 mm
Weight	approx. 480 kg

* The actual throughput depends on the product and on the processing task

2.2 Twin Screws

The twin screws are a key element of the extruder, providing many different adjustment options for process optimization. The twin screws consist of a screw shaft that positively transmits the torque on the screw elements through the wedge splice.

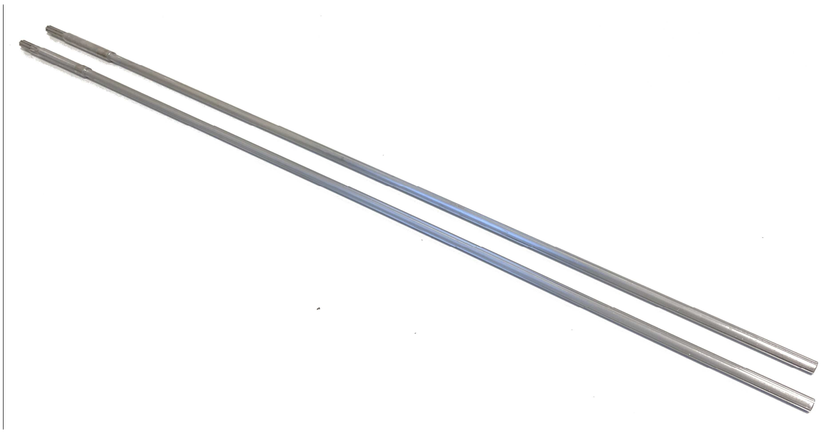


Fig. 3: Screw shaft

The screw elements are pushed onto the screw shaft from the front surface of the screw shaft. Upon completion of the screw assembly, the screw tips are screwed on and tightened with a defined torque.

To customize the twin screw to each processing task and the respective application range, there are different screw elements to convey, retain or mix the product.

2.2.1 Screw elements

2.2.1.1 Conveying elements

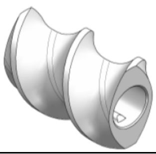
Conveying elements transport the raw material forwards towards the die head. They are available in different designs with various lengths, pitches and profiles. The screw element's designation is composed as follows (example: SE 10/20/R):

SE = designation of Erdmenger-profile

10 = pitch in millimeters

20 = length of the screw element in millimeters

R = right side (conveying)

Conveying element	Representation	Conveying effect	Pressure build-up in conveying direction	Volume
SE-10/20/R		+	++++	+
SE-20/20/R		++	+++	+
SE-30/30/R		+++	++	+
SK-40/40/R		++++	+	++

Apart from conveying elements with Erdmenger-profile, there are also such with thrust edge profile (abbreviation SK), to increase the free volume between the screw flights. Here too, different designs with various pitches and lengths are available.

2.2.1.2 Re-conveying element

Re-conveying elements are used to increase pressure at certain points during the extrusion process and to reduce it at subsequent points. In front of a re-conveying element, pressure is increased because the raw material mix needs to reach a certain pressure to overcome this screw element. Behind the re-conveying element, pressure is decreased because the raw material mix is moved on further by the subsequent conveying element.

Re-conveying elements can be recognized by the letter "L" for left-hand in the length description of the screw element.

Re-conveying element	Representation	Retaining effect	Pressure build-up in conveying direction
SE-10/10L		+	+++
SE-20/20L		++	++

2.2.1.3 Kneading elements

Kneading elements, also known as kneading blocks, generate shear in the extrusion process, distributing and dispersing the raw material in the liner. Distributive mixing with mixing effect during the extrusion process creates a distribution of at least two different components, as per example a mixture of starch and water with pigments. In contrast to that, dispersive mixing with shear effect means the dissipation of two or more incompatible products.

In order to achieve denaturation of proteins meaning the alteration of the 3D-structure of proteins to a 2D linear structure, kneading elements with an increased shear effect are needed. Like conveying and re-conveying elements, kneading elements are also available in different designs. The designation refers to the design and characteristic values of the elements.

As an example, the designation KP45/5/20/L of a kneading block refers to the following characteristics:

KP = Kneading block with ½ disk width on both sides

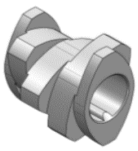
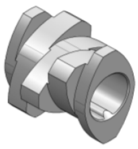
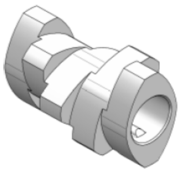
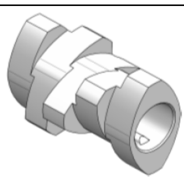
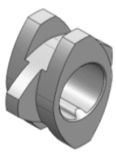
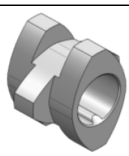
45 = Angular offset between the disks in degrees

5 = Number of disks

20 = Length of the kneading element in millimeters

L = Left side (retaining)

Apart from the KP designs with ½ disk width on both sides, there are also kneading elements featuring full disk width on both sides, marked by the initials KBW. The different designs of each kneading provide either a higher distributive or a higher dispersive shear effect with either positive, neutral or negative conveying effect.

Kneading element	Representation	Mixing effect (distributive)	Shear effect (dispersive)	Conveying effect
KP45/5/20R		++	+	+
KP45/5/20L		+++	++	-
KBW45/5/30R		+	++	+
KBW45/5/30L		++	+++	-
KBW90/3/10N		++	+	o
KP90/3/15N		+	++	o

2.2.1.4 Toothed mixing element

As compared to kneading elements, toothed mixing elements provide a higher mixing effect and a rather low shear effect. Such screw elements are frequently used between the second and third feed opening, when a raw material is fed into the first feed opening and a liquid is dosed through the second feed opening, initiating the first stage of homogenization and creating bonds between the two components.

The toothed mixing element named Z8/3/20 has the following characteristics:

Z = Toothed mixing element

8 = Number of teeth

3 = Number of tooth rows

20 = Length of the toothed mixing element in millimeters

Toothed mixing element	Representation	Mixing effect (distributive)	Shear effect (dispersive)	Conveying effect
Z8/3/20		++	o	+

2.2.1.5 Bushings

In order to reduce the L/D length, for example when feeding in the first raw material in the range of 10 D, the screws need to be equipped with bushings to avoid friction in the empty areas between the screw and the liner.

To convey raw materials compounds with the help of drag flow, bushings are mounted between the conveying or kneading elements.

Bushing	Representation
Bushing 30 mm	

2.3 Die heads

There is a variety of die heads that can be installed on the TwinLab-F 20/40 D in order to give a particular form to the extrudate or to calculate the capillary viscosity of the raw material mixture in the die head on the basis of pressure differences.
The die head is mounted to the adapter of the extruder via a threaded ring.
All die heads can be disassembled and, therefore, allow an easy cleansing. After complete disassembly of the die head and dismantling of the electrical components, the die body can be put into water for soaking.

2.3.1 Round strand die head

Fig. 4: Round strand die head

The round strand die head forms the basis for pellets and expanded products like snacks. It consists of a die body, an interchangeable round die insert, and a heating band that can heat the die head up to 400 °C. Electrically heated die heads can be rapidly cooled down by compressed air. Temperature control by water is also possible in order to generate larger temperature gradients between the last heating zone of the extruder and the die head, making the round strand die head suitable for both hot and cold extrusion. Inside the round strand die body, there are 2 measuring bores for optionally taking a pressure transducer and/or a melt temperature thermocouple to measure the pressure and melt temperature.
For extrusion setups without measuring instruments, these measuring bores are sealed by closing bolts in the standard version to avoid melt leakage.

On the front side of the round strand die head, there is a threaded bore for taking various die inserts. This way, die inserts can be interchanged even during an extrusion process with a very short interruption of the process.

Fig. 5: Die inserts

Furthermore, there are 4 threaded bores on the front side of the die head for mounting a cutting device.

2.3.1.1 Round die inserts

Round die inserts are available with diameter 1 mm to 7 mm. The raw material mixture is shaped accordingly to the threading hole's diameter.

Fig. 6: Round die inserts

2.3.1.2 Basmati die insert

The broken rice resulting from rice processing that, due to its size, falls through the sieve when sieved off is sold as low quality product. Using the basmati die insert, broken rice can be extruded to regular rice size and makes its way to the customer.
Apart from the mere processing of broken rice, additives like vitamins can be added to the rice flour during the extrusion process. Subsequently, the mixture can be extruded into the form of a rice grain again.

