Drying and caramelization of milk concentrates with a contact disc dryer

Experimental studies with the Allgaier CDry®

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Introduction

The CDry is a steam-heated disc dryer that works on the principle of contact drying. Due to the large heat transfer surface in a small space and the robust mode of operation, it has proven itself in recent years for the drying of solids loaded liquids in the fine chemicals, pigment, ceramics and fertiliser industries and even in waste water technology [1-5].

As CDry food, it is available in a version for food applications. The further development of the dryer uses only materials that are approved for food contact. The design is fully hygienic and easy to clean by applying the current EHEDG guidelines. In order to minimize plant downtimes, the process chamber and the pipe system at the CDry food can be cleaned automatically by means of Cleaning in Place (CIP).

In cooperation with the Neubrandenburg University of Applied Sciences, the Institute for Food Process Engineering and Powder Technology at the University of Hohenheim, as well as several industrial partners, extensive series of tests on the drying of skimmed milk and whole milk concentrates were carried out as part of a master's thesis. Through the targeted combination of temperature and residence time, a very wide range of powder properties can be produced when drying milk with the CDry. The tests were used to investigate the relationships between process parameters and powder properties and to compare them with commercially available spray- and roller-dried powders. Milk drying thus serves as an example of the many possible uses of the Allgaier CDry contact disc dryer in the food industry.

Keywords: milk, drying, caramelization, CDry, disc dryer, contact drying, evaporation, residual moisture, free fat content, dirt pattern

Content

1 Established milk drying processes

1.1 Spray drying

Milk powder is the most traded product in the food and feed industry worldwide in terms of volume [6]. The most widely used technology for milk powder production is spray drying. Already in 2000, 99.5% of the skimmed milk powder produced in Germany was produced by spray drying [7]. As a convective drying process, spray drying offers the advantage that drying is gentle on the product and can be designed for high throughput rates. However, there are also some specific disadvantages. The high demand for process air with mostly still high exhaust air temperatures requires powerful, large-dimensioned system peripherals (e.g. fans, filters) and leads to considerable energy losses, while a circulating gas system or heat recovery is very costly. In addition, milk powders produced by spray drying are very similar in their characteristics and there are hardly any possibilities to customize powders. The round particle shape and the drying kinetics in the air stream also lead to an inclusion of the milk fat within the particles and thus to a low free fat content [8]. In the confectionery industry, especially the chocolate industry, caramelized milk powders with a high free fat content are increasingly desired, as these properties improve the taste and melting of the chocolate [9]. In order to obtain comparable roasted flavors in the spray-dried powder, it must be subsequently and elaborately caramelized or a proportion of caramel powder is added to the standard milk powder.

1.2 Roller drying

Before it was almost completely displaced by spray drying, roller drying was a widely used technology for milk drying [10, 11]. Roller drying is still important for the food industry as a form of contact drying. However, many of the roller dryers on the market are outdated and don’t meet the current requirements for hygienic or easy-to-clean (CIP-capable) machine design. The degree of process automation is also often no longer state of the art. Other disadvantages of roller dryers are the large footprint and the limited heat transfer due to the thick-walled hollow cylinders. In addition, the long scraper blades are often difficult to adjust and wear-intensive. The rollers are usually exposed to the environment instead of being housed in a closed process room and are therefore problematic in terms of completely hygienic production.

2 The CDry as an innovative alternative

2.1 Functionality

The CDry is a novel method of contact drying that addresses the issues of optimal cleanability, hygiene and digitization. The liquid to be treated is applied in excess to all discs on both sides of a rotating and hollow disc bundle by means of so-called "feed pipes". Figure 1 (left) shows this process on a laboratory machine with a disc diameter of 540 mm. The liquid runs off the discs into the circulation tank below and leaves the liquid film to be dried on the disc surfaces. The liquids to be dried can be fed in untreated, pre-treated by fermentation or concentrated by evaporation, reverse osmosis or ultrafiltration condition. As with any drying process, pre-concentration of the liquids leads to a reduction in the necessary water evaporation and is useful for its efficient operation in most cases. While the solvent, in this case water, evaporates through the heating of the disc bundle by means of saturated steam from the inside, the solids dry on the disc surfaces and are dewatered to the desired residual moisture.


Fig. 1 and 2: Drying milk concentrate with the CDry 501 lab

After one disc rotation, the dried solids are scraped off the side surfaces of the discs (Fig. 2 right) and fall into a product dropout chute for collection or for removal and further processing. The easy-to-adjust knives for scraping the dried material off the disc are short due to their design. They are self-adjusting by spring action through a movable holder at a low preset contact pressure, so that they always lie optimally against the disc and scrape off the dried solids reliably and with little wear. Figure 3 shows the general process diagram of a drying process with the CDry.

The desired degree of dryness of the solid material obtained can be set stably and reproducibly via the speed of the discs and the steam pressure of the disc heating. Since the excess liquid applied to the hot discs drains into the circulation tank and is recirculated, there is no risk of liquid breakthrough into the dry material due to the system. The level in the circulation tank is continuously monitored and refilled as required. An optional heat exchanger for cooling the liquid in the circuit allows temperature-sensitive products to be circulated gently or preheated specifically.

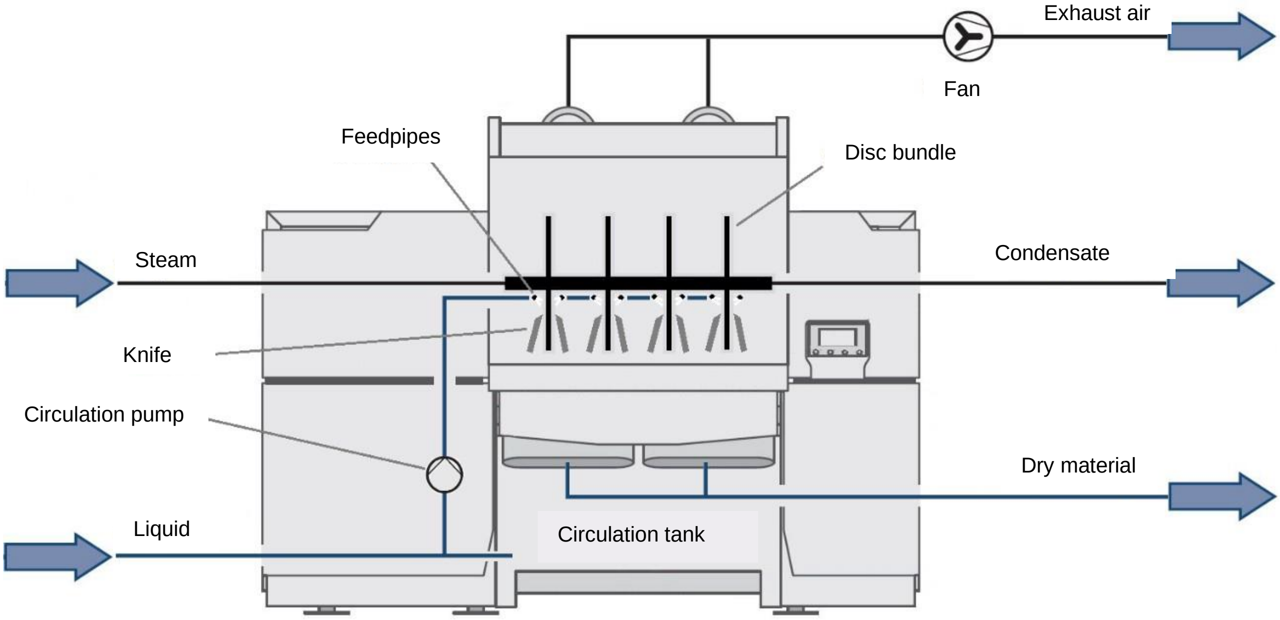

Figure 3: Process diagram of a CDry drying plant

Depending on the product behavior, the dry product is a granulate-like product, a fine powder or a film-like dry product (Fig. 4).

