The TURBO

A new cooking-extrusion principle.

All research and developmental activity at SCHAAF is continuously aimed at improving process and technology, whereby, product quality and productivity of the machine is always at the forefront of all effort.

The basic valid point to the path of further development of extrusion technology is not determined by technical or even classic and preconceived ideas. It is determined exclusively by the practical demands of the users of our machines and processes, who further have to compete along with their products in a market constantly becoming more complex and varied. All this finally benefits the end user.

Specifically in the last few years the food market has become more complicated, since it is no more sufficient to offer the consumer good and attractive products, but it is also necessary to justify the constantly growing marketing and trading structures.

The demands from the machine and the process are strongly influenced by condition of the end-consumer-market. In this regard it is often required to solve conflicting situations.

- Due to the changing nutritional habits and probably still more important - the selection strategy of large trading chains - there is a strong demand for new, improved and innovative products of outstanding quality and/or originality. Thus one has the demand for maximum possible flexibility of machines and technology used in production, in order to react quickly to new requirements.

- Constantly growing competition and price-wars, on the other side, forces one to achieve the maximum possible efficiency and productivity from the set-up being used.

SCHAAF, ever since its inception, has always been engaged in trying to solve this sometimes seemingly unsolvable conflict between flexibility and productivity. The central aim of the founder of the company, Heinz Schaaf, has always been "achieve maximum result with minimum effort". Though often put to question in the past, Heinz Schaaf's addage possesses today, under the above mentioned conditions, an unlimited relevance than ever before.

SCHAAF short-screw HTUST-extruders have been used successfully since many decades for the production of snacks, cereals and instant products The most often used screw diameter is 92.5 mm with an active processing length of 210 mm including the entry zone. With very different materials and usage conditions the machines are operated with capacities between 150 kg/hr and 300 kg/hr.

The most significant factors for determining the production capacity are:

- The characteristics of the used raw materials/recipes.
- The demands on the texture of the product.
- The forming of the extrudate.
- The technical state of the tools (screw, sleeve, dies).
- The quality of the configuration and operation.

whereby, the listed factors have extremely different meaning/priority for different users.

Even more often than in discussions with customers, SCHAAF has internally discussed in an intensive manner the question: Can we do better justice to the requirements of this branch of industry by offering double-screw systems?

If one follows the many promises and theoretical descriptions in the various publications on extrusion, one would discover actually many reasons favouring the use of the possibilities offered by the double-screw principle. However, if one considers also the numerous practical experiences and data available in the meantime from the use of double-screw systems, then one gets an altogether different picture.

Higher flexibility and production capacity per machine are the most touted advantages of the double-screw systems. However, the successful commercial products in the category of snacks and cereals produced today on the double-screw systems, except for a very few exceptions, can also be produced on the SCHAAF HTUST-extruders in at least the same quality.

During the development and definition of products on twin-screw extruders, in no case, have pre-defined configurations and parameters been determined and then transferred to production conditions, as suggested in manypromotional catalogues. Often lengthy and to a large extent empirical experiments, have finally led to success. In most cases the change of products and recipes have been found to be much more difficult as compared to even the simple single-screw machines.

Latest during the calculation of operating costs of double-screw machines it becomes clear, that even the significantly higher output cannot compensate for the other significant disadvantages:

- The setting into operation of these machines is complicated and lengthy. A lot of waste is produced. Even automatic start-programmes cannot overcome the limits as determined by physical laws (mass inertia, longer heating and cooling times, reaction inertia etc. to change in parameters).
- Efforts required for product change and cleaning are quite high.
- High costs for wear parts, maintenance and repair.
- High initial capital investment.
- Lengthy stop-times and higher cleaning efforts, in case of unscheduled machine stoppage.
- In practice sometimes higher energy consumption.

Today, SCHAAF-extruders take up a special position in many areas of food-extrusion. Our constant and intensive efforts have been to widen the process-technical possibilities of HTUST-extrusion to make the operation of machines simpler and more dependable with the permanent aim of minimizing operational costs. These are the reasons why the SCHAAF HTUST-extruder cannot be categorized in the usual manner while carrying out technical and technological comparisons between single and double-screw extrusion systems.

> **HTST** is a term usually used by experts in the field of cooking extrusion and stands for "**H**igh **T**emperature **S**hort **T**ime" for conventional single-screw extruders and in the case of double-screw extruders, this implies usually a residence time of under 60 seconds but not less than 20 seconds. This short time process is unarguably viewed as an advantage when compared to the conventional cooking process.

HTUST is a term, which SCHAAF had to introduce in connection with cooking-extrusion in order to achieve a clear demarcation from the HTST process. Whereby, **HTUST** stands for "**H**igh **T**emperature **U**ltra **S**hort **T**ime" and defines residence times of 2 to approx. 8 seconds.

For residence times under 1 second, where the rules of thermodynamics, specially the fascinating material - water - still hold many surprises and for the realization of which a lot of intensive work is already being carried out, one would have to invent another term to add to the already highly inflated jungle of terms.

Schaaf Research and development is consequently aimed at achieving **minimum possible residence times** in the extruder.

