Improving performance of high fat containing and soft powders with AEROSIL® and SIPERNAT® products

Technical Information TI 1405

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Improving performance of high fat containing and soft powders

Powdered ingredients are used increasingly in many industries. A good flowability in the food and feed industry is essential for handling powders properly, discharging them easily from a silo and dosing them exactly. However, many powders are highly cohesive and the proper processing therefore is a challenge. Additionally many powders tend to cake on storage or during transportation due to climate conditions or pressure.

Examples of ingredients, which benefit from SIPERNAT® and AEROSIL® products:

- Milk powder for ice cream, chocolate or other flavored milk drinks
- Non-dairy creamer for cappuccino or instant coffee
- Flavors or extracts with a high oil or fat content
- Fat supplements for calf-feed

Advantages of using SIPERNAT® or AEROSIL® products to optimize flow and reduce caking of fat containing powders include:

- **Optimized flow:**
  Improved dosing of ingredients
  Better mixture handling
  Increased convenience for end customers
- **Reduced caking:**
  Maintenance of quality during shelf life
  No lumps means easier preparation of the product

Fundamentals on flow aids

All particles stick together by Van-der-Waals forces as shown in **Figure 1**. For small particles these Van-der-Waals forces are much stronger than the gravitational forces which pull the particles apart and produce the powder flow. Therefore fine powders flow badly.

Flow aids are very fine powders that can cover the surface of the host powder to create a surface roughness on the powder particle. A surface roughness reduces the attraction forces between two powder particles. AEROSIL® fumed silica and SIPERNAT® specialty silica are perfectly suited to cover the surface of particles, keeping them apart, and thus reducing the attraction forces.

This is one of the reasons why they are highly efficient flow aids and anti-caking agents. This effect is shown in **Figure 2**.

In this brochure the term 'caking' is used as a time related decrease in flowability, which in extreme cases can lead to the formation of one solid 'cake' after a long storage time. Correspondingly the term 'anti-caking agent' is used in the sense of a flow agent which can preserve a good flowability for powders that are stored over a long period of time.

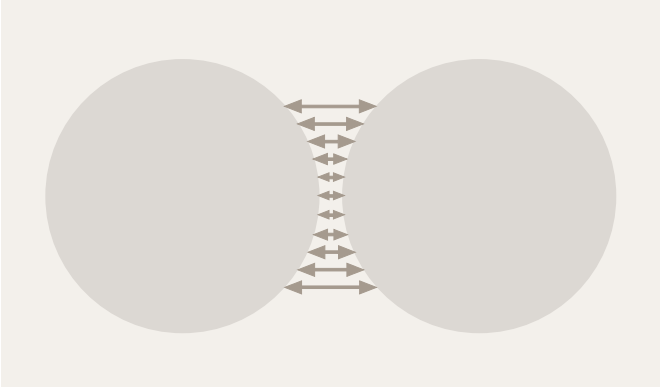


Figure 1 Particles sticking together by Van-der-Waals forces

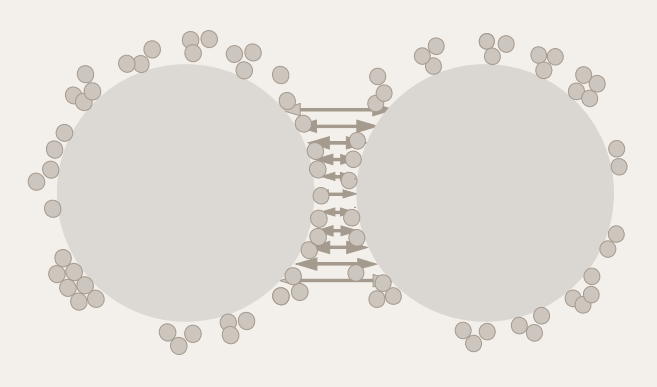


Figure 2 AEROSIL® fumed silica resp. SIPERNAT® specialty silica cover the host powder's surface and act as a spacer

Flow- / anti-caking aids for soft powders:

Powders of soft materials such as fats, milk powders with a high fat content or emulsifiers are especially challenging in handling and transport. Especially on long term storage or transport time they tend to cake heavily.