Figure 4: Examples of dry goods produced with the CDry (from left: beet pectin / brewer's yeast / protein suspension)

The evaporated liquid is discharged by means of an exhaust fan through an adjustable, comparatively low air flow, which is normally drawn in from the environment at the front of the dryer, with a high water vapor load. Only if dusty goods are produced during drying, small amounts of the solid material to be dried are removed with the exhaust air. Very often, however, film-like dry goods are produced during the drying of food products, which means that the extracted dryer vapors are practically dust-free.

Depending on the respective properties of the products to be treated, different materials are available for both the heated discs of the dryer and the knives for scraping off the dry substances. The discs are usually made of stainless steel. For protection against corrosive or abrasive media, the surface of the drying discs is optionally provided with a suitable surface protection by coating or by hardening. Various stainless steel, plastic or ceramic materials are available for the scrapers. Due to their special, slim design and the thin wall thickness of the individual discs, a very good heat transfer is made possible, which minimizes the necessary heat transfer surface for drying. The footprint of the CDry units is comparatively small due to the compact design of the disc bundles and contributes to easy assembly and flexible installation of the system.

As the process chamber is operated without pressure, the drying process can be fully monitored at all times via a large machine front covered with safety glass. The motorized, upward-opening front window also provides easy access to the disc package and the scrapers for maintenance or cleaning purposes.

For heating the CDry, saturated steam up to a maximum of 3.5 bar(g) is used, which corresponds to an absolute pressure of 4.5 bar(abs) or 0.45 MPa and thus a saturated steam temperature of 148°C. An energetically optimal mode of operation of drying with low-pressure steam, as it occurs inexpensively in many production facilities, is thus possible.

2.2 Diverse established areas of application

The CDry can be used for a variety of different liquid products from almost all areas of industry [1, 4, 5]. It solves many of the common problems of contact dryers and has a particularly robust operating behavior. In recent years, a large number of reference systems have been installed in various sectors particularly in the chemical industry, pigment production, wastewater technology, ceramic industry and even the animal feed industry. Depending on requirements and special applications, dryer models with water evaporation capacities of up to 4 tons per hour are available.

Allgaier Process Technology GmbH produces and markets CDry Technology worldwide. The complete technology complies with the European CE conformity criteria and safety regulations and can be supplied for the US market in accordance with ANSI. The external design was presented in its new, very attractive and modern form for the first time at ACHEMA 2018 in Frankfurt (Figs. 5 and 6). In addition, the system control and the process visualization meet the current requirements. Within the framework of the ACHEMA Innovation Award, the new development was placed on the short list.

Figure 5: Intelligent system control via the intuitively operated touch panel for calling up and changing the current machine and process parameters.

For particularly temperature-sensitive applications, the disc package can also be heated by means of steam in the vacuum range of 0.4 to 1 bar(abs.), whereby surface temperatures of the discs < 100 °C are possible. This also enables the efficient drying of particularly temperature-sensitive products, such as those found especially frequently in the food industry.

When designing the Allgaier CDry, attention was paid to the fact that the drying plants can be supplied as largely complete units, which minimizes the assembly work on the construction site and allows the drying plants to be installed in a compact and space-saving manner.

Fig. 6: Industrial CDry in chemical design - also available in hygienic design for the food industry from autumn 2020.

2.3 Food-conform, hygienic design

Due to the great interest from the food industry and the positive test results in the Allgaier Technical Centre, a development project called "CDry - Fit for Food" was started. Within this development project, the CDry was raised to the current standard of the Machinery Directive for food processing machines. For this purpose, the entire design was made hygienic by implementing the guidelines of the European Hygienic Engineering and Design Group (EHEDG).

Thus the Allgaier disc dryer is the only known disc dryer of this design on the market worldwide which meets the demanding hygiene requirements of the food industry. The following summary lists the details of the Allgaier disc dryer which have been raised to the standard according to EHEDG in order to meet the hygiene regulations:

- Hygienic supply and circulation pump for the liquid to be dried.
- All parts in contact with the product are made of stainless steel 1.4404.
- Product-contact surfaces with Ra ≤ 0.8 μm (hygiene class H3) and corners with a minimum radius of 3 mm for easy cleaning.
- Self-draining and CIP-capable piping system, hygienic screw connections and flange connections.
- Food-grade, particularly abrasion-resistant surface treatment of the dryer discs.
- Quick-change mechanism of the main scrapers (main blades that scrape the dry material off the discs) for a very short set-up time.
- Food-approved sealing materials (according to EC 1935/2004, FDA 21 CFR), as well as construction of the seals according to the specifications of the EHEDG with force shunt, centering and defined pressing of the seals directly at the product area.
- Exclusive use of approved lubricants according to NSF H1 and FDA 21 CFR throughout the dryer.
- Completely enclosed process chamber with the option of feeding preconditioned supply air via a front spigot.
- Process chamber designed with double-walled insulation.
- The large front window has three defined positions: Production, maintenance and cleaning position.
- Optional integrated CIP system for cleaning the process chamber consisting of a combination of different spray nozzles to avoid spray shadows and to separate the dry area.
- System control with automated start-up and shut-down routines adapted to food production.
- Complete documentation and traceability of all components used according to the standards required in the food industry.

3 Experiments on drying and caramelization of milk concentrates

Due to the possibility of making the thermal energy input more variable through contact drying and more intensive compared to spray drying, a targeted flavoring of milk powders can be achieved. In addition, in contrast to spray drying, the milk fat is not enclosed in the spherical particle, but is present as free fat due to the flake structure [8]. The structure of contact-dried milk powder has a positive effect on the sensory properties of chocolate, for example, and ensures a reduced energy requirement during conching [12].

At the Allgaier Technical Centre, extensive series of tests were carried out on the drying of skimmed milk and whole milk concentrates with the CDry 501 lab disc contact dryer [13]. Within these tests, the influences of the disc temperature, the residence time and the pre-concentration of the milk concentrate to be dried on the powder properties were investigated. The influences of various process parameters on powder properties relevant to the food industry, such as residual moisture, bulk density, solubility and color, were evaluated.

The HMF content and the color changes in the dry product allow conclusions to be drawn about the intensity of the Maillard or caramelization reaction that took place during drying.

In addition, the free fat content, the total fat content and the dirt content of the whole milk samples were determined. The influence of drying on the microbial load in the powder was investigated using a whey concentrate.

At this point, we would like to express our sincere thanks to the University of Hohenheim and the University of Applied Sciences Neubrandenburg for their support of the project and their manifold assistance with the analyses. In addition, our special thanks go to our industrial partners for supporting the project by providing reference samples and analysis facilities:

- HOCHDORF Swiss Nutrition AG
- Deutsches Milchkontor GmbH
- Wheyco GmbH
- Milchwerke Schwaben eG
- Almil AG Bützower Dauermilchwerke

3.1 Experiments with reconstituted skimmed milk

3.1.1 Infrared pictures

Uniformly heat distribution on the drying disc during drying is essential for homogeneous residual moisture in the dry product. In addition, recording the heat distribution allows conclusions to be drawn about the heat load during drying. To illustrate the heat distribution on the dryer disks, thermal images were taken at different heating steam pressures and disk speeds after calibration of the emission coefficient. As an example, Figure 7 shows the heat distribution during the drying of 36-percent skimmed milk concentrate.