Fig. 7: Basmati die insert

2.3.1.3 Square and star die inserts

Apart from the standard die inserts and the basmati die insert, special forms such as square-shaped and star-shaped inserts for particular extrudates are available upon request. As the name suggests, they form the raw material mixture to square- and star-shaped extrudates when emerging from the die. Extrudates of this kind are used e.g. for PET food or snack products.

Fig. 8: Square- and star-shaped die inserts

2.3.2 Ribbon die head

For manufacturing plates and foils, e.g. Lasagne plates and biologically based or biodegradable foils, ribbon or flat sheet die heads with different heights and widths are used. When leaving the extruder, the raw material mixture flows from a round through a rectangular transverse section. Apart from simple ribbon die heads without or with only a single measuring bore, there are also slot capillary die heads with several measuring bores for taking pressure transducers to measure the melt pressure in order to determine the shear viscosity of the raw material. The electric heater band enables temperatures up to 400 °C. For this reason, apart from the round strand die head, ribbon die heads form a basic element of both hot and cold extrusion. Ribbon die heads are divided in two categories, the inflexible and the Flexlip ribbon die heads. All die heads can be disassembled completely and cleaned with water upon removal of all electrical components.

2.3.2.1 Inflexible ribbon die head

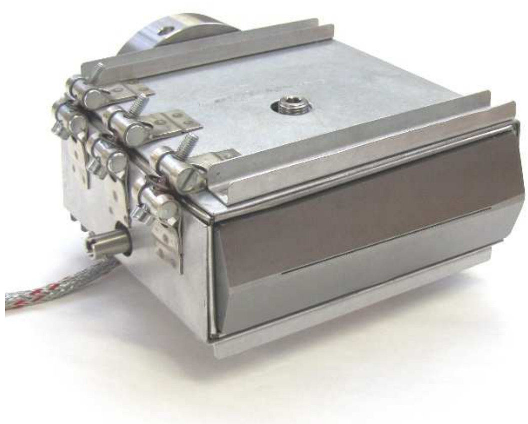


Fig. 9: Inflexible ribbon die head

For inflexible ribbon die heads, the gap size through which the raw material mixture emerges cannot be adjusted, i.e. the height and width of the gap size are constant.

2.3.2.2 Flexlip ribbon die head

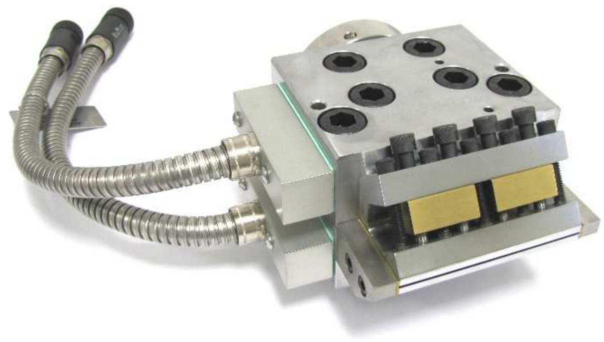


Fig. 10: Flexlip ribbon die head

Flexlip ribbon die heads feature a flexible lip which allows adjusting the height of the gap size. Adjustment can be done by tightening or loosening the clamp screws. Thus, the extrudate thickness can be adjusted even during the extrusion process.

2.3.3 Tubing die head

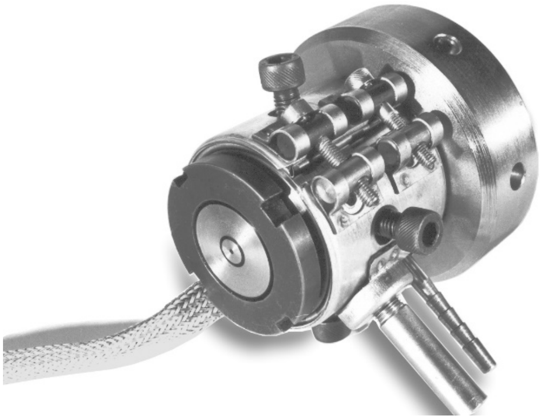


Fig. 11: Overall construction of a tubing die head

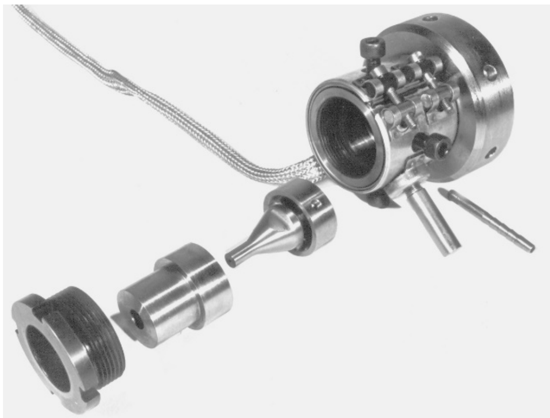


Fig. 12: Exploded view of the tubing die head

The tubing die head consists of several main components shaping the mixture coming out of the extruder to a tube or hose.

The material flows through a torpedo that divides the now roundly shaped raw material into three parts, and, subsequently, forms it to a tube or hose between a cone and a sleeve on the way to the die outlet. Inside the torpedo, there is a bore compressed air can be led through and along the cone into the extruded tube or hose to serve as supporting air which prevents the product from collapsing. Cone and sleeve, determining the inner and outer diameter of the product, are available in different dimensions and can be interchanged.

Fig. 13: Tubing die inserts

2.3.4 Co-extrusion die head

Fig. 14: Left side: Tubing die insert. Right side: Co-extrusion die head with extended inner tube

The co-extrusion die head works on the same principle as the tubing die head, the only difference being the cone length. Co-extrusion dies are used e.g. for snack products with fillings. The raw material for the hard, expanded shell flows between the sleeve and cone and, is kept in shape for a few millimeters by the extended cone insert, while the liquid filling (e.g. a chocolate mixture) is pressed into the case by means of a pump.

2.3.5 Noodle die head

Fig. 15: Noodel die head

The noodle die head is part of the cold extrusion process where the raw material mixture is extruded from the die with a temperature of less than 100 °C. It is mainly used for producing pasta and noodle products. Compared to the round strand die head, the noodle die head is shorter and has no heater band. Therefore, the die head cannot be heated electrically. Inside the die body, there are cooling channels and the supply and discharge connections for a heating/cooling agent such as water which can be heated or cooled by a circulation thermostat.

Fig. 16: Die inserts for the noodle die head

For the noodle die head, a large variety of die inserts with various forms is available. The inserts are positively positioned inside the die body by means of a clamping lever and fixed with two screws. This enables a quick and easy exchange of the die insert even during a running extrusion process, requiring only a very short process interruption and, therefore, allowing quick alteration of the extrudate shape during extrusion process.
Die inserts are available in standard stainless steel version and with PTFE inlets to reduce the adhesive friction of the extrudate and improve the surface quality at the same time.

2.3.5.1 Round die inserts

Round die inserts have either a single bore shaping the raw material mixture or several bores as e.g. 4 x Ø 1 mm, which means 4 bores with a diameter of 1°mm each to form a number of spaghettis at the same time.

Fig. 17: Noodle die insert Ø 3 mm

Fig. 18: Noodle die insert 4 x 1 mm

2.3.5.2 Slot inserts

Slot inserts have slot-shaped openings, e.g. with a width of 7°mm and a height of 1 or 2°mm. They are used for the production of tagliatelle or ribbon noodles.

Fig. 19: Tagliatelle 7 x 1.5 mm

2.3.5.3 Macaroni die insert

With the macaroni die insert, pasta in the form of small tubes like macaroni or canneloni can be produced.

Fig. 20: Macaroni die insert

2.3.6 Modular cooling die

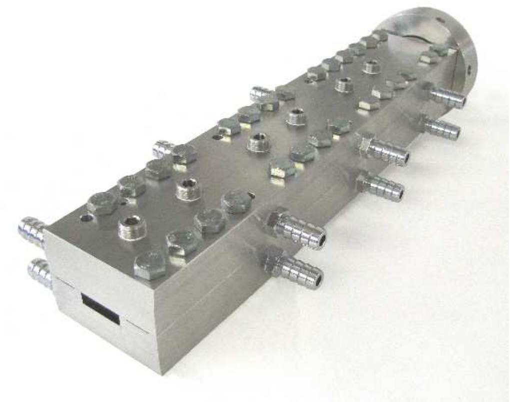


Fig. 21: Modular cooling die

Fig. 22: Open modular cooling die

Texturized products, also known as TVP or texturized vegetable protein, are meat substitutes that are produced by extrusion. After the denaturation of proteins in the extruder, peptides are cooled down in the cooling die, and amino acid chains solidify through cooling and flow effect to oblong products, forming textured structures similar to those of meat. By reducing the moisture content in the extrusion process, the texturization process is intensified.

