Virtually unlimited combinations possible

Separation systems for upgrading material properties of meat – Part 1

Meat is a premium raw material. In its natural state it is of varying composition. Grading of meat into quality classes is necessary in terms of both quality and material economics when producing sausage products. Various animal carcass pieces and individual raw materials are obtained from the slaughtering and dressing process and these are passed on for further processing as well as for consumption as foods. In this process segment, meat as a general raw material becomes material in the technological sense for grading purposes. The differences in value between the individual meat quality classes necessitate separation operations for optimal use and exploitation of the meat.

By Eberhard Haack and Wolfram Schnäckel

Meat has to be graded, prepared and processed in accordance with parameters resulting from the differing properties of meat as a raw material and from the various requirements of meat product production. Select, pre-graded, dressed meat is made ready for further processing by mincing and cutting. This raw material is largely available as a natural, firmly-textured layered mixture that can only be separated and upgraded if its mincing and reducing quality is known. Consequently processing operations such as mincing are predestined for material separation. Mixing, cutting, stuffing and thermal treatment are downstream technical/technological processes in sausage production. Mincing machines generally head the list of machinery and equipment used. A whole series of technological requirements and a particularly high number of wishes concerning machine functions for processing the raw material exist here. As the mincing machines have virtually unlimited combinations of cutting tools comprising blades, perforated discs and separating systems, they are ideal for targeted treatment and processing of raw materials in line with the technological requirements. The main objective of processing raw materials is to produce pre-products for further processing by defined size reduction:

- fine mincing application with perforated discs (perforation sizes 0.5 mm to 3.0 mm),
- production of medium meat particle sizes (perforation sizes 4.0 mm to 10 mm).
- coarse meat pieces with perforated discs (perforation size above 10 mm) and pre-cutters,
- material separation of meat, collagen tissue, sinews, hide, bones and gristle.

During the last 15 years, alongside the production of pre-products, the technological field of stuffing-mincing has developed. With the stuffing-mincing technique the raw materials are turned into a finished product using one machine. That is why particular performance capabilities with sensitive tool systems are necessary in this processing machinery and equipment.

The stuffing machines are paired with active systems from conventional mincing and grinding machinery. With this combination of equipment it is possible to manufacture finished products of outstanding quality in the minced meat sector and in sausage production in the three basic sausage varieties (cooked sausage, bologna-type sausage and raw sausage), in significantly shorter technological steps and to exploit all precision functions of the stuffing machine for this phase of the work. Meat processing with extremely fine perforated discs is the first process that really allows the transport quality of this machine technology to be utilised. Here a product-group-specific pressure control is necessary to rule out stressing the raw material and destroying the structure.

Working with stuffing-mincing equipment and machinery requires production conditions that are just as good as those possible for step-by-step production of pre-products and intermediate products. That is why maximum demands are made of separating and conveyor systems. These include cutting-set combinations with controlled, operationally reliable and integrated separating functions that are attuned to the stuffing processes.

The basic objective of processing the raw material with standard mincers and grinders is to refine the material by means of separating processes. These include primarily selective separation of material components right through to processing with coarse-sized perforated discs. This operation shortens the treatment process or can even be a mechanically self-contained operation. The results are savings in machinery, energy inputs and space. Grading in correspondingly high quality classes allows enhancing of the raw material yield.

Fundamentals of raw material processing and separating operations

The need to treat meat as a

Fig. 1: Texture analyser TA HDplus with cutting system (left), cutting punch with perforation and plug formation

raw material with special tools in order to extract products of separation results from the overall material composition of meat with its value structure, the requirements made of formulation ingredients regarding quality and nature of the processing, and the existence of foreign bodies not permitted under food law such as bones and gristle. This task evolves from the natural material structure and functional, multi-layer composition of meat.

The homogeneity of the specific material components is based on both the typical material properties and the differences in firmness. The material firmness is the auxiliary parameter for separation operations using cutting systems. Soft raw material components, such as e.g. lean meat of Grade I, can be processed more easily using the perforated disc system (with the corresponding perforation pattern and blades) than tough materials such as e.g. hide or sinews. The firmness of the raw materials and the thrust pressure of the working auger determine the material behaviour as it passes through the perforated disc and the amount remaining on the surface of these discs. This means that the raw materials spend differing lengths of time on the perforated disc and as a consequence the outflow quantities vary. Consequently the firm raw material constantly accumulates in the blade area. This leads to malfunctions in normal cutting-sets and to poor cutting quality due to the perforated disc area becoming sinewy.

Fig. 2: Special test facility (Power Tools) for Instron measuring device

By way of explanation, the fundamentals determining the active principle require first of all that the mechanical firmness properties and parameters of the raw material allowing multilateral processing be established. The objective is to obtain soft raw materials of a high quality and to separate out collagen, sinews, bones and gristle.

