ENERGY-EFFICIENT COSMETICS PRODUCTION

A guideline with:

5 efficiency concepts

Results from three Swiss cosmetics companies

Instructions for action

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Guideline for energy-efficient cosmetics production

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Use

This guideline is aimed at those responsible for and those carrying out product development, formulation and production of cosmetic emulsions. The guideline consists of a main part that is freely available to the Swiss cosmetics industry and a detailed appendix (parts A and B) with detailed background information, which can be obtained free of charge from the authors upon request.

Disclaimer

This guideline is not legally binding. The authors assume no liability for the completeness and accuracy of the content, or for risks arising from the implementation of instructions for the efficiency concepts. This guideline was created in German, French and English and is available for download from EnergieSchweiz and the SWISS SCC.

ABSTRACT

The first step on the road to decarbonization is increasing energy efficiency. To this end, three Swiss cosmetics companies, the Lucerne University of Applied Sciences and Arts (HSLU), the Zurich University of Applied Sciences (ZHAW), and the company Kinematica AG, with funding from the Swiss SCC and Energieschweiz, have developed this guideline within a two-year project. Cosmetic products and their manufacturing processes are complex. The authors have compiled the many years of experience of the people involved and clearly sorted the approaches to optimizing energy consumption and resource use in cosmetic production into five efficiency concepts (EC). As an introduction, a procedure for safe scale-up was established in the participating cosmetics manufacturing companies. A three-stage quality control was used to accompany this. The companies were able to achieve immediate energy savings of around 30%. These were possible without any investments and were also associated with productivity increase and cost savings. The companies involved so far have extensively expanded their internal communication between R&D and production. SOPs now contain additional process parameters, such as shear rate and energy input. As part of this project, all three companies involved have significantly increased their sustainability in production and are on the way to completely CO_2-neutral production.

This document is divided into two parts. The first part presents the efficiency concepts, the results achieved and lists simple instructions for action. In addition, detailed regulations for scale-up and quality determination are given. The very extensive appendix provides interested users with all the necessary background information, theory and suggestions for evaluations. This means that the efficiency concepts can be implemented in any company.