The cooling die is cooled with water by means of a circulation thermostat. Temperature conditioning is possible through integrated cooling channels all along the length of 300°mm or partially every 100°mm. The latter requires the connection of several circulation thermostats to the respective segments of the cooling die via flexible hoses.

The modular cooling die is divided horizontally. In the upper part, there are 6 measuring bores for mounting pressure transducers and melt temperature thermocouples. The lower part has got the geometry over the entire length of 300 mm that cools the raw material mixture to the final product. To realize different product geometries, different interchangeable lower parts with various geometries are available (20 x 9 mm, 25 x 7 mm, 29 x 5 mm).

2.3.7 Segmented cooling die

Fig. 23: Segmented cooling die with variable cooling lengths

The length of the segmented cooling die can be adapted easily to the specific requirements. To configure the cooling die, an initial segment and at least one extension segment are needed. Suggested overall lengths should extend 300°mm to receive a longer cooling section than with a modular cooling die with fixed length.

Each segment has a total length of 100°mm and is mounted by screw connections to the previous segment. Each extension segment has got two measuring bores on the top side. Due to the long cooling section the raw material passes through, expansion of the product is avoided even at high throughput rates.

2.4 Feeders

2.4.1 Subdivision and characteristics

Feeders are used to feed defined quantities of raw material into the extruder. The six feed openings of the extruder can be used to mount a large variety of different feeders. In general, a distinction is made between bulk feeders for feeding bulk materials in the form of powder or granules, and liquid feeders for dosing water, oil, or solutions/suspensions with a certain viscosity (e.g. like applesauce) into the extruder.

Bulk feeders are further categorized into free-fall feeders, forced feeders and side feeders. In case of free-fall feeders, the material falls down from the feeder into the feed hopper of the extruder and, from there, into the gap between the two screws. The vertical forced feeder forces the raw material into the extruder by means of a vertical feed screw.

Side feeders like the DDSR20 and the MiniTwin12, also known as MT12, are mounted laterally on the extruder. A pair of horizontal feed screws forces the raw material into the extruder underneath the twin screws of the extruder, thus optimizing the intake performance.

Free-fall and liquid feeders are divided into volumetric and gravimetric systems.

To set the feed rate, also called throughput or mass flow, in either g/min or kg/h, a feeder characteristic is needed. To create a feeder characteristic, a raw material is fed into the feeder. Subsequently, the output is measured with 3 - 5 different rpms by means of a scale. By drawing a diagram or a linear function according to the equation y = m • x + b, the output can be calculated in either g/min or kg/h. During the extrusion process, the rpms of the feeder are set accordingly to feed the calculated quantity of the raw material into the extruder.

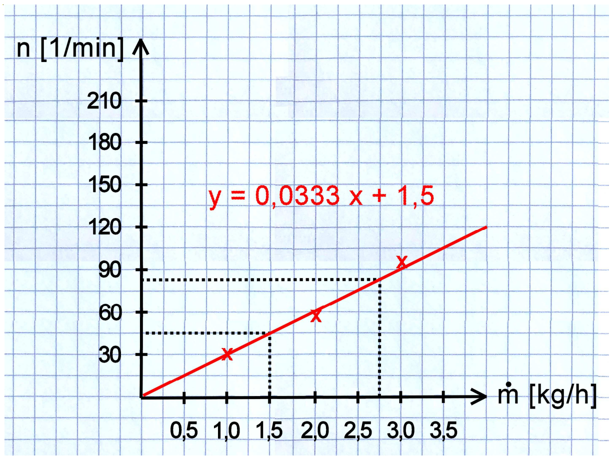


Fig. 24: Feeder characteristic

Due to the static pressure acting on the screws, the feeder feeds more raw material with a full feed hopper than with an almost empty one.

However, to keep the output of the feeder on a constant and controllable rate, gravimetric feeders with a scale underneath are being used. As the output rate is measured continuously by the scale and the motor speed is adjusted accordingly, these feeders are also called loss-in-weight feeders (LIW)). Another advantage as compared to the constant feed rate of gravimetric feeders is that creating a feeder characteristic is no longer required.

At the beginning, the raw material is inside a container and is fed for approx. one minute with two preconfigured, variable rpms. The scale determines the feed rate automatically from the loss in weight. Each further setting of the feed rate on the control unit or the on the TwinLab-F 20/40 D is no longer controlled by the rpm, but directly by the feed rate in g/min or kg/h. The actual raw material weight inside the feed hopper can be read in kgs on the control unit any time.

Apart from the feeders described in the following, there are other volumetric and gravimetric feeders available upon request.

2.4.2 Volumetric feeder DDSR20 – free-fall

The free-fall version of the volumetric feeder DDSR20 features two exchangeable, co-rotating feed screws feeding the raw material into the feed hopper of the extruder. Due to the double concave, intermeshing and, therefore, self-cleaning feed screws, this feeder is an ideal choice for conveying powders such as flour, starch or pellets.

Fig. 25: Volumetric feeder DDSR20

To cover various throughput ranges, feed screws and discharge tubes are available with different diameters and pitches. The different screw/tube combinations are characterized by a numeric designation as follows: In the designation "2012/200", the first two digits mark the outer diameter of the feed screw, in this case Ø 20 mm. The following index 12 refers to the pitch in mm per rotation. The three digits after the slash mark the inner diameter of the screw tube, which is available with the diameters 200 mm and 223 mm.

Fig. 26: Screw/tube combinations from left to right: 2012/200, 2020/223, 2011/223

The following two diagrams show the maximum throughputs of corn grits and soy protein concentrate, measured with different screw/tube combinations.

Table 2: Max. throughput of corn grits with a bulk density of 0.613 kg/l

Screw/tube combination	Max. throughput [kg/h]
2012/200	18.99
2020/223	48.70
2011/223	28.48

Table 3: Max. throughput of soy protein concentrate with a bulk density of 0.325 kg/l

Screw/tube combination	Max. throughput [kg/h]
2012/200	10.93
2020/223	23.02
2011/223	12.29

In order to prevent raw materials with poor flow characteristics from bridging inside the feed hopper and the through of the feeder and, thus, affecting the feeding process, different versions of agitators are being used to keep the raw material in motion during the feeding process.

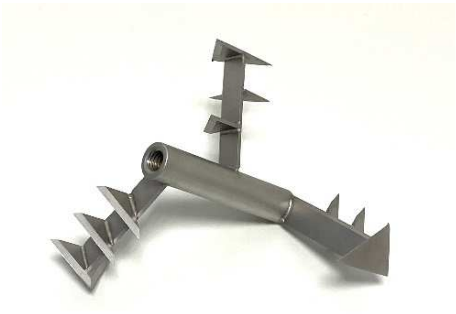


Fig. 27: Agitator with blades

Two different supporting frames are available for mounting the volumetric feeder to the extruder.

Fig. 28: Supporting frame for volumetric feeders

Fig. 29: Supporting frame with volumetric feeder DDSR20

The first of these features a fixed plate the feeder can be placed on. The supporting frame is fixed with screws on the rear side of the extruder. The supporting plate takes the volumetric feeder with the control unit to feed the raw material into the extruder at 0°D.

Fig. 30: Mobile support with flexible supporting plates and gravimetric feeder DDSR20

A mobile support with flexible supporting plates running on linear guides enables the use of up to three feeders at a time. The mobile support is not connected to the extruder to prevent any transmission of vibrations to the feeders, which might interfere with the scale.

2.4.3 Gravimetric feeder DDSR20 – free-fall

Fig. 31: Gravimetric feeder DDSR20

The gravimetric feeder DDSR20 in hygienic design uses the same screw/tube combinations as the volumetric feeder DDSR20. However, in contrast to the volumetric feeder, the gravimetric feeder features a scale underneath the feeder which measures the weight and controls the throughput precisely throughout the extrusion process. The motor, scale and control unit are housed under a stainless steel cover hood to protect them against dust and powdery raw materials. The polished stainless steel surfaces of all product wetted parts allow easy and quick cleansing.