In many other areas of food-technology (e.g. in milk-processing) it has been long recognized, that extremely short-time processes bring with them significant advantages. There, systems working with highest pressures and ultra-sonic speeds are considered amongst the most advanced. However, in the field of extrusion there are still many ideologues amongst the "experts", who do not wish to accept, that processes, which even today last in the region of many minutes, can be accomplished with numerous advantages in a few seconds or even in fractions of a second. A further, though not necessarily less effective reason prevents the short time technology in cooking extrusion to be viewed with its deserving importance. Short time systems naturally require extremely small process part volumes, e.g. screw, sleeve and die system of the cooker extruder must be very small in relation to the product throughput. Thus, it is not possible to divide the complicated process parts of the cooker extrusion into neat separate zones and processing parts as it is usual in the case of long and double-screw extruders. One must view and analyse the process in totality, which is naturally much more difficult and complicated as compared to understanding sections of a process. Understandably, it is also not possible to carry out extensive pressure, temperature and flow measurements on these extremely small processing, kneading and die parts. The reason being, that while on one hand such measurements have hardly any possibility of expressing anything about the process, on the other hand suitable sensors for measurement are not available.

The condition that heating zones, cooling zones, steam ports and innumerable temperature and pressure sensors are missing in a short time system, due to obvious reasons, is not liked by such experts who equate scientific work exclusively with the presentation of (often insufficient) measurement data with extensive analysis of the final product. Hence, the linguistically blown-up, though however, formally correct publications, often fail to address the question "why?" and have unfortunately a correspondingly low information content.

That a technology like the short-time system in the area of cooking extrusion, which is so rich in practical results, is virtually ignored due to the above described reasons is a regrettable fact. Even then, double-screw extruders must thank their extraordinary attention and proliferation, especially in the research institutes, to an unchallenged view which claims the advantage of these extruders being fitted with many switches, valves, zones, elements and sensors!

Today, SCHAAF presents what is expected to be a revolutionary new development in cooking extrusion, for which it was not possible to coin a better name than "**TURBO-EXTRUSION**", keeping in view its major characteristics. The above introduction should serve to help those expecting a complicated apparatus with blinking instruments and sophisticated electronics to form a better picture than usual.

No, the TURBO is a very simple unit based on a very simple process possessing, however, all indications of becoming the basis for a new extrusion principle. This sounds very impressive and having worked intensively for many months strongly questioning this impression, till now we have only been further encouraged and convinced to talk about this as a new cooking extrusion principle.

Till now it was usual to divide pumps in so-called friction pumps and positive displacement pumps. First a few examples:

Friction pumps	:	Centrifugal pump Single-screw extruder Double-screw extruder (co-rotating)
Positive displacement pumps	:	Rotary gear type pump Tube pump Eccentric screw pump Double-screw extruder (counter rotating) Piston pump Rotating piston pump

While friction pumps use the viscous characteristics, adhesion and friction to transport a liquid against pressure, positive displacement pumps form more or less closed chambers to transport the medium. Both pump principles have their advantages and disadvantages corresponding to their specific areas of application.

It has been shown in the meantime that counter rotating double-screw extruders are unsuitable for cooking extrusion, because besides the pure transportation of material other extensive demands are also put on the process, for e.g. mixing, kneading, heating and homogenizing. The counter rotating double-screw extruders could not prove themselves, though these, as in the case of gear pumps, had the advantage of being able to work nearly independent of die pressure and build up theoretically infinitely high pressure, independent of the viscosity of the medium. The introduction of energy through shearing and through kneading has been proved as necessary for cooking extrusion, specially in connection with the demand to obtain a maximum possible uniform processing of the mass. This demand for a uniform energy introduction could be met insufficiently, specially in long single-screw extruders as compared to co-rotating double-screw extruders, especially when the latter were fitted with specifically formed kneading elements.

Friction pumps are generally dependent on the adhesion and the friction conditions of the transported material between the rotating and static processing parts and thereby on the viscosity of the medium. As high is the friction of the material to the static part of the pump or as low is the friction to the rotating part, as intensive is the transporting effect.

As deeper the flights of the screw as high is its transport flow, though the pressure build-up is lower and there is insufficient cross-flow of material across the screw flights causing a non-uniform thermal handling of the material. People have tried to optimise the friction relation in the friction pumps in various ways. Hence, in single-screw extruders the cylinder is often roughened or profiled, in double-screw extruders the more or less intermeshing screws act as friction enhancers.

Also, here one must always account for non-uniform material treatment at the narrow shear gaps, which one tries to smoothen out with the help of kneading elements or perforated plates. The distinguishing characteristics of the short-time single-screw extruders is, that they mostly have a screw shaped profile on the extruder cylinder. This has, on the first impression, a similar friction enhancing effect as for e.g. longitudinal groves. Additionally, this profile also causes effective transport, e.g. in case the material adhers strongly to the screw and slips on the cylinder, it would still be transported. In this way, short-screw extruders with screw on the screw and inside the cylinder are capable of building-up very high pressures with very small processing elements.

The basic principle of the SCHAAF HTUST-extruder was always to be able to build-up maximum possible pressure with the screw, in order to then use this high pressure potential in free configurable static flow elements (pressure and perforated plates) in order to mix, knead and homogenize, to finally obtain a dough providing after forming on the die an uniformly texturized final product.

It is indicative, especially from the publicized research results with co-rotating double-screw extruders proving impressively, that for a final product of good quality a maximum possible portion of mechanical energy input (because of its uniformity and positive influence on the rheology of the dough) is of an advantage. The tempering via the cylinder segments has only controlling and regulating influence. Further, all earlier promises that one can produce any desired temperature profile during the process in a double-screw extruder simply by heating or cooling the cylinder segment has been finally disproved.

In the SCHAAF HTUST-machines the heat required is provided exclusively through mechanical energy input. The quantity of heat is controllable in an excellent manner by modulating the relationship between screw speed and mass-flow.

