



TIME- AND COST-OPTIMISED CHOCOLATE CONCHING

Advantages of conching in Lödige Ploughshare® Mixers and other applications of the mixer for chocolate production

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1. Introduction

Conching is a crucial, quality-critical step in the production of chocolate. The purpose of conching is to disperse the chocolate mixture, remove moisture, degas and homogenise it. This improves the flavour and the mouthfeel of the finished product. For a long time, conching was regarded as the most work-intensive process step in chocolate production, in particular with regard to the required time, which used to be multiple days. That is why a variety of procedures have been developed in the past decades to optimise this process and reduce the required time investment. However, some of these procedures had other disadvantages such as lower throughput rates, poorer moisture removal or limited control over flow properties. Other approaches are based on thermal pre-treatment of the cocoa mass and occasionally pre-drying of the milk powder to reduce the time required for the time-consuming phases of degassing, moisture removal and flavour development, thereby reducing the actual conching process primarily to homogenisation.

Below you will find a presentation of the conching process in the Lödige Ploughshare® Mixer as a low-cost, time-efficient alternative to a conventional conche. This mixer maximises rapid air contact of the particles in the fluid bed. High frictional energy can be introduced, while the shape of the mixing tools and their systematic arrangement on the mixer shaft ensure that the mixture is gripped completely, turning it into a lump-free, homogeneous end product in less time.



Figure 1: Ploughshare® Mixer type FKM 3000 for conching chocolate with a temperature control jacket and hygienically sealed insulation

2. Conching

2.1 Producing cocoa masses

Chocolate is a dispersed system. Solid particles such as sugar, cocoa particles and milk powder are present as a dispersed phase in the continuous phase that is cocoa butter. Factors such as the particle sizes of the dispersed particles and the fat content determine the flow characteristics of the chocolate mixture. The flow characteristics are an important aspect of chocolate production, as pumping of the chocolate mixture must be possible for processing it and the mouthfeel of the final product depends significantly on the size of the solid particles.

The umbrella term "chocolate" refers to a variety of products. In addition to bars of chocolate (e.g. milk chocolate or dark chocolate) it includes chocolate coats, e.g. for chocolate bars, filled chocolate products or even instant products for making chocolate drinks. In any case, the base product is cocoa mass or rather the raw materials cocoa butter and cocoa powder made from it. The production of this mass is divided into the steps described below.

2.1.1 Roasting

Cocoa beans as the base material are roasted for approx. one to two hours. This melts the fat contained in the cocoa beans (at approx. 100-120 °C). Substances dissolved in the fat react with each other and polyphenolic tannins are degraded, reducing bitter, astringent flavours. Moreover, this process reduces water and undesired flavouring substances (e.g. acetic acid, propionic acid and isobutyric acid). The amino acids and reducing sugars react in a non-enzymatic browning reaction, referred to as Maillard reaction, creating the desired characteristic flavouring compounds and the typical colour. [3]

2.1.2 Grinding

After being roasted, the cocoa beans are roughly broken and the shell is removed. Any intact cell structures are opened up in grinders and rollers to release the fat contained in them. The result of this multi-stage grinding process is the base of any cocoa or chocolate product, the cocoa mass. [3]

2.1.3 Pressing

The cocoa mass is pressed to separate it into cocoa butter and cocoa powder. These two base products are mixed with other ingredients like sugar and milk powder and then turned into a flowing liquid chocolate base in the subsequent conching process.

2.2 Basics of conching

The conching process optimises flavour, homogeneity and flow properties.

During grinding (see chap. 2.1.2) the mass is pushed through small gaps, resulting in the grinding effect. However, this also creates lumps. These are broken up by the strong shear forces during conching and distributed in the fat phase. This homogenises the mass to create an even, smooth-melting mouthfeel. To optimise the flow properties it is particularly important to remove moisture, as moisture significantly increases the viscosity of chocolate.

In general, the conching process is divided into three phases, though not every recipe or conche uses all three. The three phases described below are:

- Dry phase
- Plastic phase
- Liquid phase

2.2.1 Dry phase (dry conching)

Dry conching is particularly important for modern, time-efficient conching processes. In this process step, powdery raw materials are combined at the beginning of the filling step while a low amount of fat (approx. 1 % [1]) is added. The ingredients then undergo intense mixing, resulting in a temperature increase. The mass created in this process has a crumbly structure. Thorough ventilation of the conche is important at this point in the process, as it allows undesired volatile substances to escape optimally, because particle surfaces are still uncovered and not surrounded by a layer of fat that impedes volatilisation.