The problem becomes even worse when the product is exposed to changing temperatures – which can easily happen during sea transport. An efficient anti-caking aid is therefore a prerequisite when such powders are shipped for long distances. Soft or thermoplastic powders are deformed at rising temperature or when pressure is applied and stick together as shown in **Figure 3**.

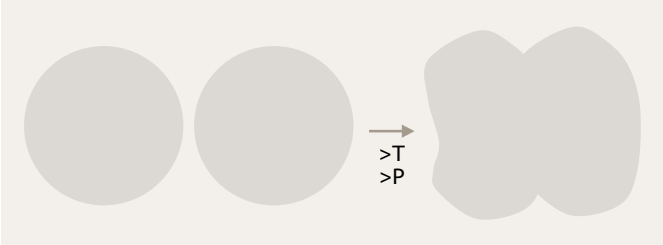


Figure 3 Soft or thermoplastic particles stick together as they are deformed on pressure and rising temperature

Silica can cover the soft powders' surface and prevent the particles from sticking together. In contrast to hard powders, however, higher addition levels of silica are needed to achieve this effect, especially when a long lasting anti-caking effect is required. Usually addition levels of silica in soft powders can be up to 5 %, whereas in hard, dry powders addition levels below 1 % are often sufficient. The reason is that part of the anti-caking agent may penetrate into the soft powder's surface on storage and thus loose its efficiency. When an adequate amount of anti-caking aid is added, enough will stay on the surface of the soft powder particle and the efficiency is preserved. This effect is shown in **Figure 4**.

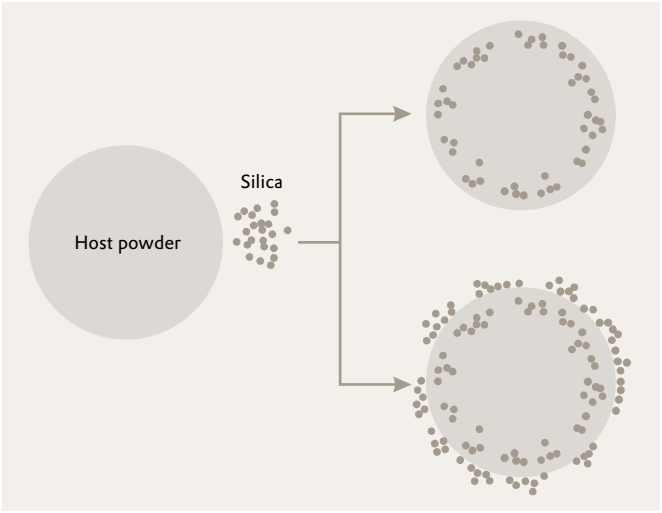


Figure 4 Soft powders capture part of the anti-caking aid

Case study A:

Improving performance of high fat containing milk cream powder

SIPERNAT® specialty silica and AEROSIL® fumed silica are commonly used in the food and feed industry to increase the flow of powdered ingredients including high fat powders. A high fat content can make it difficult to spray dry products and lead to poor flow characteristics, which, in turn, leads to a difficulty in manufacturing, conveying and packaging the high fat containing powders. For example, it can be quite difficult to fill it into bags, FIBC and containers.

1 Design of Experiment done on milk cream powder

Recently we worked on a project to improve flowability and reduce caking tendency of milk cream powder. It is used for example in preparing ice cream powder or feed for fattening calves. Tests were undertaken with the objective to evaluate if mixed blends of silica and TCP* (Tri-Calcium-Phosphate) show synergistic effects regarding free flow, anti-caking or dustiness. The model substance was cream milk powder with a high milk fat content of 42 % from the company Nöll & Co GmbH, Germany it was tested out by using a DOE (design of experiments). Variables included: Mixing times, silica grades, concentrations and mixing ratios of TCP and silica (see next page, **Figure 9**).

Used flow- / anti-caking aids

SIPERNAT® 50 S, specialty silica,
SIPERNAT® 350, specialty silica,
AEROSIL® 200 F, fumed silica,
Evonik Industries AG, Germany

* TRI-CAFOS MF, Tri-Calcium-Phosphate (TCP), Chemische Fabrik Budenheim KG, Germany

2 Test methods

2.1 Flowability

A quick method to classify the flow grade is by means of flow funnels. A defined set of flow funnels with different outlet diameters is used (**Figure 5**). The lower the flow grade, the better the flowability.

