

Dry Baby-Cereals manufactured using cooking extrusion process.

A few basic aspects and interrelationships

For many years now, cooking extrusion technology is being used for production of numerous Instant cereal products including cereals for feeding small children.

The process of cooking extrusion has to thereby compete with the conventional processes of manufacturing such products, specially roller drying, and hence often the advantages and disadvantages of both these technologies are subjects of discussion. The problem of this discussion lies in the basic fact, that various quality criteria are given different priorities, thus making a direct comparison of the two technologies extremely difficult.

There is absolutely no doubt about the economic advantages of the cooking extrusion process, which is a consequence of :

- Significantly lower energy requirement
- Lower total operational costs
- Lower investment costs

Additionally, besides everything else, the microbiological safety aspect can be a decisive factor for choosing the extrusion technology over the conventional process.

On the other hand, the cooking extrusion process is certainly different from the roller drying process, which does reflect in the properties of the final product because of primary physical laws and conditions.

In the roller drying process, a thin slurry, whose water content can be up to 65%, is applied in a thin film over heated rollers. The starch thereby quickly gelatinises in a condition of excess moisture – and this is extremely important ! – without the application of any shearing forces. As the water contained in the film evaporates, this causes formation of bubbles in the film (similar to the expansion process of waffles on a waffle plate) and finally to flaking.

On the opposite side of the roller drum, the dried film is scraped off and removed from the roller and then reduced to the desired flake size using suitable grinding equipment.

The significant aspects of this process are:

- The high water content causes an optimum gelatinisation
- The starch chains remain virtually undamaged, as there are no shear forces. Thereby a higher viscosity is achieved when the material is remixed with water.
- Due to the expansion caused by the evaporating water and the consequent small spaces formed during the loss of water, the material is formed into a porous structure with very small bubbles. Hereby capillary forces become effective in contact with water, which accelerate the absorption of water and the rehydration process.
- The very fine bubbles and channels in the dried film cause a strong diffraction of light and thereby give an optical impression of a lighter colour to the product. Thus even with relatively darker raw-materials it is possible to obtain flakes which appear nearly white in colour.

All the above described advantages are based on the higher water content of the slurry. However to evaporate these larger quantities of water higher amounts of energy are required, which is the primary factor, based in the actual process requirement, for the higher cost of production.

With the help of a cooker extruder it is possible to process the raw-materials at very low moisture contents. It is possible to plastify the raw-materials even at moisture levels below 10% and deal with the extremely high viscosity and forces which come into play as a consequence.

However, as high these viscosities are, as high are the forces which come into play and this basically leads to a change in the structure of starches in the material.

All the forces input into the dough of starches, lead to a reduction in the length of the starch chains and thereby a reduction of the maximum achievable viscosity of the instant material produced. The forces required for breaking starch chains in gelatinised condition are relatively so small, that even in masses with 30% dry substance, these forces become effective at the prevailing viscosity and lead to a break-up of the starch chains. All efforts to extrude in a „delicate“ manner, ie. by reducing the shear intensity, by reducing the shear speed and processing for longer periods, have hence failed for the above reason.

Each Wh of mechanical energy input in the dough leads to a reduction in the viscosity due to change in the starch chains. It has been proved, that there is no change if eg. 100 Wh/kg of energy is dissipated in a dough mass in a time of 10 minutes or 10 seconds. This appears to be even independent of the viscosity, in doughs with a dry substance range of 30% to 70%.

Whenever we have spoken of energy input till now, we have meant the SME or the Specific Mechanical Energy input. This should not be confused with the energy input through heat transfer, which naturally does not lead to the break-down of the starch chains.

If it would be possible to bring in a major portion of the energy uniformly through heat transfer into the dough, it would be possible to significantly reduce the starch break-down. Unfortunately in practice, this has been found to be always combined with significant and critical disadvantages. In order to convey heat to the dough through heat transfer, it is necessary to have a temperature difference at the heat transfer interface between the heat source and the dough. Overheating can only be avoided by continuous kneading and mixing of the mass ie. by continuously exchanging the dough mass in contact with the heat exchange surface. The same is valid when one tries to pump the dough through a generously dimensioned plate heat exchanger or tube bundles. In all cases it is necessary to use mechanical energy at a level, which exceeds the total energy requirement and whereby it becomes apparent, that success cannot be achieved in this manner.

The lower the water content of the raw-material during processing, the lesser the energy costs for the process. On the other hand presence of water is necessary to achieve the desired gelatinisation of the starch.

If one tries to plastify a starch dough at a water level of eg. 12% at a temperature of 140 deg C for 8 seconds, then one achieves complete conversion, ie there is no more native starch present in the dough. However, as per definition this is not gelatinisation as to a great extent the starch is converted to dextrines.