Raw material properties and processing parameters

The mechanical firmness properties determine the characteristic size differences for the separating operation. The raw material properties are determined as resistance parameters in relation to the force required to penetrate into the hole pattern of the perforated disc to a given depth of s = 2.0 mm at a hole diameter of d = 3.0 mm. As a counter test, the force is maintained constant with a tool-testing device (pull-pressure measurement) and the depth of material penetration is ascertained. The piece-type nature of the meat and the temperature of the raw material are fixed/recorded as constant quantities. The value parameters obtained are material ratio characteristics as resistance related to a base value (lean meat, animal species, location of meat extraction). Active parameters are the depth of penetration, time and the pressure required for this. The deformation of the raw material in the perforated disc holes takes place at right angles to the hole pattern. The results obtained are flow parameters of the material types. The pressure at which the raw material plug forms for the first time as a result of the resilience in the meat piece is determined. The lower pressure limit represents the start of the meat plug forming as an element of the reduction operation. The maximum boundary levels lead to cell destruction with meat juice running out. Such material is not technologically suitable for use. As a consequence the quality deteriorates and it is important to avoid this. Ultimately only the deformation parameters of the raw materials used for making products are of interest.

The raw material behaviour in interaction with reduction tools is an extremely complex and wide-ranging field of expertise. It can only be investigated by examining and clarifying the actual processes step by step with

Raw material firmness is very inhomogeneous

Tab.: Elastic deformations of raw materials as a function of the working pressure

Raw material	Sort	Deformation pressure (in bar)	Plug length (in mm)
Lean meat pork	S I	6 – 8	4 – 6
	S II	9 – 10	4 – 6
	S III	9 – 14	4 – 7
	S IV	16	2 – 3
Lean meat beef	R I	10 – 15	3 – 4
	R II	10 – 18	3 – 4
	R III	10 – 22	2 – 3
	R IV	14 – 30	2 – 3
		Working pressure (in bar)	
Fat		10 – 30	3 – 5
Hide	Pig	50 – 60	0.5 – 1.5
Collagen tissue		up to 40	0.8 – 1.5

Source: Haack and Schnäckel — Fleischwirtschaft International 4/2008

the aid of test facilities, for in practice such an examination is particularly complicated as the raw material revolves over the perforation pattern of the perforated disc with the knife blades. Generally several operations overlay each other, ruling out a partial examination. It is not possible to measure a feed or progress time for penetration into the holes of the perforated disc. That is why a wide variety of studies on the behaviour of raw material in cutting and mincing processes are carried out using test facilities. At present various sections of the interaction between raw materials and perforated discs and knife systems can be followed with two modern test rig facilities known from merchandise and material testing. This provides some measure of logical explanations of the events taking place and determining the raw material behaviour during processing.

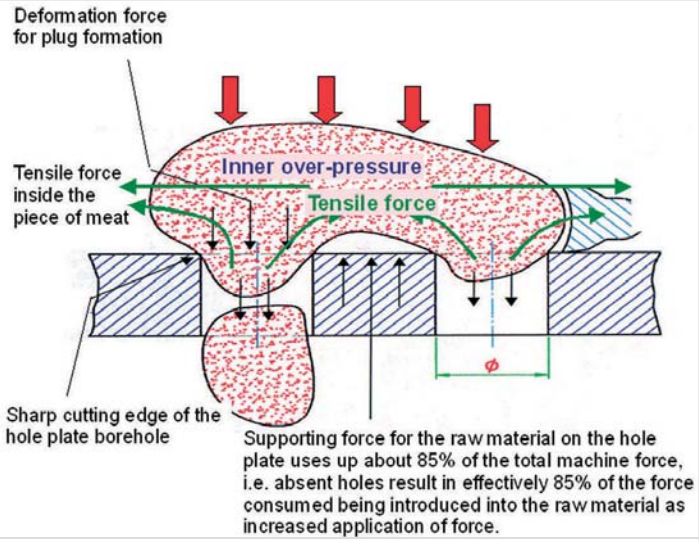


Fig. 3: Schematic representation of the meat behaviour at the perforated disc as the basis for outflow operations

Test facilities

Measuring equipment for material research from Messrs. Instron and the Texture Analyser from Messrs. Stable Micro Systems are used as test facilities. These have been supplemented by our own measuring techniques for recording pressure and path. The objective is to record material value properties. For instance the flow and deposit behaviour are to be determined as a quantity dependent on time and pressure. The raw material feed takes place via reflux-free pistons, as it were. This means that the test operation can be reduced purely to the active behaviour of raw material and tool.