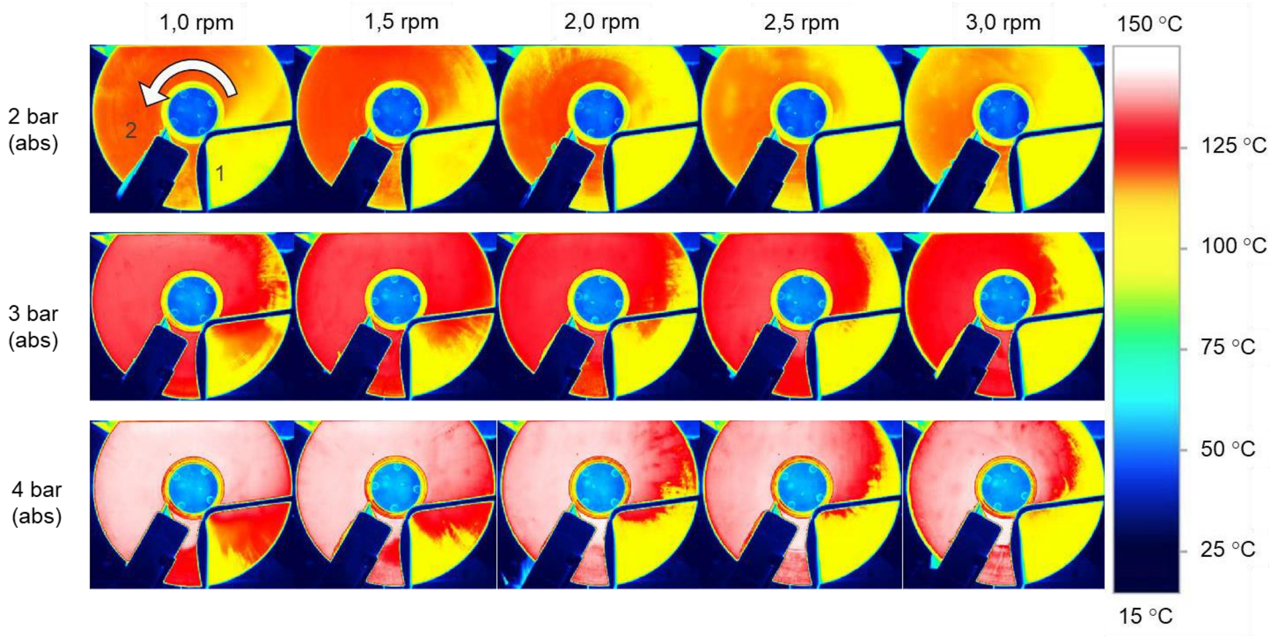

Figure 7: Thermal images of the 36-percent skimmed milk concentrate dried on the CDry 501 lab as a function of pressure and speed.

At position 1 (Fig. 7, top left), the product is applied to the drying disc at approx. 25°C. It can be clearly seen that the lowest temperatures occur in the area directly after the application of the liquid. Due to the heating of the liquid and the subsequent evaporation of water, the disc is mainly cooled in the area after the application of the liquid. In the course of rotation (counterclockwise), the product temperature rises and the dry material loses moisture. After the free water has evaporated, the product heats up to the desired or permitted product end temperature, which is related to the desired product moisture. The surface temperature of the disc is slightly below the saturated steam temperature of the heating steam used. The drying front is clearly visible and initially forms a little further at the edge than in the inner area of the disc. Until the point where the dry product is removed by the knives, the product moisture has evened out over the radius. In industrial plants with larger disc diameters (900 and 1300mm), this effect recedes into the background. Due to the short retention time of the product on the heated disc before it is scraped off, the product does not reach the maximum temperature of the disc surface. The evaporation of the moisture causes the product to cool while it is still moist and thus limits it to the maximum permissible solids temperature (Fig. 7, top left, position 2).

The infrared images in Figure 7 show that the product temperatures increase with increasing heating steam pressure. The effects of the disc speed on the temperature curves can also be seen. The lower the speed of the disc, the earlier the product dries on the disc and the sooner the surface heats up during rotation.

This illustration clearly demonstrates that the thermal stress on the product can be precisely adjusted by selecting the heating steam pressure and the disc speed. The Allgaier CDry can both drying gently as well as achieving higher product temperatures with a high thermal input.

3.1.2 Maximum product temperature during drying

In addition to the infrared images, the maximum and short-term product temperatures occurring during drying were investigated. These are particularly important for thermal sensitive products, but also for targeted heat stress. The maximum temperatures were recorded immediately before scraping with an infrared pyrometer.

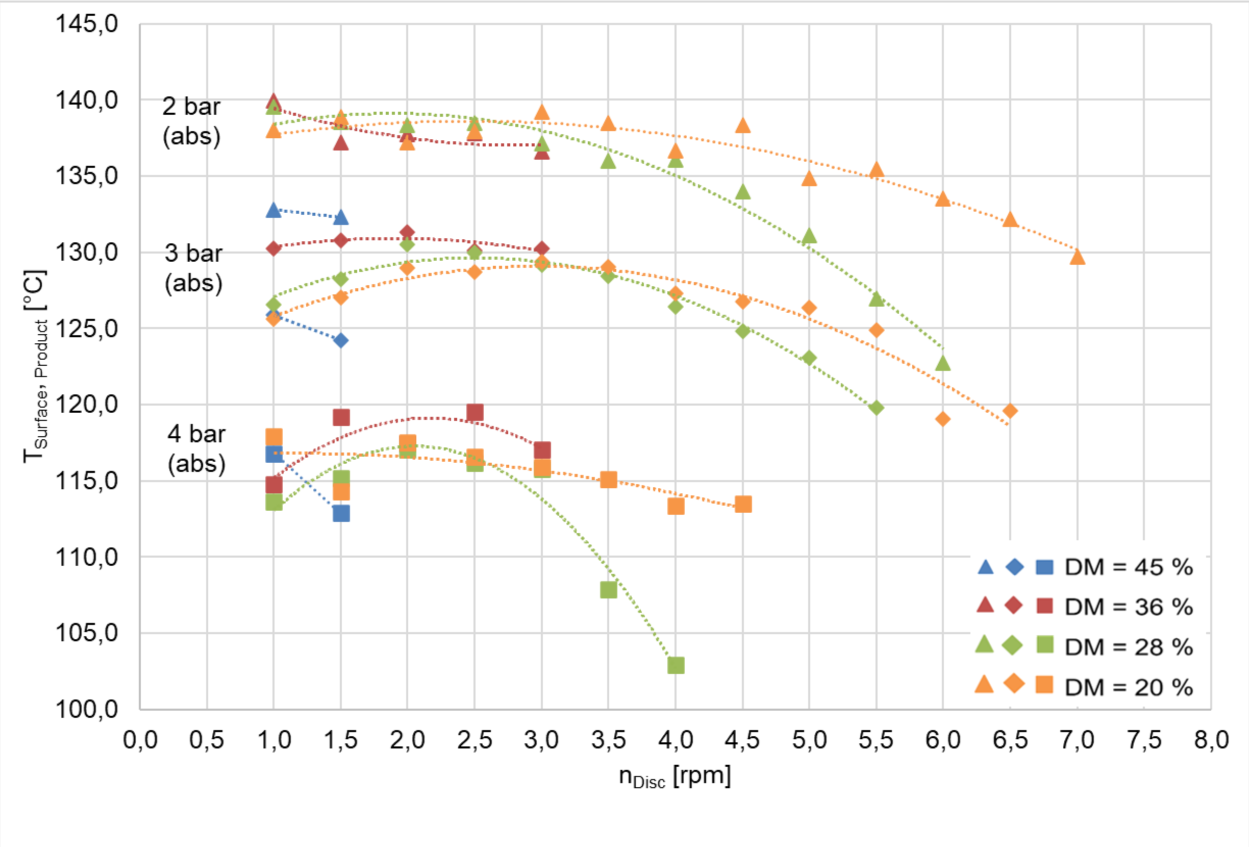

Diagram 1: Maximum product temperature occurring briefly at the end of drying

The results show that the heating steam pressure and the disc speed have a strong effect on the maximum product temperatures that occur. The surface temperatures of the discs are just below the heating steam pressure due to the low wall thicknesses of the drying discs. The maximum product temperature decreases with decreasing pressure and with increasing disc speed and thus shorter contact time between product and hot drying disc. The pre-concentration of the milk, on the other hand, showed hardly any influence on the maximum temperature. At higher speeds, the higher viscosity of the concentrate due to the stronger pre-concentration has the effect of further increasing the layer thickness and thus incomplete drying, which is reflected in a decreasing product temperature.