Fig. 32: Gravimetric feeder DDSR20 on the mobile support

The gravimetric feeder is mounted on a separated mobile support to prevent any transmission of vibrations generated in the extruder to the feeder.

2.4.4 Vertical screw feeder

Fig. 33: Vertical screw feeder

Raw materials prone to lumping and with unfavorable feeding properties are preferably fed into the extruder via the vertical screw feeder. The vertical screw forces the raw material into the extruder while a rotating agitator running close to the hopper wall continuously transports the raw material towards the feed screw.

The vertical screw feeder can be mounted at 0 D, 10 D, 20 D or 30 D.

2.4.5 Volumetric feeder DDSR20 – side feeder

The lateral version of the volumetric feeder DDSR20, also called side feeder, is mounted to the extruder at 12°D or 22°D by means of a special holder. The two self-cleaning double concave feed screws convey the raw material into the extruder. Depending on the screw/tube combination, powders or pellets up to a particle size of Ø 2 mm can be fed as well. The screw/tube combinations feature the same characteristics as those of the volumetric and gravimetric feeders. Once more, the available feed screw designs are 2012/200, 2020/223, and 2011/223. Optionally, the screw tube can be cooled with liquid (usually water) to prevent heat transfer from the extruder to the raw material inside the flights of the feed screw.

The side feeder is mounted on a mobile plate which can be moved on a lateral support, allowing to approach the feeder to or separate it from the extruder.

Fig. 34: Support for side feeders

2.4.6 Volumetric feeder MT12 – side feeder

The Mini-Twin side feeder, also called MT12, is used for laterally feeding small amounts of raw material into the extruder. With a screw diameter of 12°mm and low pitches, feed rates are considerably lower than with the DDSR20.

Fig. 35: MT12 side feeder

Like the volumetric side feeder DDSR20, the MT12 is mounted on a lateral support to approach it to the extruder and secure it against pushing off.

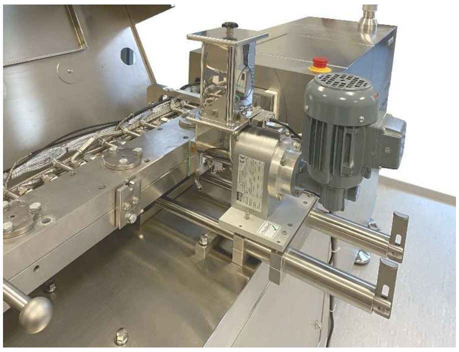


Fig. 36: MT12 on lateral support

Table 4: Maximum throughput of corn grits with a bulk density of 0.613 kg/l

Feed screws	Max. throughput [kg/h]
1204	1.34
1212	2.89

Table 5: Maximmu throughput of soy protein concentrate with a bulk density of 0.325 kg/l

Feed screws	Max. throughput [kg/h]
1204	0.89
1212	2.26

2.4.7 Liquid dosing system Watson Marlow 120U

Fig. 37: Liquid dosing system Watson Marlow 120U

For dosing liquids like water or oils into the extruder, peristaltic pumps are used. They are based on a suction effect where rotating rollers alternately exert pressure or rather relieve a hose. Due to the negative pressure generated, the liquid medium is drawn in.

The speed of the peristaltic pump can be adjusted from 0.1 to 200 rpm to cover a wide range of feed rates.

When using the pump, various hose sizes can be mounted to vary the maximum feed rate. Common hose sizes feature inner diameters of Ø 2.4 mm / 3.2 mm / 4.8 mm. The hoses are connected to a dosing bolt which, in turn, is mounted to the dosing plug of the extruder.

Table 6: Maximum throughput of water with the Watson Marlow 120U

Hose diameter	Max. throughput[kg/h]
2.4 mm	2.9
3.2 mm	4.8
4.8 mm	10.1

2.4.8 Liquid dosing system Watson Marlow 530DuN

Fig. 38: Liquid dosing system Watson Marlow 530DuN

Like the Watson Marlow 120U, the liquid dosing system Watson Marlow 530DuN works on the peristaltic principle, where a pressure load and release acts on the hose. The Watson Marlow 530DuN is used for higher feed rates and for dosing highly viscous masses like applesauce or nougat fillings. Unlike the smaller Watson Marlow 120U, the Watson Marlow 530 DuN uses built-in double hoses in the pump head to realise the required high intake pressures. Common hose sizes for low-viscosity fluids like water are hoses with an inner diameter of Ø 3.2 mm and 4.8 mm. For high-viscosity pastes, even bigger hose diameters can be used.

Table 7: Maximum throughput of water with the Watson Marlow 530DuN

Hose diameter	Max. throughput [kg/h]
3.2 mm	27
4.8 mm	54.1

Via the RS232 interface and a corresponding adapter, the pump can be connected to the TwinLab-F°20/40°D for graphical display of the pump speed.

2.5 Vacuum unit

Water content is an important factor when it comes to influencing the extrudate qualities. Looking at hot extrusion, for example, raw material mixtures with a high moisture content reduce expansion of the extrudates produced. In fish food production, adding water determines the floating abilities of the pellets.

With the vacuum unit, gas/vapors arising during the extrusion process can be extracted from the product.

Fig. 39: Vacuum unit

2.6 Measurable values in the extrusion process

Measuring instruments are of utmost value for the process evaluation in extrusion. Due to measuring instruments, a process which formerly took place in a "black box" can now be precisely controlled by various measuring values. Parameters like pressure, melt temperature, or load are part of quality assurance and a first indication of statements on the quality of raw materials and extrudates.

2.6.1 Pressure

Pressure transducers are measuring instruments that measure the pressure in the area they are built in. They feature a membrane that is absorbing force, and an electronics box converting this force into measured pressure values (bar or psi). To measure pressure in the extrusion process, a pressure transducer is mostly installed at the screw tip inside the adapter, which is the connecting element of the extruder and the die head. Pressure measurement at the screw tip, where the bursting pin is installed as a safety feature, can prevent a rupture of the bursting pin and an associated interruption of the extrusion process, caused by an uncontrolled pressure rise e.g. due to an unsuited recipe.
Depending on the die head, there may be further measuring bores in the die head for mounting pressure transducers to measure the pressure values at different points to calculate e.g. capillary viscosity in round or slot capillary die heads.

Fig. 40: Pressure transducer

2.6.2 Temperature

For product assessment, evaluation of the extrusion process, and process control, temperature is an important factor as well. Melt temperature thermocouples measure the melt temperature of the raw material mixture at different points in the extruder and die head. Possible installation points are the screw area, the screw tip and/or the die head. During the extrusion process, the material flows over the measuring tip of the melt temperature thermocouple. The measured temperature is transmitted to the software and displayed graphically in the process diagram.

Fig. 41: Melt temperature thermocouple

2.6.3 Load

Load is a parameter that expresses utilization of the drive motor as a percentage. The load is recorded during the entire extrusion process. With increasing throughput and a constant screw speed, the load increases due to the increasing filling level of the screws.

2.7 MetaBridge software

On the TwinLab-F°20/40°D, a software specially developed by Brabender is installed, recording and saving measuring values of all measuring devices and peripherals connected, and graphically displays all parameters and measuring values in clear presentations after the end of process. Peripherals like a cutting device or feeders can be mounted to the TwinLab-F°20/40°D via CAN bus and controlled through the MetaBridge software.
By entering the IP address to a network, the extruder can be monitored through any terminal devices such as computer, laptop, tablet or smartphone that are in the same network.