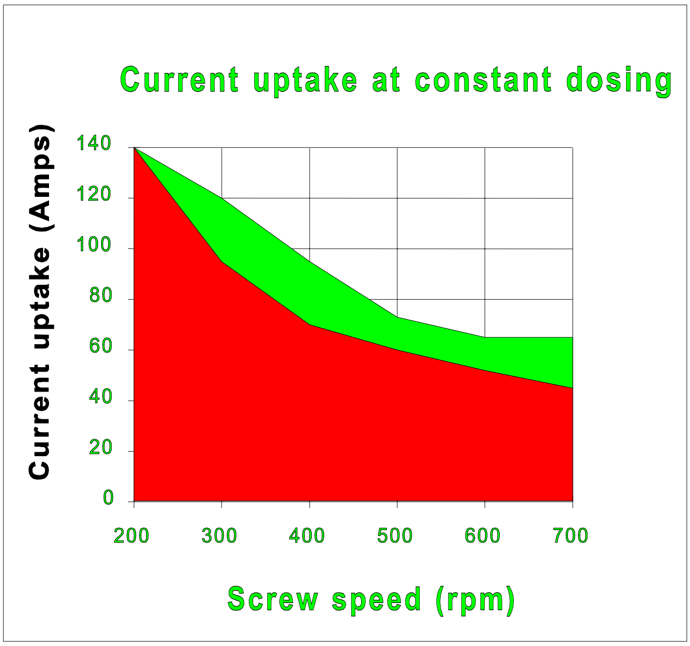


Figure 1: without TURBO

Figure 1 shows the relation between the set screw speed and the motor current uptake representing the screw moment at a constant dosing of 200 kg/hr.

Based on the relationship:

Power = rotating moment x rotation speed

As long as the power input into the material is constant, doubling of the screw speed should lead to a halving of the screw torque (as per the curve in of the dark shaded area). However, the measured values are as per the curve of the light shaded area.
From the measured valuesone can easily calculate the specific energy per kg dough dissipated in the extruder. After compensating for the slightly higher losses at higher screw speeds one

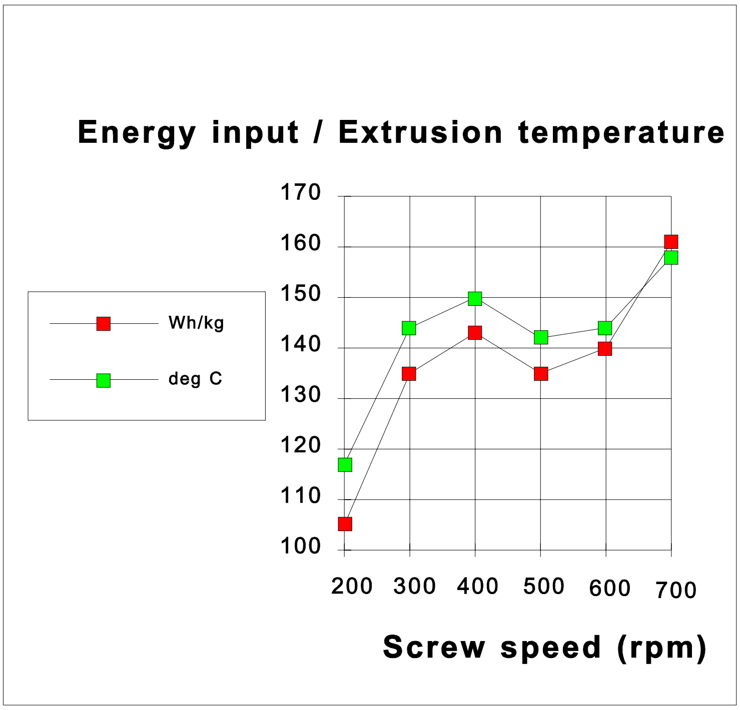


Figure 2: without TURBO

can calcul ate, assuming a specific heat of the dough of approx. 3.6 KJ/kgK and exit temperature of 20 deg C, the resulting dough temperatures, which are shown in Figure 2.

It becomes clear that exclusively by changing the screw speed at constant dosing and without changing the product moisture, the extrusion temperature can be set in the region of approx. 120 deg - 160 deg C and that with an extremely short reaction time of only approx. 4 seconds. Remarkable is the unique form of both the curves in Figure 2. In fact in practice this effect often causes problems and surprises. When for example a specified product of 140 deg C can be produced at either a low speed of 280 RPM and higher torque (motor current 125 Amps) or at high screw speed (500 RPM) but at low torque (motor current 72 Amps), at settings in between the desirable product cannot be obtained Here, as shown by numerous experiments, an interaction between dominantly screw transport to dominantly transport over the profile of the cylinder takes place. This effect is difficult to determine in advance and makes reproducible capacity optimisation often very difficult.

This effect can often be corrected and weeken d only with the result of another pressure configuration. Often these mixed versions of screw and sleeve transport extend themselves even up to the die and different temperature and flow speeds can lead to non-uniform product formation.

Generally, however, the extrusion temperature in a SCHAAF HTUST-extruder can be adjusted over a wide range even without a change of throughput and change of extrusion moisture.

As described above, friction pumps are dependent on the adhesion or friction characteristics of processed raw material. This is valid for all friction pumps thoug h it expresses itself in an amplified form in machines with very short processing parts.

Figure 3: without TURBO

Figure 3 shows the behaviour of torque on addition of approx. 3 % fat to a mixture of cereals at point of time (1). As expected, the fat builds slippage influencing strongly the friction in the systems and reducing the viscosity of the dough.