Figure 5 Glass funnels
(Available at Evonik Industries AG upon request)

2.2 Caking

Material is poured into a sleeve. A cylinder fitting exactly into the sleeve is inserted. (**Figure 6**)

Figure 6 Storage cylinders

The duration of the compression load, as well as storage conditions, for example high temperature or humidity, can be simulated in a climate chamber.

After storage, the inner cylinder is removed carefully leaving a compacted tablet.

The force that is required to scratch off a certain layer of the formed tablet can be measured and gives an indication of the caking tendency and hardness of the material (**Figure 7**).

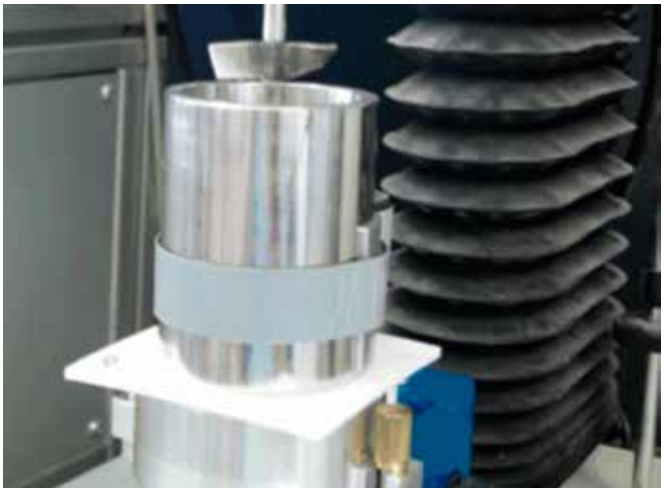
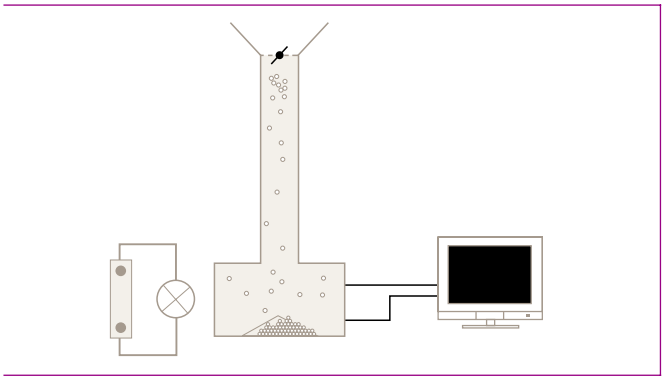


Figure 7 Measurement "Scratch test"

2.3 Dustiness

Dustiness was determined with a Palas® DustView system (**Figure 8**). Dust measured by the extinction of a laser beam. The dust value is calculated from the dust amount measured at 0.5 sec and at 30 sec.

Figure 8 Palas® DustView



2.4 Experiments done on cream milk powder

Figure 9 Experiments done on cream milk powder

Test No.	Addition Flow aid [%]	Mixing Time [min]	Concentration Silica [%*]	Proportion Silica: TCP
1	0.9	9	20	1 : 4
2	0.9	3	20	1 : 4
3	0.3	9	20	1 : 4
4	1.1	6	50	1 : 1
5	0.6	1	50	1 : 1
6	0.6	6	0	TCP only
7	0.1	6	50	1 : 1
8	0.6	11	50	1 : 1
9	0.3	9	80	4 : 1
10	0.9	9	80	4 : 1
11	0.3	3	80	4 : 1
12	0.6	6	50	1 : 1
13	0.9	3	80	4 : 1
14	0.3	3	20	1 : 4
15	0.6	6	50	1 : 1
16	0.6	6	100	Silica only
17	0.6	6	50	1 : 1

* in the flow aid mixture, leftover is TCP

3 Findings that help to facilitate handling and storage of milk cream powder

Summarizing the results of our comprehensive studies, we learned how to ease handling of fatty powder, such as cream powder, without causing disadvantages on the other hand, namely dust generation.

Generally it was possible to get a good anti-caking effect together with a lower dust level or a good flowability. The combination of silica and TCP in some tests showed better results than using the single ingredients only.