The result obtained comprises material parameters in which optimal processing conditions can be achieved. The aim is to determine boundary values that can be excluded and to ascertain the separating operations via the material cross section.

By way of example the cutting behaviour of pork when using a new cutting system with variable perforated cutting punches was investigated. Pork (leg piece with the membrane skinned) with a piece size of 40 x 40 x 40 mm at a meat temperature of 4 °C was examined during the cutting operation.

The experiments were conducted with the texture analyser TA HDplus using a cutting system with cutting punch and a pressure device for pressing in the meat to be cut (Fig. 1). The following measuring conditions applied:

- Cutting guidance crossways to the fibre direction,
- Speed of the perforated cutting punch a the texture analyser 10 mm/s,
- Contact pressure for pressing the meat into the cutting system 6.0 to 6.5 bar,
- Cutting punch with different perforations,
- Pressure compensation device at the cutter system,
- Free suspension of the cutting punch at the texture analyser,
- No additional knives in the cutting system.

The cross-cutting knife was only used later to determine further parameters by analogy with the circulating knives.

Figure 2 provides an impression of the characteristic data capture for the raw material (meat) in an original cutting system – designed as a Power Tools test device – that was combined with an Instron material testing machine.

Examinations of the raw material

When force is applied, meat as a raw material proves to be an extremely high performing substance characterised by a very non-homogeneous composition. In itself the raw material is very differentiated with its typical properties for the various material types. The natural structure in layers with alternating mechanical firmness properties makes it difficult to describe meat with technical precision. When the meat penetrates into the holes of the perforated disc, the inner cohesion in the meat piece pressing against the disc is increased. The firmness increases constantly. This tensing up operation goes hand in hand with plug formation and is generated by collagen reinforcement (rather like pre-stressed concrete). It is only the severing of the meat plugs formed that relieves the inner tension and the raw material regains its original form. The operation of plug formation can then be initiated again. Different types of material form plugs of different lengths. This is precisely what determines the firmness and the dwelling time on the surface of the perforated disc (Fig. 3).

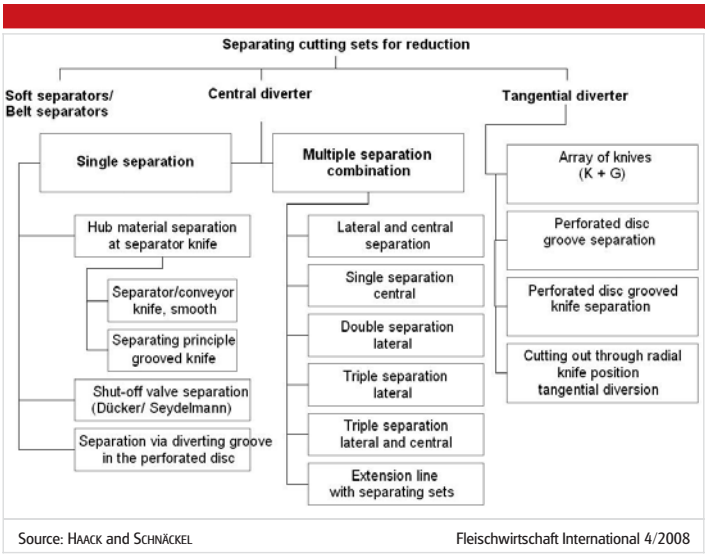


Fig. 4: Classification of the reduction separator sets on the basis of their operating principles

Rupture mechanism of the raw material

The rupture mechanism of the raw material is a function of the firmness resistance, the raw material, the cutting tool combination, the knife position and the quality of the hole pattern of the individual perforated discs. Raw material properties, the condition form of the raw material and the desired degree of reduction are crucial parameters here.

Using the Instron material testing facility, various types of tissue (muscle meat from pigs and cattle, fat, rind and collagenic tissue) were examined as regards the connection between pressure and depth of material penetration into the perforations. The following starting conditions applied: perforated disc with hole diameter d = 3.0 mm, temperature t = +3 °C and piece sizes of the sample material 30 x 30 x 30 mm. The results are shown in the Table.

The lower pressure limits for fresh meat in all quality classes are at p = 3 to 5 bar. In this case deformation of the raw material starts when the material enters the holes of the perforated disc. The upper boundary limits of p = 20 to 25 bar should not be exceeded for pork, while beef allows stresses up to 30 bar. It was found that controlled pressure reduction in the cutting area by opening diversion facilities before the final perforated disc determines the grading and separation qualities. Here central discharge dominates as the natural behaviour of raw material and machine.

With the meat reduction resistance, it is also possible to describe perforated disc qualities (number of holes per unit area) or hole sizes for the separating operation paired with knife geometries. In this part, the results are elements of tool system research.