At constant screw speed and constant feeding, this implies a significant deficit in energy input, whereby a temperature profile (curve in Figure 3) is created.
By increasing the screw speed this energy deficit can be balanced out under certain conditions, though often usually one must change the pressure relations. At fat contents of higher than 5 % longer processing lengths are unavoidable.

Similarly, even though not as significant, is the behaviour of the extruder on addition of sugar. In order to remove any misunderstanding SCHAAF HTUST- extruders can be operated with pure crystal sugar, resulting in a partly liquefied sugar mass coming out of the machine, which however is not an expanded crispy snack or cereal product.

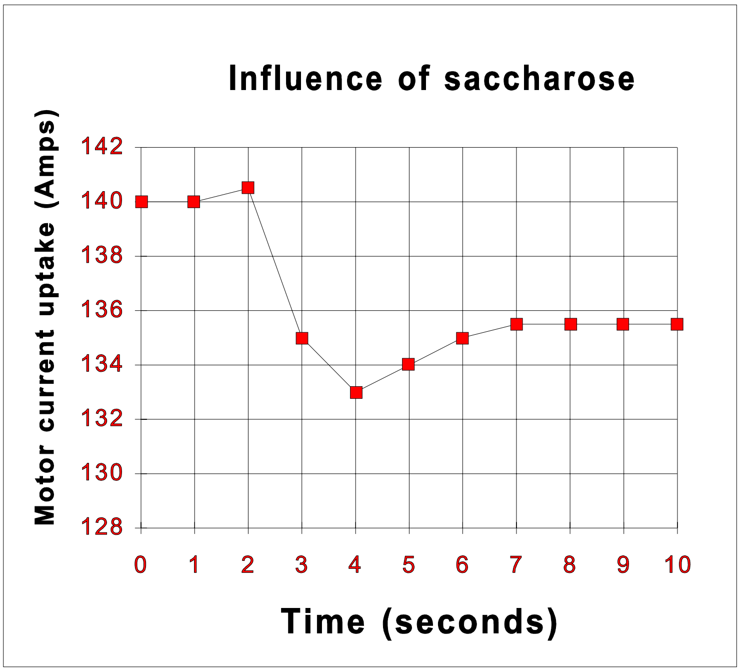


Figure 4: without TURBO

In Figure 4: 10 % sugar is added to a cereal mixture at point of time (1). The fall in temperature here is though not so remarkable as with the addition of fat, but still quite marked.

What then is the TURBO-EXTRUSION and what does it cause?

The "TURBO" is a special friction pump, which can operate either in combination with a screw machine or independently as a cooker extruder.

The principle of the TURBO, as with so many other devices, is very old and known to every housewife. The good old press for apple puree shows the functioning of a special friction pump most demonstratively.

Further, another known use of this principle is in the animal feed pellet press mostly rollers are used in. It is known about this press, that it is in a position to develop very high pressure. In the following sections we would call such units using this pump principle "scraper pumps". These should consist of at least one perforated plate and an element scraping or rolling very close to it, which is in a position to create reducing spaces in relation to the perforated plate and in this manner transport material through the perforated plate.

It is well known since long, that screw ends formed in the shape of a scraper have a positive effect on the extrusion process. While such screw ends have always been common in SCHAAF-extruders, they have been also used more often in the last few years by other extruder manufacturers.

When such scraper formed screw ends scrape over a perforated plate, they are in a position to build-up very high pressures though at a very low material flow. The formation of such a scraper pump on the end of the screw is geometrically bound to the screw diameter, that is, the scraper surface cannot be larger than the screw cross section. When in exceptional cases, the scraper head is larger than the screw diameter, the scraper surface is reduced by the core diameter of the screw. Owing to these construction related conditions, the scraper stage used till now, which were coupled to the screw speed, were in a position to transport only small volumes in relation to the screw transport. Hence the scraper in combination with a screw, under normal operating conditions, was almost meaningless, e.g. "overrun" by the material transported by the screw. The capabilities of this pump principle, therefore remained limited to such extreme situations, in which the extruder screw was no more in a position to carry out sufficient transport. For example due to a stoppage of the die and associated increase of pressure or after a power failure when the material in the die or in the pressure elements hardened itself and caused high pressure during re-starting.

Let us now observe the function of a pellet press also containing the principle of the scraper pump. The aim in this case is to compress various types of solids into composite granulates in order to improve their handling, specific volume and flow properties. The experts in this area have extensive know-how to design the process in such a manner that a product with the desirable characteristics is formed.

The forces created during pressing of the often high fibre containing raw materials are very high. RPM and feeding rates must be selected in such a manner so that no overload or damages occur. The heat generated during pressing must be controlled because the temperature has, among other factors, a strong influence on the density of the produced pellets. The raw materials have before, during and after the pressing process primarily solid character.

Under no circumstance during this processing the situation must occur, that the free movement of the pressed materials is disturbed for example due to the blockage of the product exit. When this occurs non-permissible high pressures are created and the plant must be switched off. Also in processes, where the pressing stage is carried out more than once, for example in multi-stage pressing, it must be ensured that the second press unit has a higher throughput to prevent overflow, that is the blocking of the press.

The above observations make clear the differences in application of the scraper pump principle to cooking extrusion.

- The aim of the cooking extrusion is always to obtain a plasticized (also when it is desired under certain conditions to have solids like nut pieces or seeds in the mass), primarily fluid material.

- At the exit of the scraper pump, a pressure must always be maintained, which can be directly at the die or even another scraper pump, in order to further increase the usable pressure.

What is the advantage of the use of the scraper pump principle in cooking extrusion?