In order to improve the rehydration property of the starch itself one has to process it at higher moisture levels. One achieves good gelatinisation as per definition, under conditions which have been tested and proven extensively, at a moisture level higher than approx. 35%.

At these moisture levels one gets gelatinised material with a very good grade of gelatinisation and relatively lower starch break-down. Such extruded gelatinised material is however hardly expanded, requires additional drying after the extrusion and also rehydrates very slowly in water. The precondition for quick absorption of water is, as mentioned earlier, a very porous structure and a correspondingly large surface area of the product pieces.

If one tries to achieve a larger surface area for quick absorption of water by grinding the extruded gelatinised material, then one discovers, that the viscosity of the material mixed

with water falls drastically and such fine powders demonstrate poor binding properties. Above all they tend to form lumps when brought in contact with water. Trials using other processing steps to improve the instant characteristics eg. by agglomeration, have not shown any significantly better results.

If one wants to get a good product using extrusion, then one has to expand the extrudate as highly as possible. One can get an optically good product in terms of colour only with the help of a highly porous product, which also rehydrates and binds with water quickly.

One can get expansion only at correspondingly higher temperatures. Since water evaporates at 100 deg C under atmospheric pressure, it is possible to get expansion of the dough when emerging from the die, only if its temperature is above 100 deg C.

As high the moisture level in the dough as soft and elastic the expanded dough emerging from the die. However since the water vapour contained in the bubbles of the expanding dough condense again immediately after the expansion process, the outside atmospheric pressure pushes the bubbles back again. This leads to the shrinking of extrudate.

How strongly this process effects the product can be understood, when one eg. tries to boil some water in a tin-can. If one takes the can off the heat and immediately closes it air-tight with a lid and cools it down, then the atmospheric pressure outside can implode the can ie. Crush it inwards with a loud noise.

The expansion obtained during extrusion can be retained only then, when the moisture of the dough is so little, that it leads to a sufficient hardening of the dough during the expansion process because of the loss of water and consequent cooling down.

The upper limit of moisture at which the expanded product can resist the atmospheric pressure is approx. 22 %.

Not only the quantitative aspect of the expansion, but also the way in which it occurs, is of importance for determining the rehydration and binding characteristics of the final product. If large bubbles are formed during expansion, then the cell walls between the bubbles are also relatively thick ie. the water needs more time to soften these. The formation of as many as possible small bubbles is desirable, for one to obtain a lighter colour due to the consequent diffraction of light, but also for the higher capillary effect caused by the smaller bubbles and canals.

New developments in designs of die-systems have helped here immensely for improvement and better control of the texture and bubble sizes. In the die-system itself, by intentionally

causing cavitation, it is possible to create evaporation nucleii, which help in forming many small bubbles rather than a few large ones.

It is known since a long time, that the availability of evaporation nucleii influences the development of texture and the manner of the water evaporation significantly. Evaporation nucleii are effectively all foreign particles and structures in the dough, which influence the surface tension of the fluid, in a similar manner as the marble chips in a distillation beaker in the laboratory.

Insoluble mineral particles, fibre and cellulose particles etc. show this effect. Hereby it is not the quantity of these materials in the dough which is important but the number of particles per unit area of the dough opening. Since the intentional addition of such materials is not acceptable in the production of Baby-cereals, we have tried to influence this aspect of the expansion through special die-designs.

Eg. if one creates intentional turbulence in the dough immediately before the boiling point (achievement of the exact temperature corresponding to the prevailing steam pressure), then cavitation is caused, ie. more or less simultaneous evaporation and condensation of water. In such zones, the dough is expanded and recompressed many times, thus forming laminar structures, which are very helpful in the later development of good rehydration and binding characteristics.

It should however not remain unmentioned, that the creation of cavitation is a very energy intensive process and which due to the shear forces created would certainly lead to breakdown of starch-chains and thus influence the achievable viscosity in the final product.

Summary :

The roller drier and the extrusion technology are basically different processes with very specific advantages and disadvantages.

It is physically impossible to manufacture identical products using these 2 processes.

When, and it happens often, the quality of the product is measured only by the viscosity of the prepared product, then the extruded product can never achieve the true levels of viscosity of a product manufactured using the conventional roller drier technology. However since other nutritional, microbiological and physical aspects, other than the viscosity, are actually of even more relevance for the feeding of small children, use of cooking-extrusion technology can be of greater and decisive advantage.

By the use of the new TURBO technology it has become possible for SCHAAF to reduce to a very large extent the disadvantages of the conventional extrusion in the areas of :

- Viscosity
- Dissolvability
- Colour
- Bulk density
- Retention of nutrition
- Taste

Thereby the advantages of the extrusion technology in actual practical application, in terms of economy and also microbiological superiority have been further strengthened.