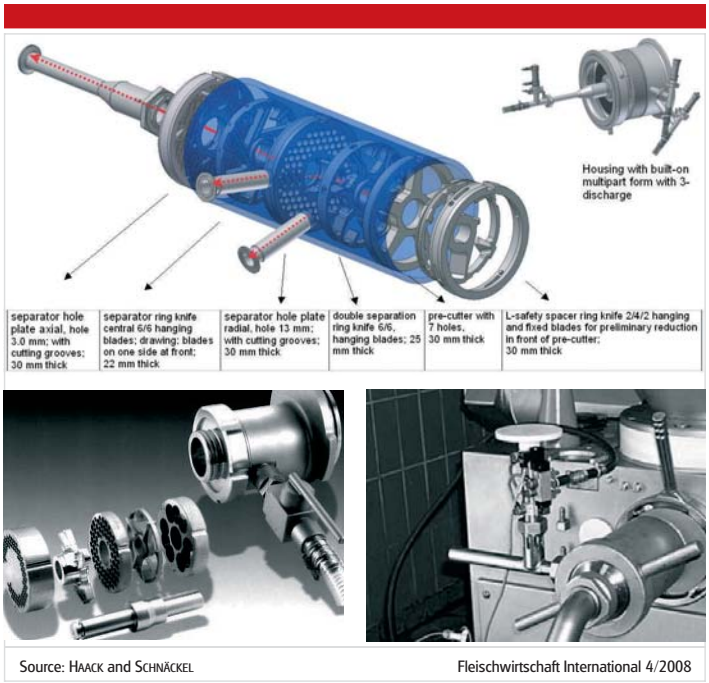
Separating systems

Over the last 30 years many system variants have developed. The reasons for this lie in user requirements, functional and mechanical-engineering prop-

erties and the growing demands made by the meat product industry.

Basically there are always three separating elements that interact – perforated disc, knife and diversion facility with regulation. A distinction is made between two different modes of operation:

- Separation using the overpressure potential of the raw material, generated by the conveyor pressure and a relieving system with pressure reduction. The use of relieving channels creates a material flow division between tough and soft raw materials that is supported by special tool geometries.
- Separation using deliberate pressure reduction and raw material withdrawal from the final perforated disc area in order to provide the soft raw material with an outflow option corresponding to its firmness properties and to remove the force potential enabling the harder material components to infiltrate into the holes of the perforated disc. This results in steerable material qualities through the use of external energy for raw material withdrawal, e.g. conveyor systems with their own drive or vacuum feed-in, or a combination of these.



Source: HAACK and SCHNÄCKEL Fleischwirtschaft International 4/2008

Fig. 5: Representation of different kinds of separator set devices

Separating cutter sets – an overview

The classification of separating systems as shown in Figure 4 can be derived from relevant literature, trade fairs and exhibitions, information from manufacturers and research conducted by a wide variety of manufacturers. For the sake of completeness and in order to compare qualities, belt separators have also been included here.

Belt separators operate on the principle of crushing separation, exploiting the mechanical-firmness properties of the material components following rough reduction of the material. Using this principle, the belt-screen system presses the soft raw materials into a drum and separates them. The tough raw materials such as e.g. fat, collagen tissue and bone residues are scraped from the outside of the drum.

Figure 5 illustrates examples of the general representations.

In principle, in material separation all separating systems use the differences in mechanical firmness within the material system to remove the tough components via pressure-relieving diversion systems. The pressure differential in the deformation properties is deliberately used as a working pressure in order to ensure deformation of the soft material particles to form meat plugs. Pressures at which the tough material components cannot enter the holes must be maintained. The best separating results are obtained in this pressure range from p = 8 to 15 bar.

Further possibilities for improving the separating operation by design of the areas and bars are generated by an analysis of normal perforated discs. The same also applies for the knife geometry.

It is evident from an overview of research by the firm Power Tools that meat raw materials, organic materials, right through to stones can be separated according to this basic principle.

Alongside pure material separation, changes in the analytical-chemical material composition too lead to the desired processing properties. As a consequence raw materials needed for processing to quite specific sausage products are produced with separating systems.

Conclusion

Grinding/mincing machines of conventional design for raw material processing, as well as stuffing/mincing machines and extruder mincing machines are equipped with new tool systems that will substantially shorten the processing chains from the initial raw material right through to the pre-product (meat) in a ready-to-stuff filling material in future. On the basis of new findings about material properties of meat as a raw material with all its different tissue components, qualitative tasks performed by separating operations and segregation of raw material can increasingly be integrated into the holistic treatment process through control and regulating systems.

The second part of this article will describe the modes of operation of perforated disc/knife systems and diversion systems as well as special application technologies in raw material separation and upgrading in detail.

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