If one uses a suitably designed and dimensioned scraper pump, in this case being called the TURBO, between the screw and the die in a food extruder (consider as the SCHAAF HTUST-extruder with a screw diameter of 92.5 mm and effective screw length of 210 mm), which is driven in the simplest case by the screw shaft, then one can observe numerous, though also observed separately, very different but very effective and important effects.

Let us first observe the most important effect, **the capacity**:

Example 1 Peanut flips from maize

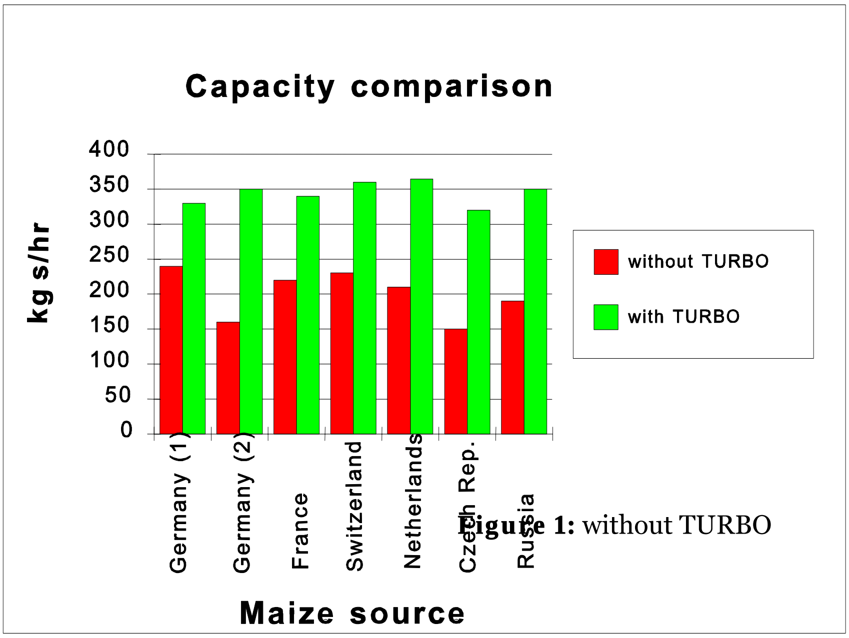


Figure 5

Peanut flips were made using various types of maize from Germany, France, Netherlands, Switzerland, Czech Republic and Russia.

An effort was made to achieve the maximum capacity with the various raw materials while maintaining good product quality. In the tests well worn out tools were used (screw 91.7 mm, sleeve - 93.3 mm). In the trials without TURBO the capacity limits were reached either by non-uniform shape (short and long flips) or by non-uniform texture (inside/outside). The capacity limits in the trials using the TURBO were achieved either by the change in the diameter of the flips or by exceeding the capacity limits of the dosing unit or the extruder motor. The products using TURBO were still of uniform texture and length even at maximum capacity.

A further example of capacity increase for various products:

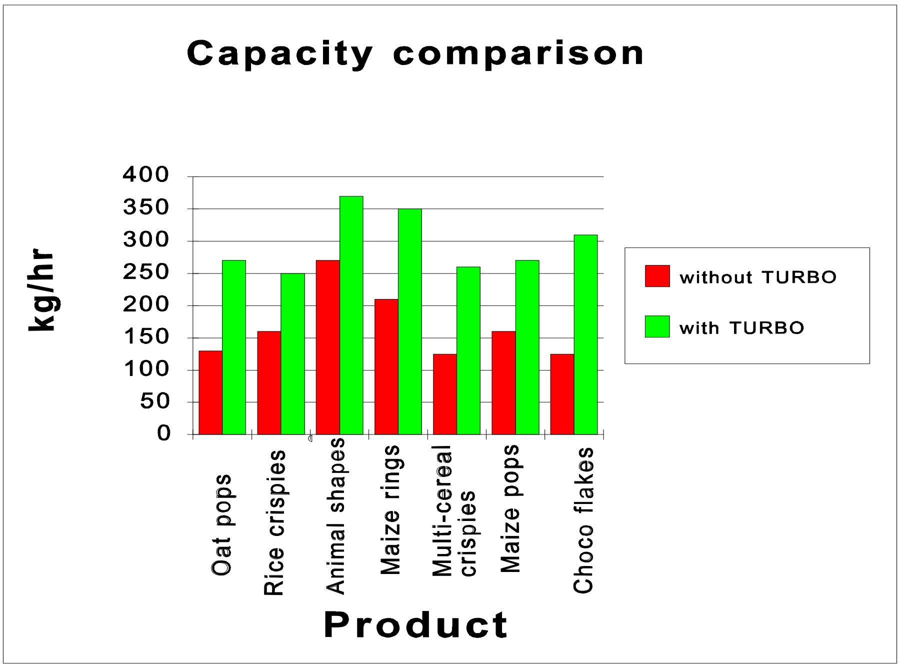


Figure 6

Before we try to establish reasons for the surprisingly positive behaviour of the TURBO, here is some information about the configuration of the used units in most of the above capacity trials.

A 4-flight screw of known construction and with standard screw profile was extended at the leading end by an adaptor. This adaptor was made to pass through the first pressure plate which was located, as usual, in front of the scraper formed surface at the screw's leading end. The adaptor was used to mount the scraper element, which scraped over a second pressure plate and thus formed the second scraper stage. The usual die plates closed the system. Both the pressure plates formed a scraper chamber in which the scraper element was rotated. The scraper element with a circular cross section was only slightly thinner than the scraper chamber formed by the two pressure plates. With the help of the pressure plate's thickness and the number and the size of the holes, the pressure relations could be specifically influenced.