For example, SIPERNAT® 350 and AEROSIL® 200 F were most suitable to avoid caking in cream powder and improve the flowability at the same time. SIPERNAT® 50 S only improved the flowability however did not improve the caking behavior.

Another advantageous blend was 0.6 % flow-aid addition of a 1 : 1 mixture of SIPERNAT® 50 S and TCP which showed an superior flowability and anti-caking in comparison to the addition of comparable concentrations of TCP or SIPERNAT® 50 S alone. The mentioned combination achieved this good powder behavior already after a very short mixing time of only one minute, thus allowing to shorten overall processing times resulting in an increased throughput.

On the other hand, flow aids such as 0.6 % TCP used on its own showed a very poor performance to improve flowability of cream milk powder.

Figure 10 SIPERNAT® 350, 50 S, AEROSIL® 200 F and TCP

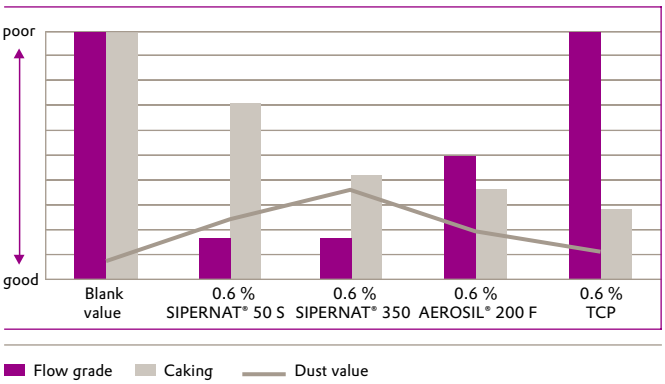


Figure 11 SIPERNAT® 50 S, TCP and mixture of both

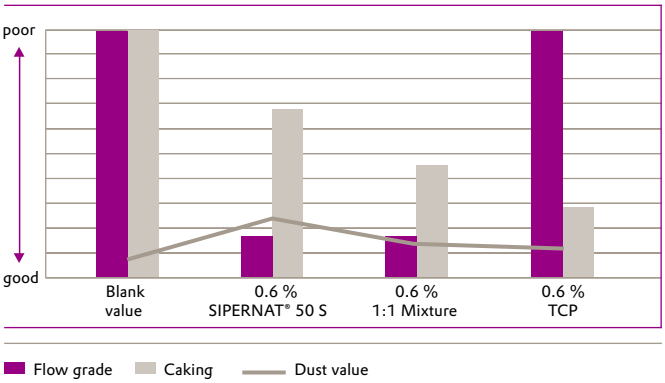


Figure 12 SIPERNAT® 350, TCP and mixture of both

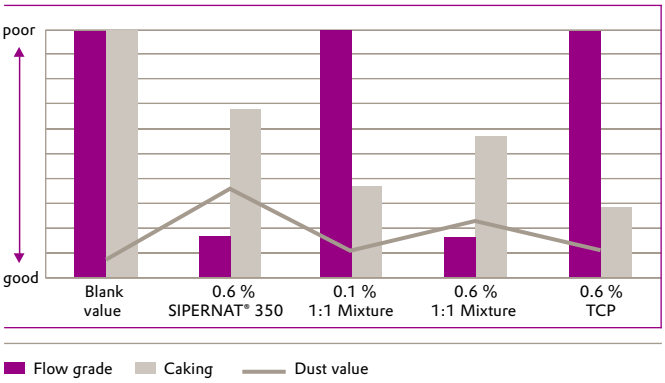
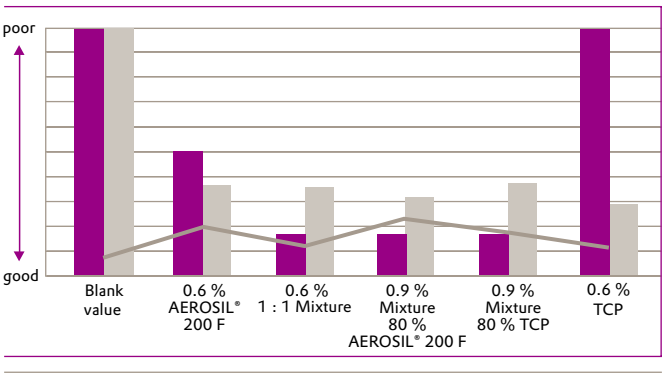