In milk chocolates, the moisture content is approx. 1.6 % and should be lowered to 1 % [1]. Dark chocolate already has a low moisture content of under 1 % at the start, so in this case moisture absorption must be prevented [1]. A closed system, such as the Lödige Ploughshare® Mixer, is an advantage because it allows, for instance, milk chocolate and dark chocolate to be processed in the same production area without any undesired exchange of volatile components. Moreover, an ideal system should make it possible to control the temperature in a systematic manner. The Ploughshare® Mixer does so with a temperature-controlled double jacket. On the one hand, this supports the evaporation of volatile components through an initially slow increase of the temperature. On the other hand, it supports the mixing process, as lump formation can occur at the end of the drying phase at the transition point to the plastic phase, which occasionally causes the mass to adhere completely to the mixing elements. It is possible to avoid this by adapting the temperature and fat content [1].

2.2.2 Plastic phase

At the end of the drying phase and at the beginning of the plastic phase, a particularly high amount of energy is required for mixing. A powerful system with efficient mixing elements is an essential

prerequisite. High application of energy causes the temperature to rise quickly. As ideal flavour development is highly dependent on the temperature profile, active cooling, for instance by means of the double jacket, is required. The double jacket temperature must be a few degrees lower than the temperature of the chocolate mass in the mixer [1].

As soon as the moisture has been removed from the mass and the particles in it are covered in fat, the viscosity of the now pasty mass decreases. After a final addition of fat and emulsifier, the liquid phase is reached.

2.2.3 Liquid phase (wet conching)

In this phase, the ingredients added last are mixed. Once a consistent viscosity is achieved, this phase can be concluded, as no more quality-promoting reactions will occur at this point. The power consumption of the equipment can be used to detect whether the viscosity has to be adapted. This is crucial, as a consistent, reproducible viscosity is required for further processing of, for instance, chocolate coats. [1]

Addition of the emulsifier lecithin (in use since the 1930s) in a final step reduces the viscosity of the melted chocolate mass dramatically. [3].

2.3 Conventional conche

The first conche was created by the Swiss inventor Rudolphe Lindt in 1879. His system, which later became known as the longitudinal conche, consisted of a granite trough shaped like a conch shell. In it, the cocoa mass and additional ingredients like sugar and cocoa butter are moved back and forth by granite rollers. The frictional heat causes the chocolate mass to melt. When the roller makes contact with the sides, the liquified mass moves over the rollers back into the basin. During this process, the dispersed solid particles in the cocoa butter are reduced in size to under 20 µm and coated in cocoa butter. This prevents the human tongue from recognising the particles as such - the texture is now perceived as soft and smooth-melting. This conventional conching process could take up to 96 hours. [1, 3]

In addition to optimising the mouthfeel, the conching process also creates the ideal flavour. The surface increase caused by the particle reduction allows embedded desired flavouring substances to diffuse into the surrounding fat phase, thereby intensifying the overall flavour. In addition, the heated mass is ventilated, causing undesired volatile flavouring substances, e.g. acetic acid, and the remaining undesired moisture to evaporate [3].

However, the disadvantage of this conche is that conching in the dry phase is not possible. Due to its design, this conche can only be filled with pasty or semi-liquid masses. This means that the particles are already enclosed in fat and removing volatile components and moisture is a very slow process, resulting in extremely long process times. Other disadvantages include high energy consumption, relatively low filling levels and insufficient temperature control. [1]

2.4 Modern conching

The disadvantages of the conventional conche described above led to the development of different conches.

Not every conche type can perform all three phases of conching. This needs to be taken into account when selecting raw materials or additional equipment may have to be acquired.

In general, systems permitting continuous production were developed in addition to the conventional batch conche. However, these are not suitable for producing varied recipes, as is frequently required.