The type of the conical expansion of the perforations to the scraper element influences the addition/friction of the mass on the pressure plate surface and thereby their transport characteristics.

If one carries out trials in which a scraper element, as described above, is allowed to rotate in a space formed by the two perforated plates being significantly wider than the space in the above example, or the scraper element is not enclosed within close tolerance of the back and front pressure plates and the die, then one finds an improvement in homogenisation.

However, there is still no comparable increase in capacity or a remarkable linearization and reproducibility of the process behaviour:

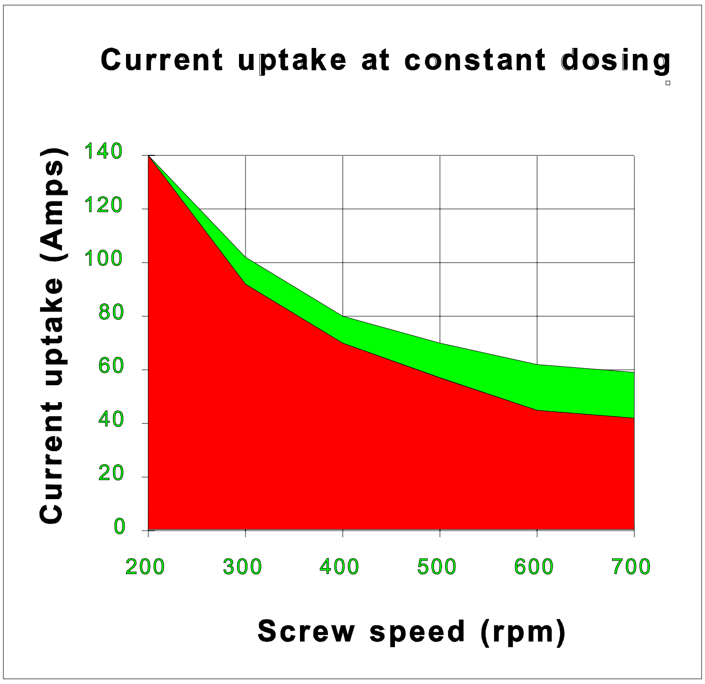


Figure 7 with TURBO

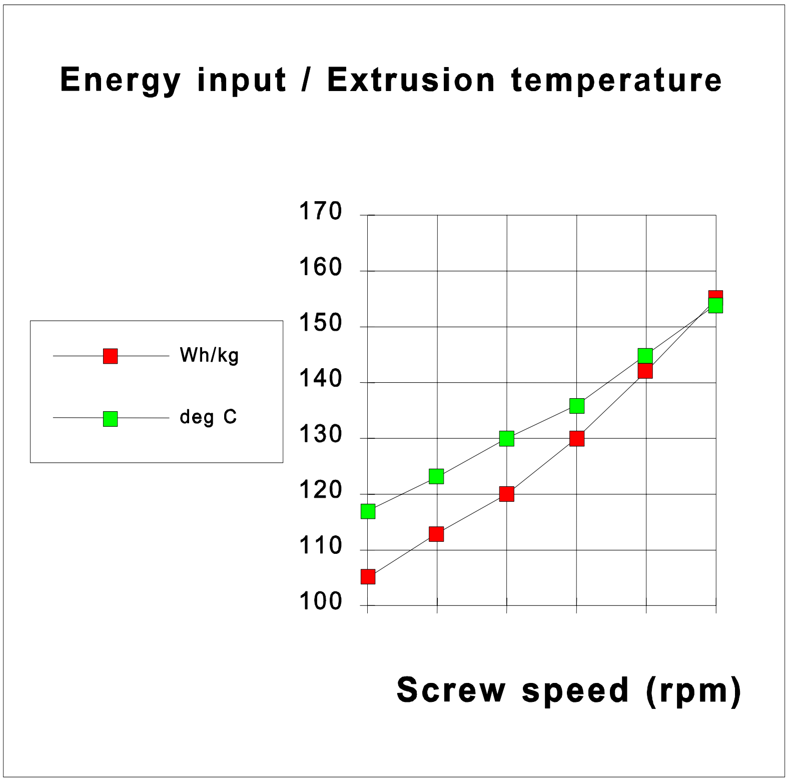


Figure 8: without TURBO

If one compares specially Figure 8 with Figure 2, then it becomes clear how essentially the TURBO linearises the process behaviour, thereby making it calculable and improving the controllability of the machine. This has a direct influence on the product quality and its reliable reproduction in daily routine.

If we now look at the influence of fat and sugar while using the TURBO we would discover a further reason for the significant capacity increase even by using varying raw material compositions.

The trial conditions are identical with the trials not using the TURBO corresponding to Figure 3 and Figure 4.