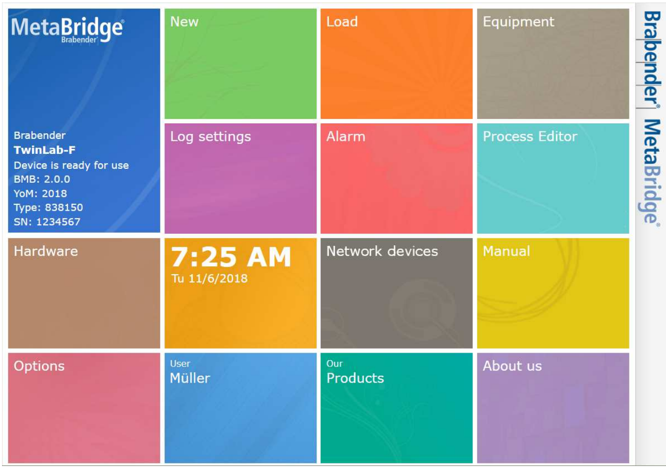


Fig. 42: Brabender MetaBridge

2.8 Downstream equipment

2.8.1 Cutting device

2.8.1.1 Design and performance features

Fig. 43: Cutting device

A cutting device is needed to shorten the extrudate when it is leaving the die. The cutting device is fixed with four screws on the front side of the round strand die head. The motor has a maximum rpm of 300°U/min. In operation, the cutting frequency depends on the number of cutting blades.

The perspex protective screen is made for continuous control of the cutting process. The mist condensating on the perspex screen depends on the application and can be removed by blowing compressed air into the cutting chamber of the cutting device. After the cutting process, the extrudates fall down into the container provided.

2.8.1.2 Straight aligned cutting knives

Fig. 44: Straight aligned cutting knife with two blades

Straight aligned cutting knives are used for cutting solid extrudates like expanded corn curls. These cutting knives are available with different numbers of blades, typically with 2, 4 or 8 blades. Apart from that, special versions like balanced knives with a single blade are available.
The cutting knives are mounted on a spacer ring centered on the motor shaft.

2.8.1.3 Angle-offset cutting knives

Fig. 45: Angle-offset cutting knife with 10 blades

Cutting knives with angle-offset blades are suited for cutting soft extrudates like sinking fish food. The angle-offset cutting knives are currently available with 3 blades for low cutting frequencies and with 10 blades for high cutting frequencies and short extrudates. With a maximum motor speed of the cutting device of 300°U/min, the 10-blades knife enables up to 3000 cuts per minute. Each blade has a cutting edge on each side. In case of one cutting edge being damaged or blunt, the blade can be turned by 180 degrees first before replacement. This increases the lifetime of the knives significantly. Oblonged holes in the blade allow fine adjustment of the distance between die and blade. Further angle-offset knives with a different number of blades are available on request.

2.8.2 Conveyor belt

Fig. 46: Conveyor belt with nip roll

When leaving the die head, the shaped extrudates like TVP or pasta are taken away from the extruder by a conveyor belt. The haul-off speed of the conveyor belt can be set between 0.1 m/min and 6 m/min. For faster haul-off speeds, a conveyor belt with 18 m/min is available. A nip roll which can be mounted on the conveyor belt as an option creates a counterforce to the conveyor belt to draw off the extrudates.

By adjusting the height of the conveyor belt, pellets cut by the cutting device, meat substitutes from the cooling die head, and pasta products can directly be taken away from the die head.

2.9 Equipment for sample preparation

2.9.1 Rotary mill

Fig. 47: Rotary mill

The rotary mill shreds raw materials and extrudates of various kinds before or after extrusion. For sample preparation, raw products like peas or lentils need to be crushed before the extrusion process so that they can be fed into the extruder through a feeder.
After extrusion, products may need to be crushed for further analyses, e.g. measurements of gelatinization or residual gelatinization of samples in the ViscoQuick, Viscograph or Micro-Visco-Amylograph.
By using different sieve inserts, different degrees of fineness can be achieved.

2.9.2 Break mill

The break mill SM4 is a mill with indexable inserts for complete grinding of raw products like peas, lentils, or coffee in order to prepare the samples for extrusion. The degree of grinding is infinitely variable due to an adjustable milling gap.

Fig. 48: Break mill

2.9.3 Moisture Tester MT-CA

The Moisture Tester is used to measure the raw material moisture which is an important parameter to the process of extrusion.

The Brabender Moisture Tester, also called MT-CA, is an electronic moisture analyzer that works on the principle of heat drying in moved air (oven drying method). The loss in weight of the sample material resulting from drying is measured. Due to the permanent exchange of the moist air, the drying process is proceeding much faster than in a conventional drying cabinet without ventilation.

Fig. 49: Moisture Tester MT-CA

3 Experimental setup of the applications

Food and feed extrusion is divided into three main applications, namely cold extrusion, hot extrusion, and high-moisture extrusion (wet extrusion), also called HME. They differ in temperature ranges and in the moisture extent in the extruder.

3.1 Cold extrusion

In cold extrusion, temperatures do not exceed 100 °C. Typical products are pasta such as tagliatelle, or sweets such as licorice, chewing gum, caramel mixtures and chocolate.

3.1.1 Experimental setup for cold extrusion

Fig. 50: Setup for cold extrusion

Figure 50 shows an exemplary setup for cold extrusion, comprising the TwinLab-F 20/40 D with a gravimetric feeder DDSR20 that feeds the raw material such as durum wheat semolina at 0°D into the main feed opening of the extruder, as well as a peristaltic pump for adding water at 10°D. Die heads that can be used are e.g. the pasta or round strand die head, both with the corresponding die inserts. Apart from that, ribbon die heads can be mounted to produce lasagne or dough. A conveyor belt serves as downstream equipment to take off the product.

3.1.2 Screw configuration for cold extrusion

Depending on the raw material and on the extrudate to be produced, screw configurations generating little shear are being used. Especially when it comes to cold extrusion, no re-conveying elements are used in order to achieve short residence times and keep the mechanical energy input on a low level.

Fig. 51: Exemplary screw configuration with little shear for cold extrusion

3.2 Hot extrusion

Hot extrusion is performed at high temperature over 100 °C in order to gelatinize the starch contained in the raw material with the aim of improving the digestibility of the final product, or in order to denature proteins. Common extrusion products are expanded snack products like flips, flat bread, and cereals.

3.2.1 Extrusion setup for hot extrusion

Fig. 52: Extrusion setup for hot extrusion

Fig. 52 shows an exemplary setup for hot extrusion. The raw material, e.g. corn semolina, is fed into main feed opening of the extruder at 0°D. At the second feed opening at 10°D, water is added with a pump. A round strand or ribbon die head heated up to more than 100 °C causes the corn semolina and water mixture to expand when it leaves the die. The degree of expansion is specified by the expansion index. This is a characteristic stating the relation between expansion diameter of the extrudate and die diameter. The formula applied is:

SEI = $\left(\frac{De}{D}\right)^2$

SEI = Sectional expansion index

D_e = Expansion diameter of the extrudate

D = Die diameter

For cutting elongated flips or round expanded balls behind the round strand die head, there is a cutting device with an angle-offset cutting blade mounted to the round strand die head.

3.2.2 Screw configuration for hot extrusion

Based on the application with corn grits, which expands when leaving the die head, screw configurations creating a slight to medium shear to the raw material mixture are being used in order to gelatinize the starch inside the extruder by heat and shear.

Fig. 53: Exemplary screw configuration with slight shear for hot extrusion

3.3 High-Moisture Extrusion (HME)

As indicated by name, the application of high-moisture extrusion (short form HME) uses higher moisture contents that may exceed 40 %, depending on the raw material. The main application area is the manufacturing of meat substitutes out of raw materials with a high protein content. Due to the addition of water and the effect of shear and heat, proteins contained in the raw material are first split up and solidified afterwards by cooling in the cooling die. The resulting tendon-like texture of the extrudate resembles the texture of chicken nuggets or fish fingers.

3.3.1 Extrusion setup for high-moisture extrusion (HME)

Fig. 54: Extrusion setup for HME

The raw material, e.g. a soy protein concentrate, is fed into the extruder through the main dosing opening at 0°D. For dosing the large amount of water that is needed, a pump tubing with a comparatively wide inner diameter is used in order to feed more water into the extruder with the peristaltic pump. Depending on the throughput requested, the application of the larger peristaltic pump Watson Marlow 530DuN may be necessary. After passing through the extruder, the raw material mixture of soy protein concentrate and water passes through the modular or segmented cooling die that is cooled by a cold circulation thermostat. When leaving the die head, the extrudate is taken off by a conveyor belt. For further analyses such as for example texture analysis with the Texture Analyser, the extrudate can be cut to length.

3.3.2 Screw configuration for HME

The screw configuration used for HME includes kneading blocks and re-conveying elements in order to achieve high shear. This is necessary in order to denature proteins with simultaneous heat influx inside the extruder.