Figure 13 AEROSIL® 200 F, TCP and mixture of both



Summary of Results

- AEROSIL® 200 F in combination with TCP is most efficient in improving flowability and ensuring this over a long storage period (**Figure 13**; test no. 2, 5 and 13 of **Figure 9**)
- SIPERNAT® 350 and 50 S are very suitable in improving flowability (**Figure 10**; test no. 16 of **Figure 9**)
- SIPERNAT® 50 S combined with TCP is the optimal flow aid whenever short mixing times, thus short processing times are key (**Figure 11**; test no. 5 of **Figure 9**)
- A 1 : 1 Mixture of SIPERNAT® 50 S and TCP improved the flowability and anti-caking effect. The dustiness was almost the same like the blank value (**Figure 11**; test no. 5 of **Figure 9**)
- SIPERNAT® 350 S and a mixture with TCP improved the flowability (**Figure 12**; test no. 5 and 16 of **Figure 9**)

3.1 Why it is so difficult to reach a good flowability and anti-caking effect at the same time?

On one hand a good flowability causes a higher density, due to the effect that the particles are closer together because of the better flowability, on the other hand it is easier for the particles to stick together when loaded with a weight (e.g. the lower layers on a pallet) due to the closer distance between the particles.

3.2 Dustiness

The dustiness sometimes is a little higher with silica than with TCP, however in the same low range.

The topic of free flow, anti-caking on one side and dustiness on the other side always has the conflict between separated particles that causes more dustiness, or sticky and agglomerated particles that cause no dust but cakes strong and show a poor flowability.

Finally it depends on the customers preferred aim if improved flowability and anti-caking or less dustiness in your product has priority.

4 Improving performance of fat powder

Fat powders are soft, sticky and generally not easy to handle. AEROSIL® fumed silica and SIPERNAT® specialty silica are perfectly suited to cover the surface of fat particles, keeping them apart and reduce the stickiness. When coated with a complete layer of fine grinded silica flowability is improved, caking during storage can be prevented and the fat is more stable against pressure. The SEM pictures (scanning electron microscope) in **Figure 14** and **15**, show palm fat without and with SIPERNAT® 350.

4.1 Test results on palm fat powder

An addition of 3 % SIPERNAT® 350 covers the fat particles (BergaFat F-100) completely with a closed layer of silica (see **Figure 15**) this leads to a very good anti-caking effect. Advantage is that the fat particles do not stick together and also after a longer storing period a free flow is possible.

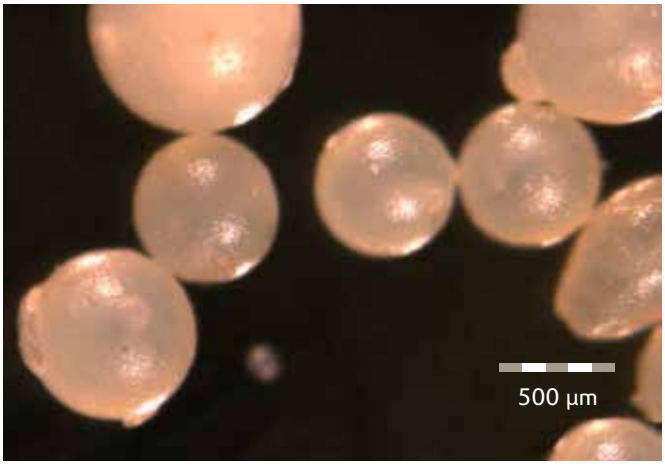


Figure 14 BergaFat F-100 without anti-caking aid (palm fat, Berg + Schmidt, Germany)

Figure 15 BergaFat F-100 coated with 3 % SIPERNAT® 350

4.2 Test results on powder with 80 % fat content

A short mixing time and 1.15 % SIPERNAT® 350 or 22 S improved the flowability of a fat powder (DP Supply Fattics 80 PAU) from a worse flow grade to a good flow grade. The same concentration TCP (customer sample) improved the flowability to a medium flow grade, only (see **Figure 16**).