In summary, it can be stated that in the CDry, the heat effect on the product can be reproducibly adjusted through the combination of temperature and retention time. In this way, temperature-influenced product properties can be generated in a targeted manner. This allows interesting possibilities for the food industry to develop powders with individual characteristics and to specifically influence the sensory properties of end products (various chocolates, milk drinks, yoghurts, etc.).

3.1.3 Residual moisture

The residual moisture in the powder product is a very important criterion, which is specified in a very narrow range depending on the intended use of the powder; it is also an important influencing factor on the perishability and storage stability of the powder. Especially when used in oleophilic systems such as chocolates, a very low residual moisture is desirable, as the milk powder is the main source of water input and this increases the viscosity and the necessary conching time in an undesirable way [14]. If, on the other hand, the milk powders are used in aqueous systems, the water content plays a rather subordinate role. Product moisture contents in the range of 1.5 to 5% are common and desirable for good storage stability [15].

The residual moisture of the milk powder dried with the CDry was determined using an infrared moisture balance. For the moisture determination, approx. 5.0 g of the dry milk products produced were coarsely chopped and distributed on aluminum sample trays. Drying took place at a set temperature of 102°C. A mass difference ≤ 1 mg/140 s was chosen as the cut-off criterion.

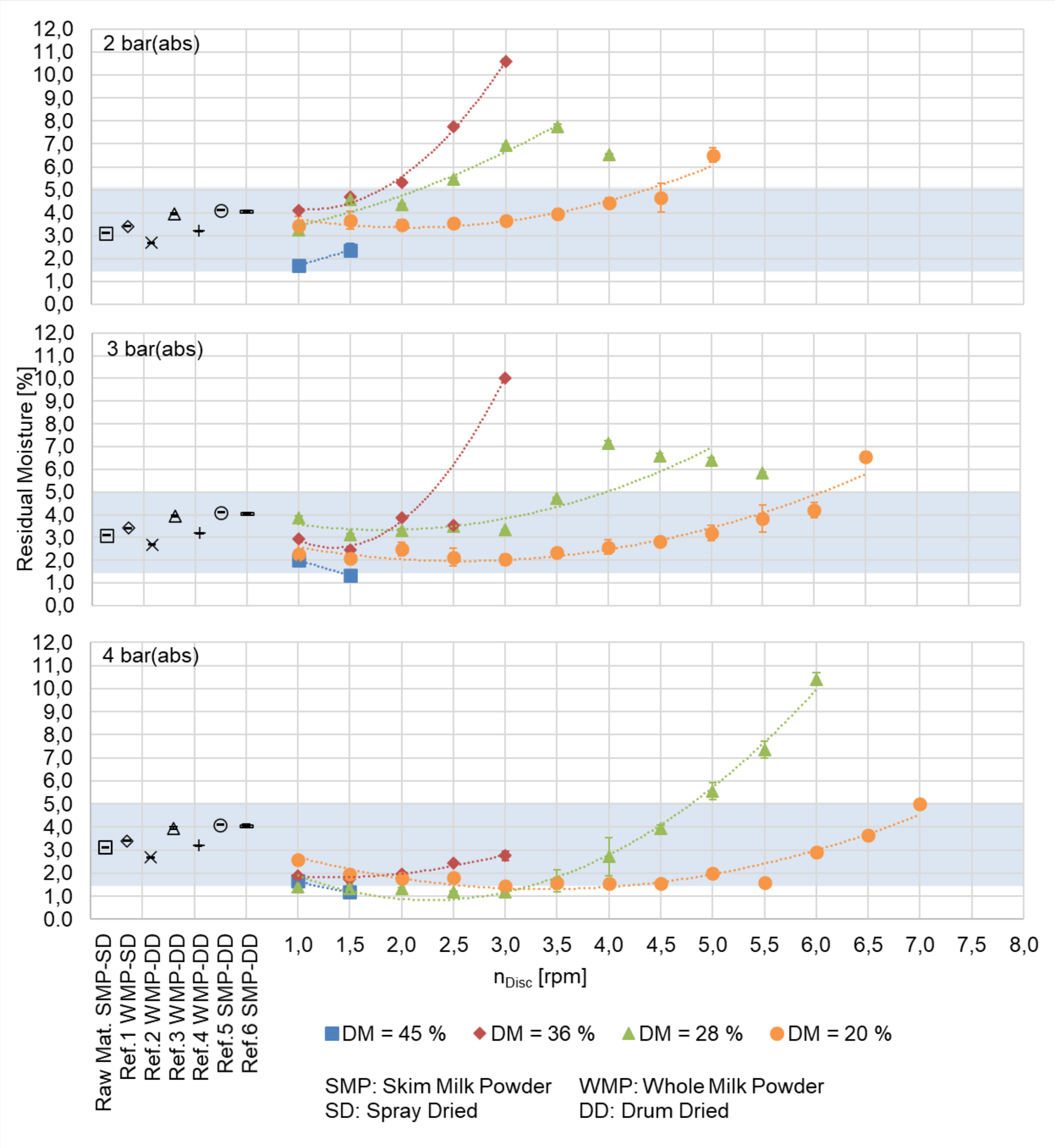

Diagram 2: Residual moisture of skimmed milk concentrates dried at the CDry and reference samples

The blue marked area in the diagram shows the range of residual moisture that is aimed for in the production of commercially available milk powders (1.5-5.0 %). In addition to the results of the products manufactured on the CDry, the reference samples of milk powders traded on the market are also shown in the diagram. Influences of the steam pressure, the disc speed and the solids content of the concentrates on the residual moisture of the dry products produced could be determined. In all three diagrams it can be seen that the samples produced with the CDry reach the range of the commercially available reference samples.

In addition, the residual moisture can be selectively under- or exceeded - depending on the setting of the heating steam pressure and the disc speed. The diagrams show across all concentration levels and heating steam pressures that an increase in the disc speed and the resulting reduction in the retention time causes an increase in the residual moisture, as expected. Similarly, increasing the heating steam pressure causes a decrease in residual moisture. The desired degree of dryness of the manufactured products can be set reproducibly.

3.1.4 Bulk density

Besides the residual moisture, the bulk density is another important parameter that has a great influence on the subsequent processability of the powder. When mixing chocolate base masses or aqueous milk powder solutions, a high bulk density is generally technologically advantageous. With higher bulk densities, smaller particles are present, which distribute and dissolve more quickly and evenly in other matrices. Likewise, the highest possible bulk density is desirable for transport, as the transport volume is lower in this case [15].

To determine the bulk densities of the milk powders produced with the CDry, they were first comminuted using a fine mill. For optimal comparability, the samples and the reference samples were sieved and the particle fraction 100 µm < x > 300 µm was analyzed. This was done to enable comparability with the example samples from the market or their usual particle sizes. The investigation of the bulk densities was carried out by means of a bulk density measuring device, in which the powder sample is transferred by means of a device into a vessel with a defined volume and withdrawn. After determining the transferred powder mass, the bulk density was calculated.