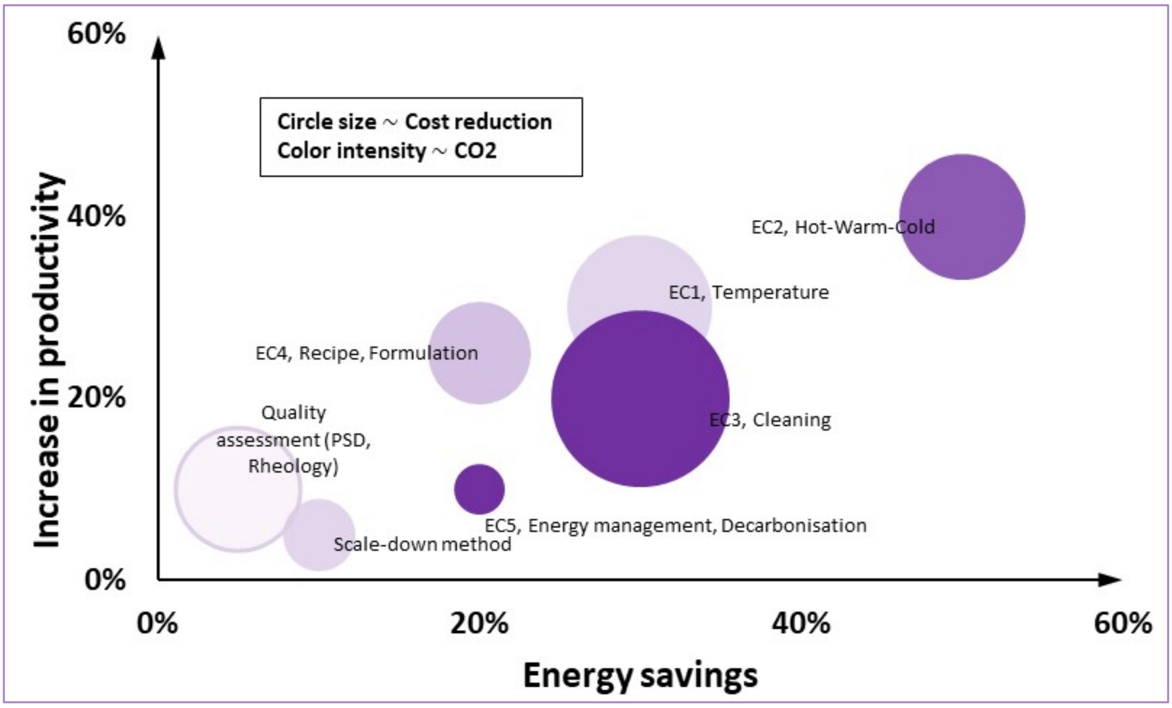

Figure 1 Overview of the possible energy savings and productivity increases with the efficiency concepts (EC) documented in this guideline. The bubble size symbolizes the "amount" of possible cost savings and the color intensity reflects the potential for CO_2 savings; the darker, the greater.

The energy saving potential was determined for an example case of a batch size of 1000 kg and without investments and is shown in Figure 2.

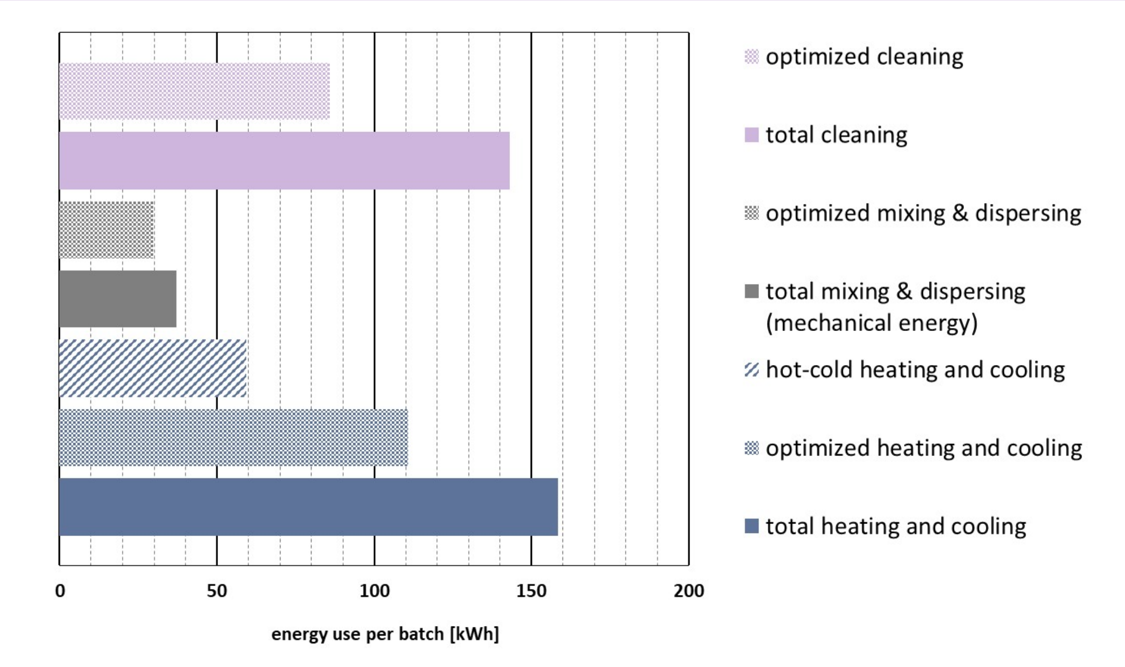

Figure 2 Concrete savings potential for a batch of 1000 kg.

The authors and companies involved were amazed by the huge savings potential, particularly in cleaning (see Figure 3). The costs, particularly due to product loss, are high and can be easily reduced without investments of the order of CHF 50 or more per batch.