During conching in impact mills, a fan is activated after binding of the powdery components to permit moisture removal and evaporation of undesired volatile components. However, all in all, moisture and gas removal is not as thorough as in a conche. [4]

The Viennese process is a closed system in which recipe components of the chocolate mass circulate. The chocolate mass is transported via a pre-mixing unit through a pipe system via two circulation conches to an agitator ball mill. From this point, the mass is transported back through two units referred to as "flavour modifiers" and into the circulation conche. The mass runs through the agitator ball mill until the final fineness is reached. The disadvantages of this procedure are low throughput, decreased moisture removal and limited control over flow properties.

Some conventional conches are based on round containers in which a mixing tool rotates on a vertical shaft. These conches are able to perform all three conching phases. However, their disadvantages include poor control over temperature and frequently low system capacities. [1]

Many advantages such as excellent temperature control, powerful drives and minimised process time are provided by conches with a horizontal mixing shaft. These include the Lödige Ploughshare® Mixer described below.

3. Use of the Lödige Ploughshare® Mixer for the conching process

3.1 System layout

The classic Ploughshare® Mixer described below in a hygiene design with specially adapted mixing elements is used for the conching application.

3.1.1 General description of Ploughshare Mixer

The technical design of the Ploughshare® batch mixer is based on mixing with the mechanically generated fluid bed process introduced to industrial mixing technology by Lödige and described in the relevant technical literature.

Ploughshare® shovels arranged on a shaft in a special system rotate as mixing elements in a horizontally fitted, cylindrical drum. The size, number, positioning, geometrical shape and the circumference speed of the mixing tools are adapted to each other so that they generate a three-dimensional movement of the components. [2]



Figure 2: Example of a Lödige Ploughshare Mixer for conching in a hygienic design

This forced mixing process subjects the complete contents of the mixing drum to a three-dimensional movement including intense loosening of the mass by rotating Ploughshare mixing tools. The shape and angle of the shovels prevents the mixture from being pressed against the drum walls. This minimises

product adhesion and frictional heat. Precise adaptation of the cover doors to the rounded shape of the drum prevents the existence of dead space. This design makes it impossible for the mixing process to miss any product components and there are no zones of insufficient horizontal and vertical product movement in the moving mass. [7]

The design of the side walls ensures formation of large product surfaces during the drying phase. Because the particles are separated in the fluidised bed, they come into contact with air more vigorously and more frequently. The design and adjustment of the base plate in relation to the tempered mixing drum wall permits the introduction of high frictional energy. Due to the shape of the tools and their systematic arrangement on the mixer shaft, the mass is continuously and vigorously mixed, so that a lump-free, homogeneous end product results. [5]

The rotation speed of the shovels is chosen so that heavy particles cannot be ejected by the centrifugal force and separation is impossible. The shovels continue rotating while the mixers are emptied, thereby maintaining the precise mixture in the discharge phase. The mixing process is gentle to the structure of the processed materials. [7]

3.1.2 Mixing tools for conching

The original Lödige Ploughshare® shovels have been modified for the conching application, so that they optimise not just the mixing process but also material restructuring in the processed product. To ensure this, the elements are installed at a larger distance from the interior drum surface in the front section than in the rear section as seen in the mixing tool circulation direction. [6]

This design subjects the product located between the mixing tool and the interior drum surface to pressure during the mixing tool revolution, causing a product modification at the single grain or individual volume levels of masses. This helps modify, for instance, the flow properties, the particle surface structure, the flavour or the colour. [6]

Moreover, the mixing tool geometry ensures that the product in the gap between the mixing tool and interior drum surface is frequently replaced, thereby achieving homogeneous and even processing of the entire product in the drum as well as excellent specific mixing performance. [6]

The mixing tools in the drum interior are arranged symmetrically in relation to an axis. The advantage of this arrangement is that displacement movements in the product cause the product to be evenly distributed in the mixing compartment. A high mixing quality is therefore achieved. [6]

In addition to the above-mentioned full mixing tools, half-mixing tools are attached near the front walls of the drum interior. These half-mixing tools are located at a larger distance from the front wall interior in the front section than in the rear section. These half-mixing tools also generate lateral compression processes that contribute to restructuring processes in the product. [6]

The "melting texture" of chocolate masses can be affected in defined ways through use of these modified mixing tools. The flavour is demonstrably optimised. The arrangement of mixing elements makes it possible to apply high energy to the processed product throughout the entire length of the drum. Small particles in the chocolate mass are restructured without initiation of side reactions that may lead to undesired secondary particles and generate unfavourable flavour profiles. [6]

The following diagram [6] illustrates the structure of the mixing tools: One mixing tool (10) is fastened among several on a shaft (11). The shaft has a pivot bearing on both sides in the front walls (21) of a horizontally aligned drum (12). The mixing tools end at a low distance from the interior drum surface (18) and the shaft has drive equipment to drive the mixing tools in the direction of the arrow (13). The mixing tools are installed at a larger distance from the interior drum surface in the front section (19) than in the rear section (20) in the shaft circulation direction.