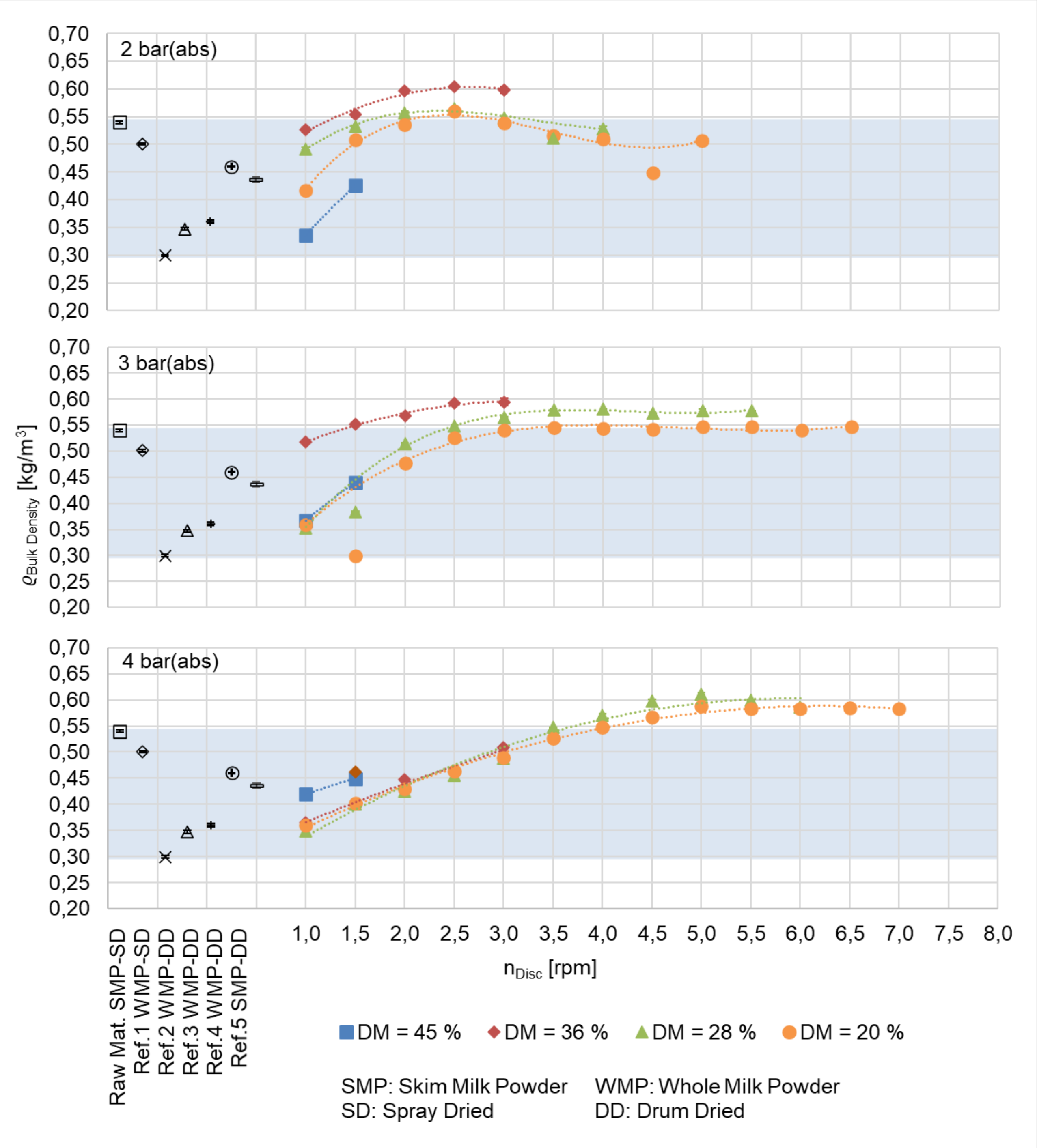

Diagram 3: Bulk densities of the dried skimmed milk concentrates and reference samples.

Again the area marked in blue shows the range in which commercially available comparison products are placed. The reference samples show that spray-dried powders have higher bulk densities than roller-dried powders due to the homogeneous particle shape [8] and particle size distribution. In the roller-dried reference samples, whole milk powders tended to have lower bulk densities than skimmed milk powders. The disc speed was found to have an influence on the bulk density. The pre-concentration and the steam pressure, on the other hand, have no influence on the bulk density.

The CDry has advantages over competing technologies in this respect as well: At all shown vapor pressures, the bulk density can be adjusted very variably with the help of the rotation speed. By selecting the appropriate speed setting, typical bulk densities of spray-dried and roller-dried powder can be achieved as well as slightly higher bulk densities.

3.1.5 Solubility

Depending on the further processing and the intended use of the powder, solubility is another important product property. If the powder is dissolved in water within further processing, good solubility ensures complete rehydration. In applications where the milk powder is used within fat-based emulsions, for example in chocolate products, solubility is of secondary importance.

The solubility of the milk powders produced was analyzed using the methodology of Bassler [11, 16]. In this measurement, powders are dissolved with tempered water and centrifuged. The supernatant is removed, made up with tempered water and centrifuged again. The "Insolubility Index" is a characteristic value for the solubility of powders in water and is given as the volume of the sediment in milliliters [ml] after centrifugation. For optimal comparability with the reference samples, only the particle fractions 100 µm < x < 300 µm were examined here as well.

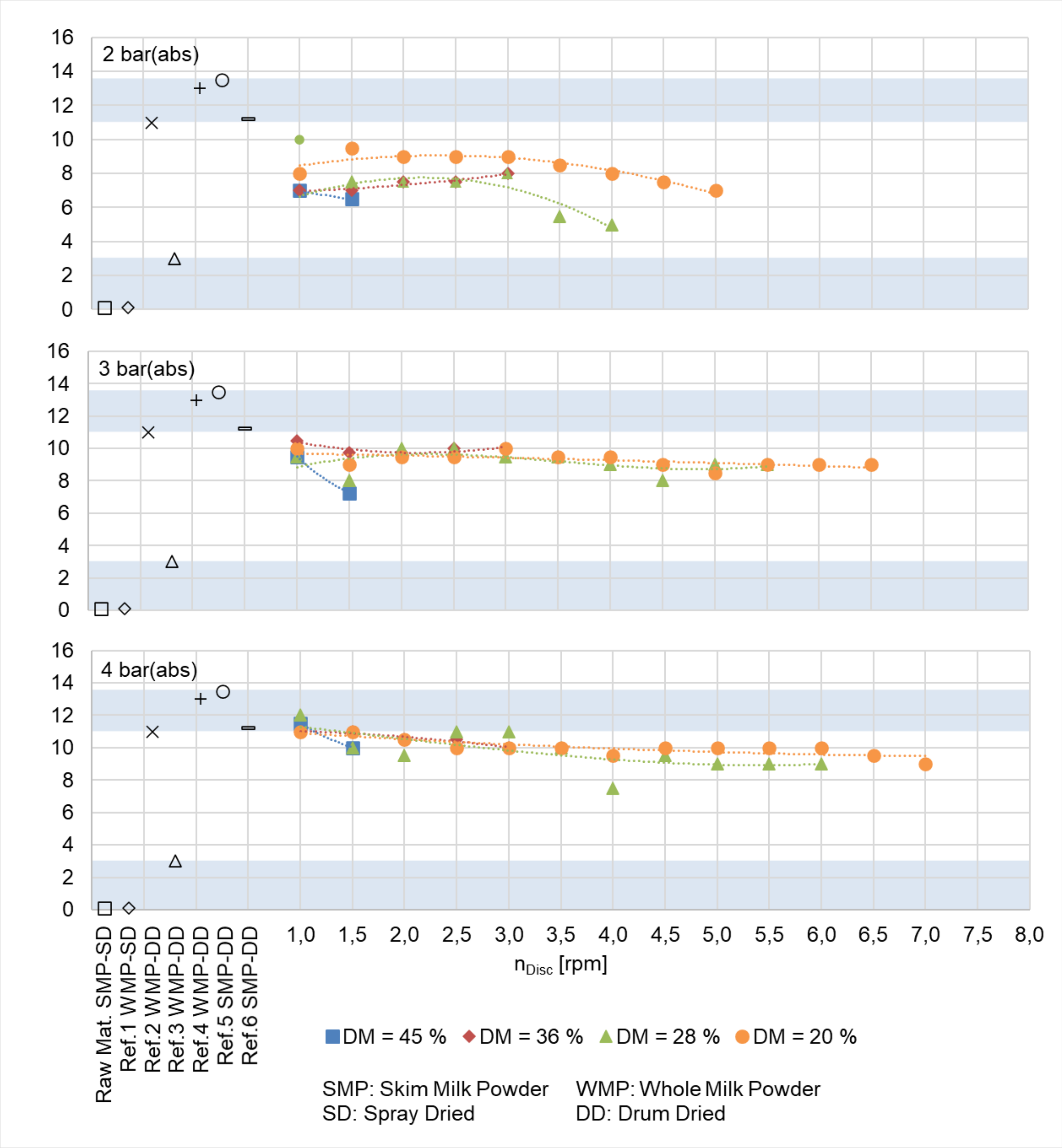

Diagram 4: Solubilities of the dried skimmed milk concentrates and reference samples.