Fig. 55: Exemplary screw configuration with high shear for HME

4 Cold extrusion

4.1 Cold extrusion – pasta – durum wheat semolina

4.1.1 Application

In the Italian sense, pasta or noodles is the designation for pasta products made from durum wheat semolina and water in different sizes and shapes. Durum wheat semolina is mixed with water, and the resulting dough is pressed through a ribbon, pasta or round strand die head with the corresponding die insert to give the product its final shape.

4.1.2 Material

- Durum wheat semolina
  - Supplier "Mühlenkönig"
  - Raw material moisture 9.81 %
- Tap water

Fig. 56: Durum wheat semolina

4.1.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Vertical screw feeder at 0 D
- Segmented screw pair "Cold extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Ribbon die head 20 x 0.5 mm

  <u>or</u>
- Noodle die head
  - Tagliatelle die insert
- Conveyor belt

Fig. 57: Ribbon die head

Fig. 58: Tagliatelle die insert

4.1.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 60 - 65 °C
- Screw rpm: low
- Total throughput: 4 kg/h
- Total moisture: 33 %

Fig. 59: Pasta plates made from durum wheat semolina

Extrudate properties	
Moisture content	33 %
Extrudate width	20 mm
Extrudate thickness	0.5 mm

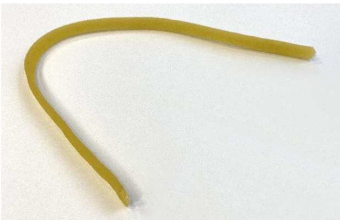


Fig. 60: Tagliatelle made from durum wheat semolina

Extrudate properties	
Moisture content	33 %
Extrudate width	7 mm
Extrudate thickness	1 mm

4.2 Cold extrusion – pasta – rice

4.2.1 Application

Due to the increasing gluten intolerance in our society, the demand for gluten-free products is on the rise. In order to meet this high demand, pasta products from gluten-free ingredients like rice are the current trend. For creating new products, additives like vitamins or spices can be added to the rice during the extrusion process in order to work them into the product, which will finally be rice grain shaped again.

4.2.2 Material

- Basmati rice
    - Supplier "Müller´s Mühle"
    - Raw material moisture 12.66 %
- Tap water

Fig. 61: Basmati rice

4.2.3 Equipment

- Laboratory mill
- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "cold extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Noodle die head
    - Tagliatelle die insert

or:

- Round strand die head
    - Basmati die insert
- Cutting device
- Conveyor belt

Fig. 62: Tagliatelle die insert

Fig. 63: Basmati die insert

4.2.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 60 - 65 °C
- Screw rpm: low
- Total throughput: 2 kg/h
- Total moisture: 35 - 40 %

Fig. 64: Rice made from basmati rice

Extrudate properties	
Moisture content	35 %

Fig. 65: Tagliatelle made from basmati rice

Extrudate properties	
Moisture content	40 %
Extrudate width	7 mm
Extrudate thickness	1.5 mm

4.3 Cold extrusion – dough – wheat flour

4.3.1 Application

Wheat flour that is formed to a dough through kneading with water can be pressed through a flat sheet die head in the extruder, in order to produce flat and homogenous doughs. When using a Flexlip die head, dough plates up to a thickness of 1.5 mm can be produced. In case greater thicknesses are desired, the dough plates may be formed to balls after discharge from the die and rolled out again afterwards.
Baking additives like yeast can be fed to the extruder through further dosing systems and be homogenously incorporated in the dough.

4.3.2 Material

- Wheat flour "Iysvogel"
    - Supplier "Meneba"
    - Raw material moisture 13.5 %
- Tap water

Fig. 66: Wheat flour "Iysvogel"

4.3.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented screw pair "cold extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Flexlip die head 150 x 0 - 1.5 mm
- Conveyor belt

Fig. 67: Flexlip die head

4.3.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 45 - 50 °C
- Screw rpm: low
- Total throughput: 4 kg/h
- Total moisture: 47 %

Extrudate properties	
Moisture content	47 %
Dough thickness	1.5 mm

Fig. 68: Dough shaping by means of a Flexlip die head

Fig. 69: Oven-baked Chapati

5 Hot extrusion

5.1 Hot extrusion – expanded snack products – corn grits

5.1.1 Application

Expanded snacks like peanut flips are products made in two consecutive processing steps. The raw flips are pre-produced in the extruder without adding any spice mixture, using the effect of shear, heat and high pressure. When the water/raw material mixture leaves the die, the boiling water suddenly escapes and the extrudates solidify. Due to this process, extrudates receive their puffy structure. Subsequently, the raw flips are coated with a mixture of fat, spices, and salt.

5.1.2 Material

- Corn grits
  - Supplier "Cornexo"
  - Raw material moisture 10.61 %
- Tap water

Fig. 70: Corn grits

5.1.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Vertical screw feeder at 0 D
- Segmented screw pair "hot extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Round strand die head
  - Round die insert Ø 3 mm
- Cutting device

Fig. 71: Round die insert Ø 3 mm

5.1.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 135 - 140 °C
- Screw rpm: low
- Total throughput: 12 kg/h
- Total moisture: 16 %

Fig. 72: Round snack products made from corn grits

Extrudate properties	
Moisture content	16 %
Extrudate diameter	11.8 mm
Expansion index	15.47

Fig. 73: Elongated snack products made from corn grits

Extrudate properties	
Moisture content	16 %
Extrudate diameter	11.7 mm
Extrudate length	35 mm
Expansion index	15.21

5.2 Hot extrusion – expanded snack products – wheat starch

5.2.1 Application

A high starch content in the raw material increases the expansion index, which describes the extrudate's extent of expansion when leaving the die (see chapter 3.2.1 "Extrusion setup for hot extrusion"). Apart from the starch content, the expansion diameter is also influenced by the total throughput and the die diameter. Generally speaking, the higher the total throughput and the lower the die diameter, the lower the expansion index, meaning the lower the expansion of the extrudate behind the die head.

5.2.2 Material

- Wheat starch
    - Supplier "Crespel & Deiters"
    - Raw material moisture 6.81 %
- Tap water

Fig. 74: Wheat starch

5.2.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Vertical screw feeder at 0 D
- Segmented pair of screws "hot extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Round strand die head
    - Round die insert Ø 4 mm
- Cutting device

Fig. 75: Round die insert Ø 4 mm

5.2.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 160 °C
- Screw rpm: low
- Total throughput: 3 kg/h
- Total moisture: 15 %

Fig. 76: Round snack products made from wheat starch

Extrudate properties	
Moisture content	15 %
Extrudate diameter	10.1 mm
Expansion index	6.38

5.3 Hot extrusion –expanded snack products – rye flour

5.3.1 Application

Expanded snack products of rye flour are rich in fiber as compared to products of wheat flour. Therefore, they are especially suitable as fiber-rich breakfast cereals for gluten intolerant customers.

5.3.2 Material

- Rye flour type 1150
    - Supplier "Plange & Küpper"
    - Raw material moisture 10.59 %
- Tap water

Fig. 77: Rye flour type 1150

5.3.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "hot extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Round strand die
    - Round die insert Ø 3 mm
- Cutting device

Fig. 78: Round die insert Ø 3 mm

5.3.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 160 °C
- Screw rpm: low
- Total throughput: 4 kg/h
- Total moisture: 14 %

Fig. 79: Round snack products made from rye flour

Extrudate properties	
Moisture content	14 %
Extrudate diameter	9.4 mm
Expansion index	9.82

Fig. 80: Snack product with visible expansion made from rye flour

Extrudate properties	
Moisture content	14 %
Extrudate diameter	9.2 mm
Expansion index	9.4

5.4 Hot extrusion – expanded snack products – soy

5.4.1 Application

Soy, a crop species of legumes, has been cultivated as agricultural crop since 3500 B.C. For producing expanded snack products and breakfast cereals, soy offers a large variety of processing possibilities. Soy products used are soy flours, soy protein concentrates and -isolates. Soy protein concentrates have a protein content of 60 - 70 %, which is gained by reducing the fat content by means of a fat extracting agent, e.g. hexane.

Due to the high content of valuable proteins, soy products are especially suitable for the range of breakfast products.