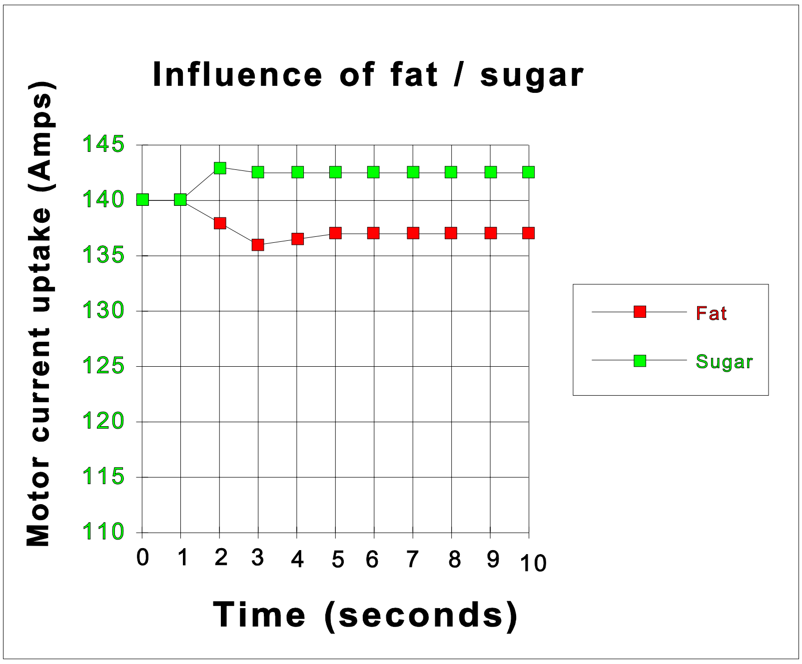


Figure 9

The addition of 3 % fat shows only a small effect in the energy input and thereby on the extrusion temperature. The addition of 10 % sugar leads to surprisingly and even higher energy input. The trials have shown that fat contents up to 10 % show satisfactory expansion results, without extension of processing parts, whereas sugar contents of up to 40 % in cereal mixtures still give crispy cereals.

In multistage TURBO designs, the limits on the sugar or fat content is set no more by the transport capabilities or the friction but much more by the dough elasticity limiting the expansion.

In spite of wide experience and know-how in the die production in SCHAAF it has been, until now, only partially possible to have numerous complex die openings on one die plate without causing serious problems in product forming. The laminar flow conditions from the screw to the die and even very small temperature differences cause
different flow in the outer and in the inner areas of the die opening and thereby non-uniform product forming.

Often consumers express the wish to have different types of shapes on the same die system to produce a mixture of sophisticated shapes and forms using only one extruder.

The complicated stacked flow conditions cannot be solved even by complex pressure and flow elements, which is why it has not been possible till now to produce multiple forms simultaneously in a good shape quality. Even, when it should be possible to achieve satisfactory results under very specific operating conditions and a defined production capacity, just a small variation in the throughput or in raw material behaviour would be enough to destroy the symmetry of the shapes.

Tests were carried out by using 4 exit ring die. Even by changing throughputs, uniformly thick rings were obtained till up to a cutting length of 30 mm. The results show, on one hand, how uniform and homogeneous is the energy distribution in the dough and, on the other hand, what influence the TURBO has in achieving a stable flow condition in the die.

In all the products produced using the TURBO one observes very homogeneous texture e.g. uniform porosity, which was till now, especially at higher capacities, not possible to achieve.

How can we explain such fantastic results? What physical laws are involved in the effectiveness of the TURBO, even in a very elementary and simple form?

In the last few months many comparison trials were carried out always comparing the new processing principle with the one commonly in use. While it was still easily explainable why the extremely inclined scraper elements with maximum transporting efficiency had a corresponding influence on the throughput, explanation had to be found also why the simple circular form influences the process in such a significant manner. If one operates a conventional 4-flight screw with a die system demanding high pressure, then one reaches the capacity limits very soon. Even while using very small tool tolerances (screw 92.3 mm, sleeve 92.9 mm), the transport capacity of the screw in the reference trial was reached already at a screw moment, measured as 90 Amp motor current, at a throughput capacity of approx. 150 kg/hr at a screw speed of 450 RPM.

If one carries out the same trial with the above described TURBO using the same die, raw material and same RPM as in the above referenced trial, then one reaches the current limit of the main drive at 145 Amps at a capacity of 232 kg/hr. The higher throughput of 232 kgs/hr must create a higher pressure than at a throughput of 150 kg/hr.

Even then this higher pressure can be seemingly overcome, without reaching the transport limit of the system and that too at a screw diameter of the TURBO screw of 91.5 mm and a sleeve dimension of 93.3 mm.

Even more impressive are the series of trials, with a screw which had a diameter of 91.2 mm after approx. 2000 production hours and therefore was no longer usable for production under usual conditions. This screw was further "artificially" worn down to exactly 90.0 mm fitted with a TURBO and then used together with the sleeve of 93.3mm. Consequently, there was a gap of approx. 1.6 mm between the screw and the sleeve, a condition where, without the TURBO it would be impossible to carry out the desired production in an economic manner. With this configuration it was possible to achieve, using a flips die with 24 bores each of 2.8 mm diameter, an output of 300 kg/hr while maintaining very good product quality. From the foregoing one can infer that the tolerances between the screw and the sleeve, which had a major importance for the quality and output of the product in the past, had been reduced to negligible significance by the TURBO. Thus, TURBO further opens up whole new areas of further optimisation with the possibility of modifying screw design among other changes.

The key to the transport characteristics of the TURBO in the simple circular shape of its scraper elements, even an expert would hardly expect any pumping action from, is apparently the component - water. Many false directions taken by the process engineers and "experts" in the past, moving from the area of plastic extrusion to bio-polymers, could have been avoided if they had realised that water is a really interesting material. This was probably so because unlike in food extrusion water does not play a role in plastic extrusion.

As commonly known, water boils at 100 deg C. This boiling point is dependent on pressure. Cooking extrusion is unimaginable without water. Even when it is present in only small quantities, water dominates the thermodynamics of the cooking extrusion process. Water is responsible for a major part of the total energy balance by influencing the specific heat of the raw materials significantly and thereby the net amount of energy which would be required for heating the dough. Water is the carrier for the most important energy transfer and distribution process in the extruder and finally it is water, which by its violent vaporization at the die causes the product to expand thus making it a consumable food. Water is in the position to spontaneously swing the dough to different temperatures by either vaporizing or condensing, depending upon the prevailing pressure.