The reference samples show a tendency that the spray-dried powders have a better solubility than roller-dried milk powders. The solubility of the powder samples dried with the CDry is more in the range of roller-dried milk powders. However, by increasing the speed, especially at low steam pressures, the solubility can be significantly improved compared to the roller-dried reference powders.

3.1.6 Color measurement

The color measurement of the powders produced is of great interest, especially with regard to the heat stress and caramelization reaction taking place and the evaluation of their intensities. The color of milk powders plays a role in applications where color is a significant property, for example when used in white instant drinks or white chocolate, or when used in browned products such as ice cream or chocolates.

The color measurements were made using an L*a*b colorimeter and the corresponding color measuring device for powdery samples. As an example, the L-value of various skimmed milk concentrates is shown here as a function of the speed. Here, too, particles of 100 µm
< x > 300 µm were examined.

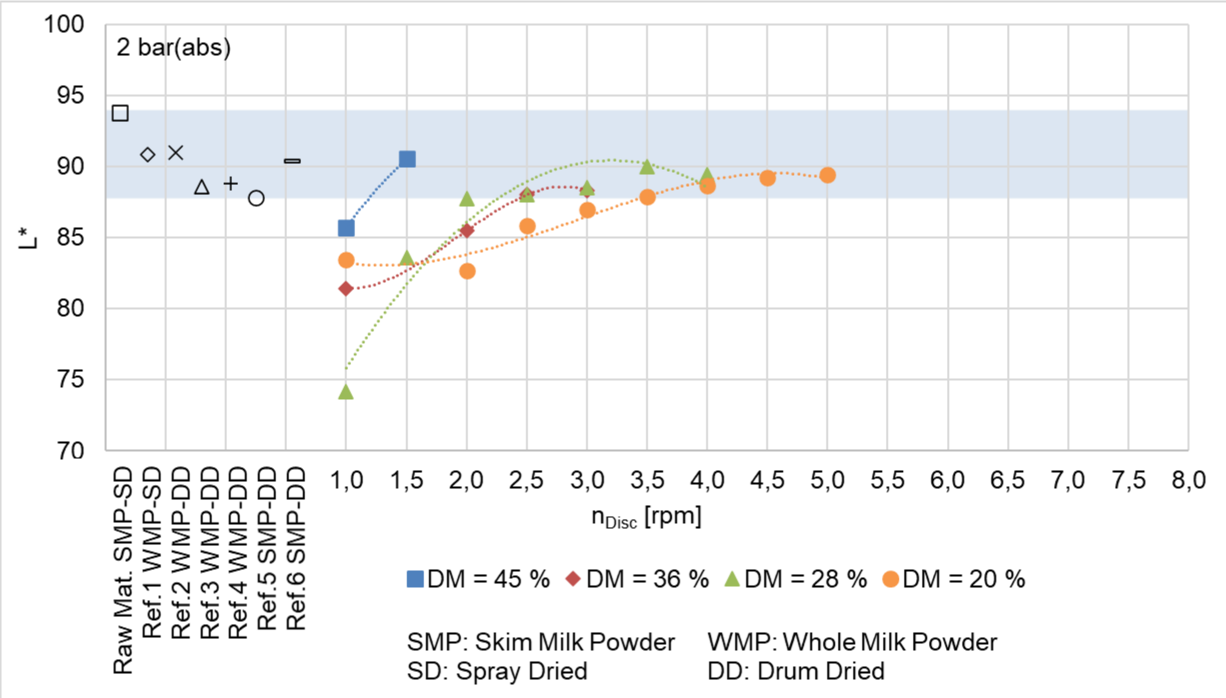

Diagram 5: Brightness (L-value) of the skimmed milk concentrates dried at the CDry and reference samples.

The investigations show that the disc speed has an effect on the brightness of the powders produced, while pre-concentration has a rather minor effect. At high disc speeds, i.e. short drying times, the resulting product is only slightly darker than the raw material. The difference is remarkably small when considering that the dry material was exposed to multiple heat loads due to the production of the reconstituted milk concentrates from powder that was initially already spray dried. At high speeds, apart from the raw material, there is no difference between the CDry products and the reference samples. A stronger browning of the powder occurs especially at low speeds. Thus, the brightness of the powder can be specifically influenced with the help of the speed. Since the color changes in the powder are largely caused by products of the Maillard reaction [17], this proves that CDry can be used to achieve targeted browning and caramelization of the milk powders.

3.1.7 HMF content

Besides the color change, the total content of 5-hydroxymethyl furfural (HMF) is an important chemical marker that maps the heat stress of milk powder. In addition, HMF within the Maillard reaction is a good marker of the advancing aromatization as well as the achieved caramelization of the milk proteins and lactose during drying [18]. In its statement of 2011, the Federal Institute for Risk Assessment does not see a particularly pronounced toxic potential in HMF, as it also occurs in large quantities in dried fruits and coffee, among other things. However, since the studies on the possible carcinogenicity of HMF differ internationally, the aim is to keep the HMF content in sensitive products such as baby food as low as possible [19]. In addition, the content of the essential amino acid lysine is lost as a result of the Maillard reaction.

The determination of the total HMF content was carried out according to the HPLC-DAD method of Hurtado et al [20] with a slight modification according to Tritscher [21]. As the sample capacity was limited, only samples from reconstituted skimmed milk with 36% dry matter, which was dried at 2 bar(abs) and 1-3 disc revolutions per minute, were analyzed.