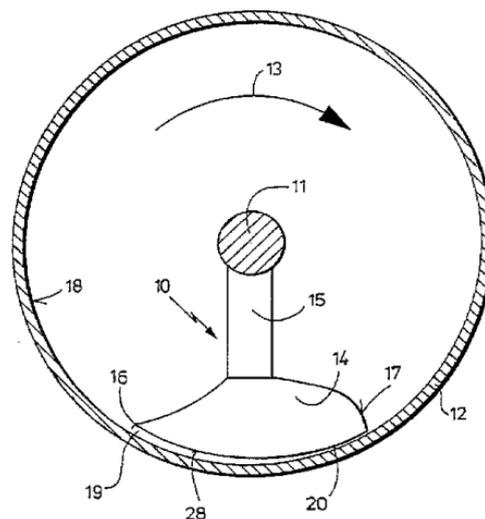


Figure 3: View of modified mixing tool cross-section [6]

3.1.3 Hygienic design

Nowadays, food safety requirements have become increasingly stringent, even where less perishable foods are concerned. The industry demands certification according to standards such as the IFS (International Featured Standards Food) as a basic prerequisite for many suppliers. Among other things, a suitable system design for the conching system is essential for meeting the food safety requirements and producing high-quality products. For instance, dead space must be avoided to prevent product contamination, for example at sealing points. The EHEDG (European Hygienic Engineering and Design



Group) provides specific requirements for the implementation. That is why the design of the Lödige Ploughshare® Mixer is based on the EHEDG guidelines.

3.1.4 The functional principle

Control of the process is based on output and time, and the rotational speed is regulated by the power consumption of the motor. Targeted temperature equalisation of the mass takes place via the application of warm or cold water running through the double jacket of the drum wall. Larger mixers are equipped with scrapers on the front walls. Additional nozzles are installed on the end plates for the injection of purified compressed air. This supports the discharge of vapours that arise during the conching process. [5]

In the fluid bed, the particles are separated to ensure that they come into contact with the air repeatedly and intensely. In addition, this process permits optimised application of high shear energy. Thanks to mixing tools that are perfectly adapted to the process in an optimised arrangement, the mass is continuously and thoroughly mixed, so that a homogeneous mixture without lumps is created.

A slight horizontal mixer incline promotes discharge of the complete final product.

Thanks to the hygienic design of the system, it can be cleaned efficiently either by an automatic procedure or by hand.

4. Other applications of the Lödige system in chocolate and confectionery production

The Lödige Ploughshare® Mixer's broad range of applications in chocolate and confectionery production is particularly advantageous for production of varied recipes, seasonal articles, etc.

4.1 Additional applications for chocolate production

In chocolate production, the systems are, for instance, also used with great success for producing white chocolate and milk chocolate. Other applications include:

- Production of chocolate coats
- Production of fillings
 - e.g. grape, nut/almond
 - Production of nougat
 - Cream fillings
- Production of instant chocolate drink powder

In addition to conventional powder mixing tasks, the confectionery industry also uses the mixers for applications such as coating of crispies, coating of powders and homogenising of fondant and icing.

Detailed information on specific applications in chocolate production will follow in future white papers. However, should you already be interested in more detailed information, please do not hesitate to contact us at the contact information listed on the final page. We would be happy to assist you.

Lödige offers systems and expertise for confectionery and chocolate production, processing of the relevant raw materials and many other applications (e.g. milk powder drying, steam sterilisation and cocoa alkalisation).