When the scraper element rotates in the scraper chamber and this is designed suitably, then one needs no special faculties to imagine that in front of the scraper element in the direction of the rotation there is higher pressure and behind the scraper element there is a lower pressure. Now, when the dough at a temperature of say 140 deg C is in the zone of low pressure of say 3.5 bars, the water evaporates and the dough expands in volume.
In this condition, a mixture of steam bubbles and fluids, the dough has a significantly higher viscosity as compared to the dough in a pure fluid state. Hence, the higher dough viscosity provides a greater resistance to the approaching scraper. This leads to the creation of pressure, which condenses the water and the latent heat released during condensation, warms up the dough again and the process is repeated.

The dough on the high pressure side of the scraper element has a lower viscosity as compared to that on the low pressure side. The dough on the high pressure side is pressed through the perforated plate from where it naturally attempts to flow back to the low pressure side of the scraper element. Since the dough, during its passage through the perforated plate, has picked up a certain amount of heat, it is hot and tries naturally immediately to again flow through the perforated plate into the zone of low pressure behind the scraper element, as long as there is no colder material there with higher viscosity. Since this material is at a lower temperature while still being in the process of expansion, the dough has no other way out but in direction of the die.

This constant alternation between very high pressure and low pressure below the boiling point caused by the scraper element, causes an enormous homogenising effect in the dough. It also causes an extremely effective energy exchange, thereby preventing partial overheating and forms the most significant basis for the surprisingly good pumping behaviour of the scraper stage. By the constantly occurring expansion and compression, the heat transfer within the system is significantly improved. Consequently, the flow properties of the bio-polymer dough is positively influenced. By changing the screw speed at constant throughputs, the number of energy dissipating expansion and compression processes per dough unit is increased and translated into a nearly linear increase in temperature.

The positive effect of water in the above described manner can be very easily proved. By creating such a high die pressure, that the difference in pressure caused by the scraper element does not allow a vaporisation of water on the low pressure side, one finds that a major part of the positive effect disappears.

From the before mentioned example, the simple two stage design of the TURBO could already prove many surprising advantages. The research and development in the area of bio-polymer cooking extrusion is, with quite certainty, enriched by another milestone. The further development of the technology leaves one eagerly expectant of still many surprising discoveries and processes. We are now at the beginning of seemingly fascinating possibilities, many of which have been already proved in practice in the short time since the invention was made.

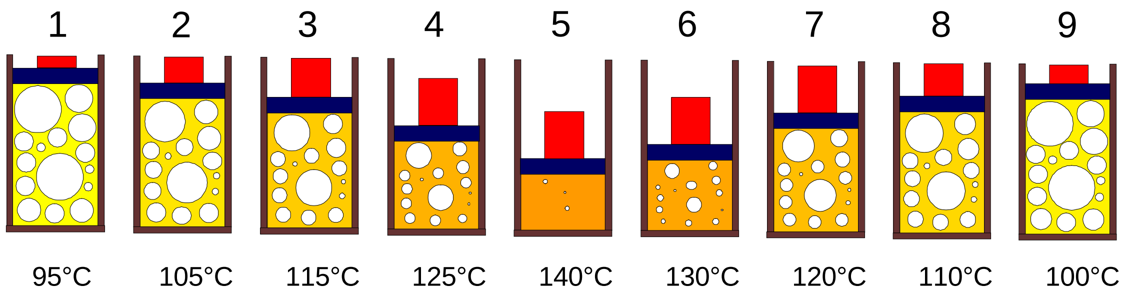
Once again, a summary of the already proven advantages of the TURBO technique discovered today:

- Up to 100 % higher capacity attainment.
- Better product quality due to uniform flow and texture.
- Excellent process control possibilities.
- Very easy handling of parts.
- Economical tools.
- Significant reduction in wear parts cost.
- Insensitivity to variation in raw materials.
- Significantly higher flexibility in recipe compositions.
- Energy saving in systems using DC drives.
- Flexibility in the materials used for the wear parts.

All designs till now refer to the HTUST-extrusion, e.g. the production of direct-expanded products. For cooker extruders and formers for the production of pellets, there are still no available extensive trial results. However, the indications are that with help of the TURBO technique it is possible, even in the case of pellet production, to follow totally new routes and control much more, specifically the creation of certain dough characteristics. The shear speed distribution is very important in the extrusion of pellet products.
Here one can expect significant improvements in comparison to conventional extruders. It is also foreseeable that higher pressure, e.g. in formers with low energy input, is achieved through scraper extruders. Finally, all indications show that the scraper extruder may become the ideal machine for cold pressed products.

Following illustration (in a very simplified form) should demonstrate clearly the relationship between temperature and pressure within the dough during compression and decompression in front of and behind the wing of the scraper unit.

One has to imagine a cylinder in which varying pressure conditions are created with the help of a piston:



In the extruder the screw speed determines the number of the compression and decompression cycles to which the dough is subjected during the passage through the processing zone and hence the dough temperature.
During each compression process, energy is introduced in the dough. As often the dough is compressed and again decompressed, as high a temperature does it tend to reach.

Every portion of the dough mass, irrespective of the temperature that it initially rises to, is forced to the same lower temperature which corresponds to the prevailing pressure during the following decompression process (as a result of removal of the latent heat). This makes it nearly impossible that overheating in any portion of the dough mass takes place for a period of time greater than the period of one cycle of compression and decompression.