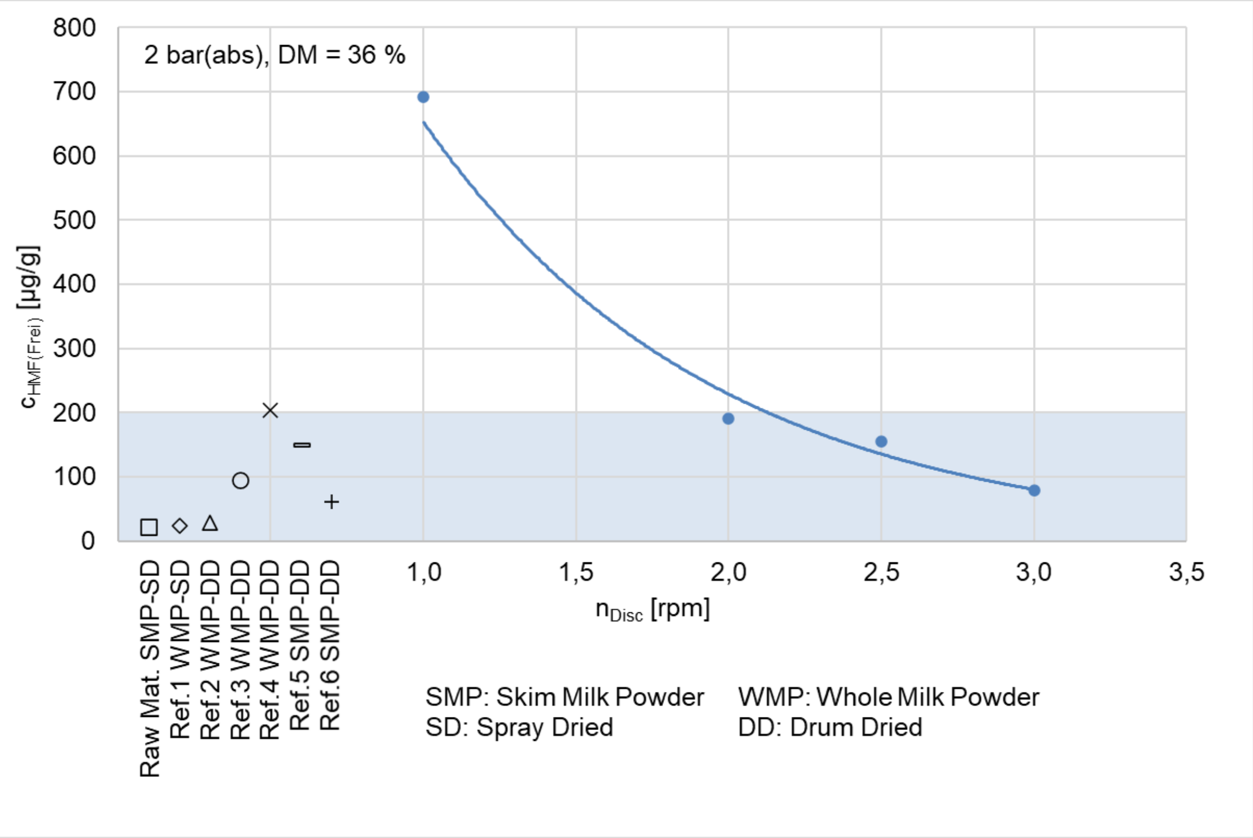

Diagram 6: HMF content of skimmed milk concentrates dried at the CDry and reference samples.

The spray-dried reference samples have a very low total HMF content, which is below the roller-dried powders. This confirms that spray drying tends to be less heat stressful than roller drying. The HMF contents of the CDry samples show a strong dependence on the speed. At lower rotational speeds and thus longer drying times, high HMF contents are achieved. This shows that CDry technology offers the possibility of exerting high and very high thermal effects on the powder to create specific flavours in the powder.

However, the CDry also offers the possibility of very gentle drying by increasing the speed and thus shortening the drying time. Above two revolutions per minute, no difference in HMF content could be detected compared to other roller-dried powders. While maintaining a maximum residual moisture of 5%, the speeds could be increased up to five revolutions per minute. Unfortunately, these samples could not be analyzed due to the limited analysis capacity. Based on the speed-dependent temperature distributions (Fig. 7), it can be assumed that the HMF concentration will continue to decrease with increasing speed. With the help of the speed, therefore it’s possibleto dry gently and to produce caramelized milk powder. This offers specialty manufacturers a wide range of possibilities for product customization.

3.2 Trials with reconstituted whole milk

3.2.1 Dirt pattern

The dirt pattern is another decisive property in the assessment of powder quality. Burnt particles in the milk powder or the products made from it, meet with consumer rejection, especially in the case of light-colored end products, and should therefore be avoided or reduced to a minimum.

The dirt pattern was determined according to the American Dairy Product Institute (ADPI) Scorched Particle Method, in which the sample powder is dissolved, cleaned and filtered. The dirt pattern on the filter paper is classified into categories A-D based on reference samples. A reconstituted 36-percent whole milk concentrate served as raw material.

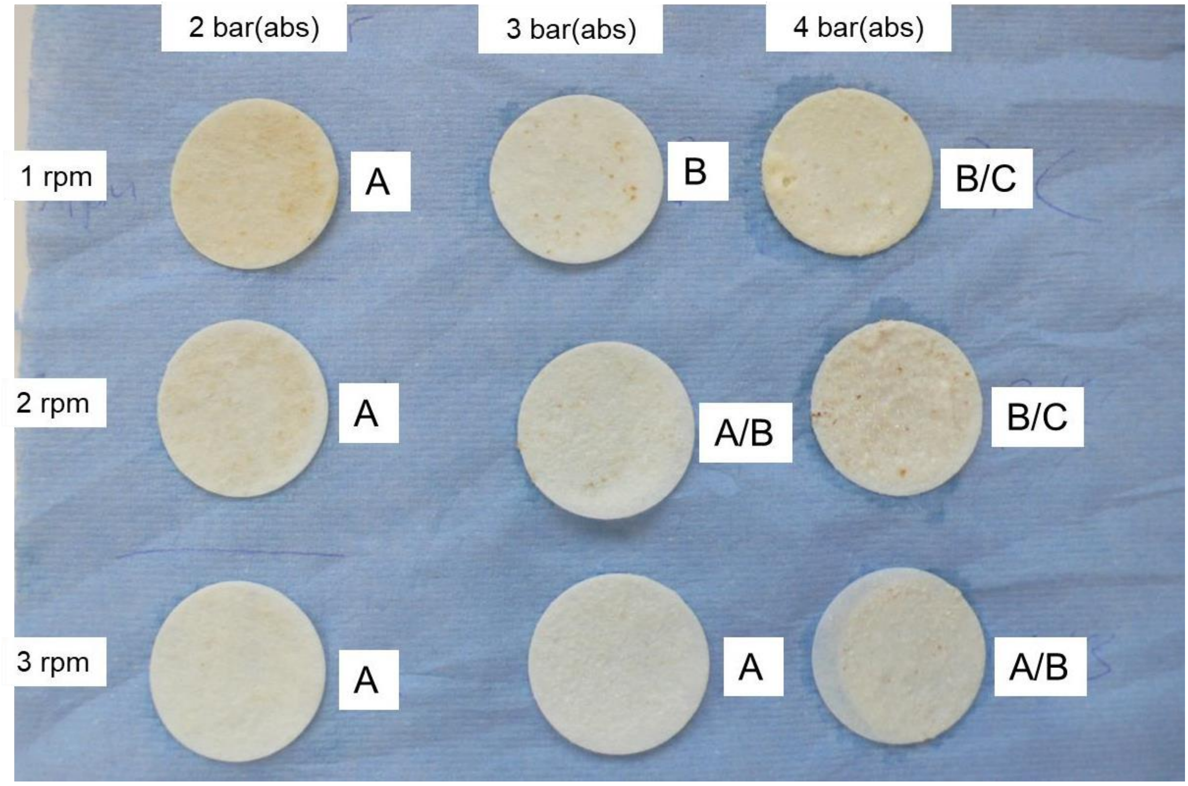

Figure 8: Dirt images (ADPI method) of the whole milk concentrates dried at the CDry.

It can be seen from the results on the dirt pattern that the degree of dirt tends to increase with higher heating steam pressure and lower disc speed. The best results are achieved when drying at low steam pressures and high speeds. As a rule, at least category B is specified for spray-dried powders and at least category C for contact-dried powders. Overall, therefore, all samples are in a very good range for contact dryers. This is mainly due to the very effective scrapers on the CDry food, which reliably remove the dried product from the dryer discs.

3.2.2 Free fat percentage

The free fat content plays a major role especially in the application of the powder for chocolate products. A high free-fat content improves the sensory properties of the powder and ensures lower energy consumption during conching [12]. As the general trend in the market is increasingly towards high-quality chocolate products, the free-fat content is also becoming more important.

The free fat content was determined by extraction with diethyl ether in the Soxhlet apparatus according to DIN 12602 and subsequent distillation of the solvent. The total fat content was determined according to the Roese-Gottlieb method. A whole milk concentrate reconstituted from a spray-dried powder with a dry matter content of 36 % was investigated, which was dried with the CDry at a heating steam pressure of 4 bar(abs).