4.2 Coating of crispies

Coating processes in which products are enveloped in layers are used in a variety of industries, e.g. for production of medication, fertilisers and also in the food industry. While many applications require complex, costly equipment such as coaters or fluid bed machines, some processes, e.g. confectionery production, can easily be performed in the less costly Lödige Ploughshare® Mixer. One of these processes is coating of extruded cereals, also referred to as "crispies" with chocolate or fat. These crispies are frequently used as toppings in yoghurts or in muesli. The processed particles are characterised by their

porous surface and frequently uneven particle sizes. Depending on the process, up to ten times the volume of e.g. chocolate mass may be applied. The final product must maintain the crispy properties. [5]

When using the Lödige Ploughshare® Mixer for the coating process, it is important to take into account that the filling level will expand during the coating process. Gentle yet efficient mixing can be achieved by a moderate fluid bed, which is, in turn, achieved by adapting the mixing tools and circumference speed accordingly. To prevent multiple crispies from sticking to each other in the coating process, liquid nitrogen can be added directly to the product bed. This ensures even and rapid crystallisation of the mass. In addition to the volume of coating liquid added, use of a double jacket for temperature control can also affect the process and product quality. [5]

4.3 Coating of powders

In the baking and confectionery industry, products such as fruit cakes or other quality pastries are frequently dusted and decorated with powdered sugar. However, powdered sugar dissolves on contact with the baked goods and is not temperature-stable. To prevent this, the fine sugar crystals are coated with an incredibly thin layer of fat. This product is referred to as "icing sugar" or "snow sugar" and adds the final appealing touch to products. This "snow" does not melt even at higher temperatures (up to 45°C), does not dissolve even when it comes into contact with greasy surfaces and is characterised by excellent flow properties.

To manufacture icing sugar, first, a uniform premix is created from all the powdered raw ingredients (sucrose, dextrose, other sugar-based powders and aromas). A temperature control jacket is used to heat this premix to a temperature in the range of the melting point of the fat that will be added later. Ideally, the double jacket is then heated to a temperature above the melting point of the fat, in order to prevent the product from sticking to the mixing drum walls. The fat is then dosed directly into the rotating choppers inside the machine. This causes the melted fat to coat the powder. It also creates a granulate texture, which has a positive effect on the flowability of the powder. In the final step of the process, liquid nitrogen is injected into the mixer interior to cool the product to approx. 20 °C. This accelerates fat crystallisation to prevent the product from lumping and caking. [5]

4.4 Homogenisation of fondant and sugar icing

Icing and fondant, which are available in a wide variety of colours, are used by the baking industry and artisan bakeries to decorate high-quality baked goods and confectionery. Both products can be manufactured highly economically in the Lödige Ploughshare® Mixer. Liquid sugar icing, which consists of powdered sugar and water (or fruit juices), will harden after processing. Fondant, on the other hand, is characterised by its soft or pasty and therefore mouldable consistency. That is why additional glucose syrup and other ingredients such as coloured food dyes, sugar substitutes or gelling agents are added



during fondant production. The homogeneous sugar-glucose syrup mixture is heated in the mixer and the introduction of mechanical energy turns it into a mouldable mass. The remaining recipe components are then added. The rotational speed of the mixing tools is adjusted to the active recipe. The speed can be infinitely adjusted via a frequency converter. [5]

5. Summary

Conching is a crucial process step of chocolate production. The quality of the final product, particularly its flavour and melting texture, is highly dependent on this process step. Conching homogenises the mass to create an even, smooth-melting mouthfeel. The process removes moisture that would, among other things, create an undesired increase in viscosity, and undesired volatile components that have negative effects on the flavour.

To reduce the time required for the formerly highly time-consuming process, the original conche was further developed, creating multiple new systems. However, these often reach their limits where capacity and performance is concerned.

Processing in a Lödige Ploughshare® Mixer is a time- and cost-saving method for achieving high-quality results. A large number of equipment options, including modified shovels, temperature control jackets and addition systems, allow optimal adjustment of the system and make it possible to achieve optimised results in a very short time.

The mixer is not just powerful, it is also universally suitable for other processes in the production of baked goods and confectionery (e.g. homogenisation, coating). The Lödige Ploughshare® Mixer has proven its worth as a multi-purpose machine for these processes and it creates top quality. The system is equally suitable for processing milk chocolate, instant cocoa powder, fondants and many other products, provided it is equipped accordingly. This is a cost- and space-saving solution, for instance for companies with seasonal products and changing recipes.

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