5.4.2 Material

- Soy protein concentrate "Alpha 8"
    - Supplier "DuPont"
    - Raw material moisture 8.69 %
- Tap water

Fig. 81: Soy protein concentrate "Alpha 8"

5.4.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "hot extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Round strand die head
    - Round die insert Ø 3 mm
    - Without die insert
- Cutting device

Fig. 82: Round die insert Ø 3 mm

5.4.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 150 - 155 °C
- Screw rpm: low
- Total throughput: 3 kg/h
- Total moisture: 30 - 40 %

Extrudate properties	
Moisture content	30 %
Extrudate diameter	6.1 mm
Expansion index	4.13

Fig. 83: Round snack products made from soy protein concentrate

Extrudate properties	
Moisture content	30 %
Extrudate diameter	6.12 mm
Extrudate length	35 mm
Expansion index	4.16

Fig. 84: Elongated snack products made from soy protein concentrate

Extrudate properties	
Moisture content	40 %
Extrudate diameter	14 mm

Fig. 85: Soy chunks made without die insert from soy protein concentrate

5.5 Hot extrusion – expanded snack products – rice

5.5.1 Application

Rice snacks are produced of rice flour, or mixtures of rice-, corn-, or wheat flour. Apart from this starch containing component, other components like salt or sugar can be added. During extrusion, the starch contained in the rice is subject to gelatinization. When reaching the die, the water evaporates which causes the product to be torn apart and evolves the typical puffy structure.

5.5.2 Material

- Basmati rice
  - Supplier "Müller´s Mühle"
  - Raw material moisture 12.66 %
- Tap water

Fig. 86: Basmati rice

5.5.3 Equipment

- Laboratory mill
- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "hot extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Round strand die head
  - Round die insert Ø 3 mm
- Cutting device

Fig. 87: Round die insert Ø 3 mm

5.5.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 60 - 65°C
- Screw rpm: low
- Total throughput: 2 kg/h
- Total moisture: 16 %

Fig. 88: Expanded snack product made from basmati rice

Extrudate properties	
Moisture content	16 %
Extrudate diameter	9.8 mm
Expansion index	10.67

5.6 Hot extrusion – expanded snack products – fruit fly protein

5.6.1 Application

The use of insects for food or feed production has increased in the last few years. Either flour from pulverized insects or extracted insect protein are used. Apart from sports nutrition and burger patties, chocolate bars, crispy snacks and pasta are now available as well.
The reasons for food and feed producers for enriching their products with insects are mostly of ethical nature, an important argument being for example the significantly smaller ecological footprint as compared to conventional protein sources in human nutrition.

5.6.2 Material

- Fruit fly protein formulation, consisting of:
  - Fruit fly protein
  - Corn flour
  - Soy protein concentrate
  - Raw material moisture 8.97 %
- Tap water

Fig. 89: Fruit fly powder

5.6.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Modular pair of screws "hot extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Round strand die head
  - Round die insert Ø 3 mm
- Cutting device

Fig. 90: Round die insert Ø 3 mm

5.6.4 Experimental parameters in the main experiment

- Melt temperatur at screw tip: 150 - 155 °C
- Screw rpm: low
- Total throughput: 15 kg/h
- Total moisture: 25 %

Fig. 91: Elongated snacks made from fruit fly protein

Extrudate properties	
Moisture content	25 %
Extrudate diameter	5.8 mm
Expansion index	3.74

5.7 Hot extrusion – co-extrusion

5.7.1 Application

Co-extrusion means the manufacture of products consisting of 2 or more material layers. A common final co-extrusion product in the breakfast cereals program are, for example, chocolate tresors with a creme filling inside. In a first processing step, the outer, solid shell is produced. In a second step, the creme filling is pressed into the shell by means of a peristaltic pump.

5.7.2 Material

- Outer shell
  - 41 % of corn flour
  - 41 % of rice flour
  - 10 % of cocoa
  - 8 % of sugar
- Tap water
- Light nut cream

Fig. 92: Recipe of the outer shell

Fig. 93: Light nut cream

5.7.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "hot extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D

  <u>and</u>:
- Peristaltic pump Watson Marlow 530DuN for nut cream
- Co-extrusion die head
  - Die insert Ø 8 mm/Ø 10 mm
- Conveyor belt

Fig. 94: Co-extrusion die head

5.7.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 135 °C
- Screw rpm: low
- Total throughput: 3 kg/h
- Total moisture: 15 %

Fig. 95: Chocolate snacks filled with nut cream

Extrudate properties	
Moisture content	15 %
Outer diameter	12 mm

5.8 Hot extrusion – aqua culture – fish food, starch-based

5.8.1 Application

Fish food for ornamental and farmed fish can be produced in two different ways: either using a pellet press or by extrusion. In the extrusion process, both floating and sinking fish pellets with various additives can be produced by adjusting moisture and temperature accordingly. Carps and catfish species need floating fish food. This characteristic can be obtained by expansion. Expanded pellets offer the special advantage of adding valuable additives like vitamins and fatty acids under vacuum into the puffed matrix.

5.8.2 Material

- Starch-based fish food recipe, consisting of
  - 70 % of corn flour
  - 15 % of soy protein concentrate
  - 15 % of fishmeal
  - Raw material moisture 9.35 %
- Tap water

Fig. 96: Starch-based fish food recipe

5.8.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "hot extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Round strand die head
  - Round die insert Ø 2.5 mm
- Cutting device

Fig. 97: Round die insert Ø 2.5 mm

5.8.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 110 - 115 °C
- Screw rpm: low
- Total throughput: 6 kg/h
- Total moisture: 30 %

Fig. 98: Floating, starchy fish food

Extrudate properties	
Moisture content	30 %
Extrudate diameter	3.5 mm
Expansion index	1.96

5.9 Hot extrusion – aqua culture – fish food, protein-based

5.9.1 Application

Apart from floating fish food, sinking fish pellets can be produced by changing the recipe, moisture content, and temperature profile. These pellets sink to the ground of the water where they are eaten by species like koi or salmon which by nature take their feed from ground.

5.9.2 Material

- Protein-based fish food recipe, consisting of
  - 20 % of soy protein concentrate
  - 20 % of wheat protein
  - 25 % of fishmeal
  - 35 % of wheat flour
  - Raw material moisture 8.36 %
- Tap water

Fig. 99: Protein-based fish food recipe

5.9.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "hot extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Round strand die head
  - Round die insert Ø 3 mm
- Cutting device

Fig. 100: Round die insert Ø 3 mm

5.9.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 105 °C
- Screw rpm: low
- Total throughput: 8 kg/h
- Total moisture: 25 % and 45 %

Fig. 101: Sinking protein fish food

Extrudate properties	
Moisture content	45 %
Extrudate diameter	3.1 mm
Expansion index	1.07

Fig. 102: Floating protein fish food

Extrudate properties	
Moisture content	25 %
Extrudate diameter	4.5 mm
Extrudate length	10 mm
Expansion index	2.25

5.10 Hot extrusion – pet food – dog food

5.10.1 Application

In dog food production, a distinction is made between cold extraction and extrusion. Extrusion stands out for hydrolysis of the components which makes the final product more easily digestible. Vitamins and nutrients are frequently added after the extrusion process in order not to affect their functionality by shear and heat. Likewise, oils and fats are usually applied after the extrusion of the pellets.

5.10.2 Material

- Dog food blend, consisting of
  - 10 % of rice grits
  - 50 % of corn grits
  - 20 % of sugar beet pulp
  - 20 % of poultry meal
  - Raw material moisture 9.61 %
- Tap water

Fig. 103: Dog food blend

5.10.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Vertical screw feeder at 0 D
- Segmented pair of screws "hot extrusion"
- Peristaltic pump Watson Marlow 120U at 10 D
- Round strand die head
  - Square die insert 5 x 5 mm
- Cutting device

Fig. 104: Square die insert 5 x 5 mm

5.10.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 110 °C
- Screw rpm: low
- Total throughput: 6 kg/h
- Total moisture: 25 %

Fig. 105: Dog food extrudate in the form of pillows

Extrudate properties	
Moisture content	25 %
Extrudate diameter	5.5 mm

5.11 Hot extrusion – coffee roasting

5.11.1 Application

Roasting means the refinement of raw coffee under heat. During this process, a large variety of aromas is created. The industrial roasting process runs at temperatures around 200 °C and takes up to 20 minutes. During this process, the raw material changes in many different ways: The color of the raw coffee bean changes from greenish to light brown and finally dark brown shades, water and fat are released, the volume increases, sugar caramelizes, and manifold aromas are born. The higher the roast grade, the less acidity is left in the coffee and a bitter taste develops.