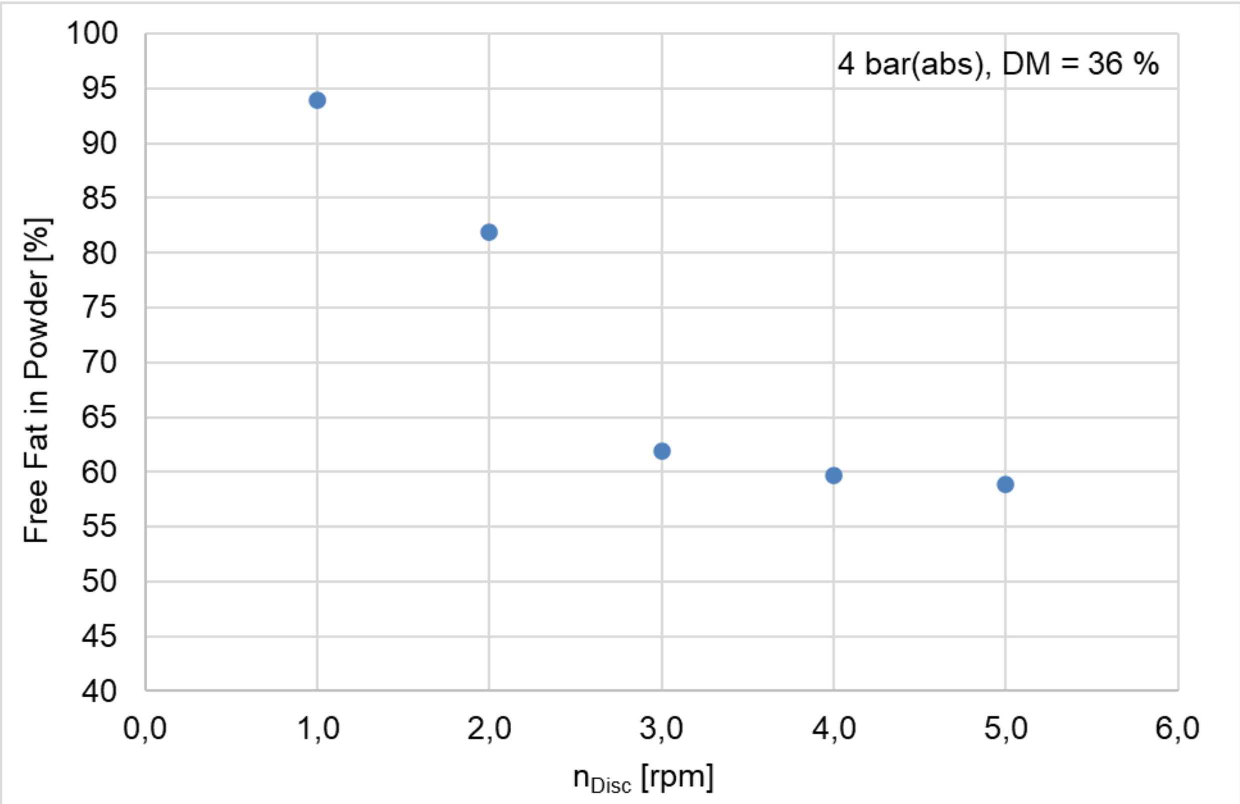

Diagram 7: Free fat content of whole milk concentrates dried on the CDry as a function of the disc speed.

The total fat content in the whole milk powder is approx. 26 % based on dry matter, while the free fat content varied between 59.7 % and 93.3 %. The free fat content shows a strong dependence on the speed. The higher the speed was set, the lower the free fat content. This offers a very interesting individualization option for a wide variety of end products, especially for the chocolate industry.

3.3 Tests with whey concentrate

3.3.1 Influence of drying on the microbial load

The microbial load in the powder, in combination with the moisture or water activity in the powder, has a very great influence on the storage stability and shelf life of the products [8]. In addition, depending on the application, e.g. when used in baby food or sausage products, a high initial germ load is problematic. It is therefore highly desirable to reduce the microbial load as much as possible during the drying step.

To determine the bacterial count reduction, a whey concentrate with approx. 10 % dry matter was examined as a liquid product before drying and the powder after drying with the CDry. Drying was carried out at 3 bar(abs) and at 2 disc revolutions per minute.

	Concentrate before drying [CFU]	**Powder after drying [CFU]**	**Method**
Total germ count	$2{,}3*10^{9}$	$2*10^{3}$	MUVA-MET509 according to L00.0-88/1:2015-06, ASU according to §64 LFGB
Thermophilic germs	< 10	< 10	MUVA-MET552 Rev. 3 2020-04(a)
Yeasts	$3{,}2*10^{4}$	< 10	MUVA-MET543 according to L01.00-37:1991-12. ASU according to §64 LFGB (a)
Mould	< 10	< 10	MUVA-MET543 according to L01.00-37:1991-12. ASU according to §64 LFGB (a)

Aerobic spore formers	> $3*10^7$	< 10^3	MUVA-MET526 according to VDLUFA M7.17.2:1993 (2. Erg) (a)
Coliform germs	> $2*10^7$	< 10	MUVA-MET533 according to L01.00-3:1987-03 ASU according to §64 LFGB (a)
Thermophilic aerobic spore formers	< 100	< 10	MUVA-MET595 according to VDLUFA M7.17.2: 1993 (2.Erg.) (a)

Table 1: Germ count reduction by drying whey concentrate with the CDry.

With 2.3*109 CFU, the total germ count before drying was very high. After drying, all germination rates examined were significantly reduced. The total bacterial count was reduced by approx. 6 log levels to 2*103 CFU. The number of coliforms, which can cause severe gastrointestinal diseases in humans, was particularly high at > 2*107 CFU before drying. Here, too, a reliable reduction of approx. 7 log levels was achieved. In conjunction with the low residual moisture, microbiological stability of the powders produced can therefore be expected even with high initial bacterial counts. Since the values achieved are strongly dependent on the product composition, they cannot be easily transferred to other products or to other, e.g. large-scale production conditions, but they do show a good tendency.

4 Summary and outlook

The CDry contact disc dryer for drying liquids was presented by Allgaier at ACHEMA 2018 and was awarded a place in the Short List as part of the ACHEMA Innovation Awards. Since then, the CDry has been successfully established in the chemical industry.

The innovative technology is now also fully available for the food industry. While retaining the proven functional principles, the dryer has been elaborately further developed for the food sector in strict compliance with the current Hygienic Design Guidelines of the EHEDG.

The CDry food meets all the requirements of a modern, safe and easy-to-clean drying system for the food industry. In cooperation with the Institute for Food Process Engineering and Powder Technology at the University of Hohenheim, the Neubrandenburg University of Applied Sciences and several industrial partners, extensive series of tests were carried out on the drying of skimmed milk and whole milk concentrates. Within these tests, influences on the powder properties, such as the disc temperature, the disc speed or drying time as well as a pre-concentration of the milk concentrate to be dried were investigated and evaluated. The influences of the above-mentioned process parameters on powder properties relevant to the food industry, such as residual moisture, bulk density, solubility and color, were determined. The HMF content and the color changes in the dry product allow conclusions to be drawn about the intensity of the Maillard or caramelization reactions that take place during drying. The investigations of the HMF content confirm that, depending on the setting of the process parameters, the CDry food can be used both for gentle drying and for targeted caramelization and flavoring of the milk powder. In addition, the free fat content and the dirt pattern were determined on the produced whole milk powder samples. The reduction in the bacterial count due to the drying process was investigated based on the drying of a whey concentrate.

The investigations show that the CDry is very well suited for drying milk-based products. The properties usually specified in the dairy sector can be reproducibly adjusted. In addition, the achievable powder properties go beyond those attainable with conventional processes, which offers producers a wide range of customization options for the powders and end products. The investigations on milk drying serve as an example of the diverse application possibilities of CDry in the food industry.

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