Although it is possible to decrease the caking tendency obviously by the use of silica or TCP, it is not possible to prevent caking of fat powder completely with an addition of 1.15 % flow aid. An addition of 1.15 % SIPERNAT® 350 reduces the caking barely half. An addition of 0.5 % SIPERNAT® 50 S reduces the caking tendency even a little better than 1.15 % TCP (see **Figure 17**).

Figure 16 Flowability of fat powder

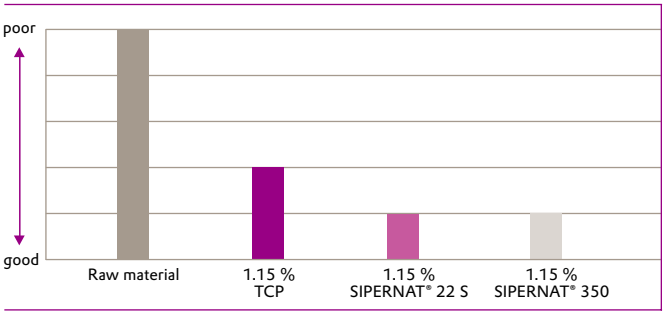
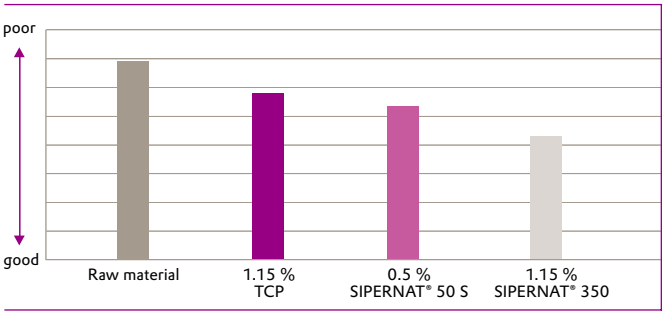


Figure 17 Caking tendency of fat powder



5 Conclusion

SIPERNAT® and AEROSIL® products improve flowability and avoid caking of powder products enabling convenient handling and dosing with minimized dustiness for you and your customers.

It is important however to find out the most suitable silica grade and application conditions such as; like mixing speed and time, flow aid concentration etc. by testing.

Our applied technology, available in Asia, Europe and the US will be glad to support you.

Food additive certification

www.sipernat.com, www.aerosil.com

All hydrophilic SIPERNAT® precipitated synthetic amorphous silica as well as all AEROSIL® fumed synthetic amorphous silica mentioned in this brochure comply with 21 CFR (Code of Federal Regulations, USA) §§ 172.480. Silicon dioxide is listed as "anti-caking agent" which "may be safely used at a level not exceeding 2 %".

The mentioned hydrophilic SIPERNAT® precipitated synthetic amorphous silica as well as the mentioned hydrophilic AEROSIL® fumed synthetic amorphous silica are in line with food additive requirements for E551 according to EU-directive 2008/84/EC, as we know from typical data.

Kosher and Halal certificates are available on request.

SIPERNAT®- and AEROSIL® products as flow agents are produced according to HACCP and FAMI-QS guidelines and are offered over the broadest range of properties on the market. Typical AEROSIL® fumed silica and SIPERNAT® specialty silica used for free flow application in the food and feed industry include:

SIPERNAT®- and AEROSIL® grades

Silica	Surface area [m^2/g] (N_2), Multipoint following ISO 9277	DOA*-absorption [g/100g] internal method	Particle size [µm] (d_{50}) Laser diffraction following ISO 13320
SIPERNAT® 22 S	190	240	13.5
SIPERNAT® 50 S	500	290	18
SIPERNAT® 350	55	170	4.5
AEROSIL® 200 F	200 ± 25	255	41 **
AEROSIL® 380 F	380 ± 30	290	33 **
SIPERNAT® D 17	100	170	10

* DOA = Dioctyl adipate, the numbers show the absorption capacity of a product, higher numbers means a larger absorption capacity, measured on original substance

** Coulter LS 230 dry powder module

SIPERNAT® D 17 is Evonik's hydrophobic silica approved for feed applications
SIPERNAT® D 17 is not allowed in food applications

The given data are typical values. Specification on request.

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