5.11.2 Material

- Raw coffee beans
    - Supplier "Meinrohkaffee"
    - Raw material moisture 8.78 %

Fig. 106: Raw coffee beans

5.11.3 Equipment

- Break mill SM4
- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "hot extrusion"

5.11.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 205 - 215 °C
- Screw rpm: low
- Total throughput: 0.3 kg/h

Fig. 107: Roasted coffee

6 High-moisture extrusion (HME)

6.1 High-moisture extrusion – texturized meat substitutes – soy

6.1.1 Application

Renouncement of products containing meat leads to a protein deficit in the human body. By extruding high protein raw materials such as soybeans using the cooling die head, meat substitutes can now be produced which can largely compensate for this deficit. Apart from soy, other raw materials are being tested in order to extend the range of suitable products and try out further applications. The resulting extrudates show a fibrous structure, called texture, which resembles the texture of real meat.
The extrudates can be post-treated for example by shredding them, adding spices, flavors and binding agents and then pressing them to burger patties.

6.1.2 Material

- Soy protein concentrate "Alpha 8"
    - Supplier "DuPont"
    - Raw material moisture 8.69 %
- Tap water

Fig. 108: Soy protein concentrate "Alpha 8"

6.1.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Vertical screw feeder at 0 D
- Segmented pair of screws "HME"
- Peristaltic pump Watson Marlow 120U at 10 D
- Modular cooling die head 20 x 9 mm
- Conveyor belt

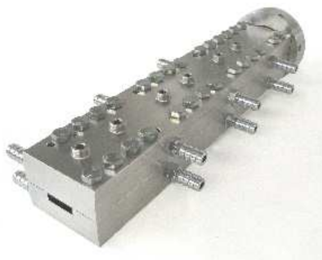
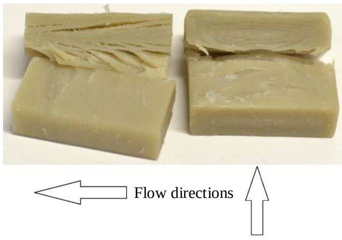


Fig. 109: Modular cooling die head 20 x 9 mm

6.1.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 125 - 130 °C
- Screw rpm: high
- Total throughput: 12 kg/h
- Total moisture: 65 %



Extrudate properties	
Moisture content	65 %

Fig. 110: Texturized extrudate made from soy protein concentrate, cut

Extrudate properties	
Moisture content	65 %

Fig. 111: Texturized extrudate made from soy protein concentrate, torn open

6.2 High-moisture extrusion – texturized meat substitutes – pea protein

6.2.1 Application

Like soybeans, peas belong to the legumes. Due to their high protein content, pea protein concentrates are perfectly suited for the production of texturized meat substitutes by high-moisture extrusion.

6.2.2 Material

- Pea protein concentrate
  - Supplier "Vestkorn"
  - Raw material moisture 10.62 %
- Tap water

Fig. 112: Pea protein

6.2.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "HME"
- Peristaltic pump Watson Marlow 120U at 10 D
- Modular cooling die head 20 x 9 mm
- Conveyor belt

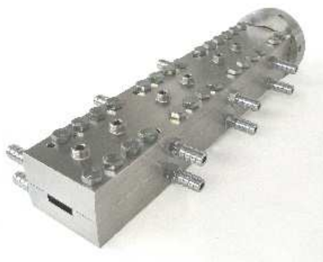


Fig. 113: Modular cooling die head 20 x 9 mm

6.2.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 120 - 125 °C
- Screw rpm: high
- Total throughput: 2.5 kg/h
- Total moisture: 55 %

Fig. 114: Texturized extrudate made from pea protein

Extrudate properties	
Moisture content	55 %

6.3 High-moisture extrusion – texturized meat substitutes – fava bean protein

6.3.1 Application

The fava bean, also called field bean, European bean, English bean or horse bean, belongs to the family of legumes. It has a bitter taste which even persists in meat substitutes made of fava bean concentrate.

6.3.2 Material

- Fava bean protein concentrate
    - Supplier "Vestkorn"
    - Raw material moisture 10.93 %
- Tap water

Fig. 115: Fava bean protein concentrate

6.3.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "HME"
- Peristaltic pump Watson Marlow 120U at 10 D
- Modular cooling die head 20 x 9 mm
- Conveyor belt

Fig. 116: Modular cooling die head 20 x 9 mm

6.3.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 130 - 135 °C
- Screw rpm: high
- Total throughput: 3 kg/h
- Total moisture: 60 %

Extrudate properties	
Moisture content	60 %

Fig. 117: Texturized extrudate made from fava bean protein concentrate

6.4 High-moisture extrusion – texturized meat substitutes – oat protein

6.4.1 Application

Oat belongs to the sweet grass family. The best known foodstuffs produced from oats are oat flakes, oat milk and oatmeal. However, using high-moisture extrusion, oatmeal and oat protein concentrates can also be used as a basis for texturized meat substitutes.

6.4.2 Material

- Oat protein
  - Supplier "Proatein"
  - Raw material moisture 5.70 %
- Tap water

Fig. 118: Oat protein

6.4.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "HME"
- Peristaltic pump Watson Marlow 120U at 10 D
- Modular cooling die head 20 x 9 mm
- Conveyor belt

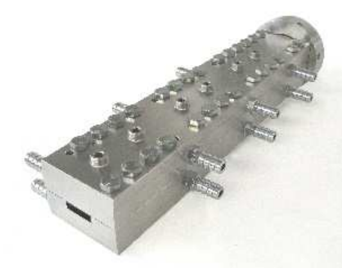


Fig. 119: Modular cooling die head 20 x 9 mm

6.4.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 125 - 130 °C
- Screw rpm: high
- Total throughput: 5 kg/h
- Total moisture: 50 %

Fig. 120: Texturized extrudate made from oat protein

Extrudate properties	
Moisture content	50 %

6.5 High-Moisture-Extrusion – texturized meat substitutes – sun flower protein

6.5.1 Application

Sunflowers cannot only be used to produce sunflower oil, but are also the basis for gaining sunflower protein. For this purpose, the seeds are pressed in a first step, before the press cake is finely ground. After the extrusion process, the texturized meat substitute is characterized by a slight nutty taste.

6.5.2 Material

- Sunflower protein
  - Raw material moisture 9.90 %
- Tap water

Fig. 121: Sunflower protein

6.5.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "HME"
- Peristaltic pump Watson Marlow 120U at 10 D
- Modular cooling die head 20 x 9 mm
- Conveyor belt

Fig. 122: Modular cooling die head 20 x 9 mm

6.5.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 115 - 120 °C
- Screw rpm: high
- Total throughput: 3 kg/h
- Total moisture: 65 %

Fig. 123: Texturized extrudate made from sunflower protein

Extrudate properties	
Moisture content	65 %

6.6 High-moisture extrusion – texturized meat substitutes – insect protein

6.6.1 Application

Protein gained from insects can be mixed with protein concentrates from soy or other legumes to be used for the production of meat substitutes by means of high-moisture extrusion as well. In many applications, the use of insect protein can help to reduce the percentage of vegetable protein sources considerably.

6.6.2 Material

- Recipe, consisting of:
    - Fruit fly protein
    - Soy protein concentrate
    - Raw material moisture 6.73 %
- Tap water

Fig. 124: Insect protein

6.6.3 Equipment

- Moisture Tester MT-CA
- TwinLab-F 20/40 D
- Gravimetric feeder DDSR20 at 0 D
- Segmented pair of screws "HME"
- Peristaltic pump Watson Marlow 120U at 10 D
- Modular cooling die head 20 x 9 mm
- Conveyor belt

Fig. 125: Modular cooling die head 20 x 9 mm

6.6.4 Experimental parameters in the main experiment

- Melt temperature at screw tip: 125 - 130 °C
- Screw rpm: high
- Total throughput: 3 kg/h
- Total moisture: 62 %

Fig. 126: Texturized extrudate made from fruit fly protein

Extrudate properties	
Moisture content	62 %

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