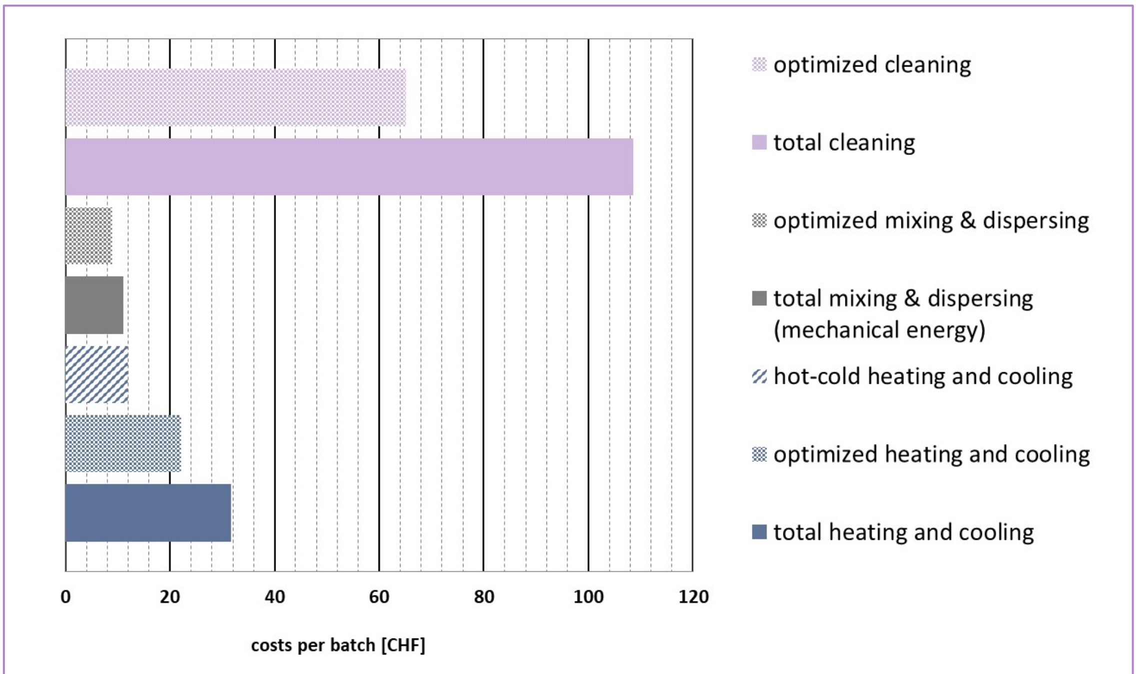

Figure 3 Concrete savings potential for a batch of 1000 kg.

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INTRODUCTION

In 2015, the member states of the United Nations adopted the 2030 Agenda with 17 Sustainable Development Goals (SDGs). SDG 12 is dedicated to the efficient use of energy and sustainable production. Politicians and companies have set themselves the goal of reducing CO_2 emissions. EnergieSchweiz estimates the energy saving potential in companies to be between 20 and 40 percent, depending on the industry.

Within the cosmetics industry, the demand for sustainability is being pursued at various levels. The market demand for "clean" or "conscious beauty" is increasing. Interesting articles on holistic sustainability and how the cosmetics industry or industry associations support their members can be found in a special edition of the IFSCC magazine (Vol25/3, 10/22, www.ifscc.org). In addition, there is considerable energy-saving potential in the cosmetics industry, as many manufacturing processes, especially the hot/hot process, are still energy-intensive.

This guideline aims to optimize and reduce the process-related aspect of energy consumption in the cosmetics industry. The efficiency concepts described in this document are based on many years of research and development by the authors.

The knowledge gained often leads to further questions. Not all follow-up questions that arose during this industrial cooperation project could be fully answered, particularly colloid chemistry questions. Statements on long-term stability were not the focus of this project; rather, short-term assessments were carried out. Since emulsions are thermodynamically unstable and slowly changing systems, the quality measurements always only represent snapshots.

The project follows the approach of examining existing recipes of established commercial products and transferring them to the laboratory plant using a clear scale-down procedure. Optimizations are carried out on a laboratory scale. This is followed by a safe scale-up to production sizes (up to a maximum of 2500 kg). Quality measurements confirm successful improvements.

Often there is little time within day-to-day business for series of tests to reduce energy consumption. However, a significant side effect of the efficiency concepts is the time saved in production! One goal of this project is to motivate and enable employees in the development and production teams to implement process changes with manageable effort. With the findings from this project, the authors offer a practical approach to implementing energy savings in the cosmetics industry.

METHOD

This guideline is based on an initiative of the Lucerne University of Applied Sciences and Arts (HSLU), the Zurich University of Applied Sciences (ZHAW) and the Swiss Society of Cosmetic Chemists (SWISS SCC), with the support of EnergieSchweiz, the Energy Lab and the companies La Prairie AG, Frike Group, Steinfels Swiss and Kinematica AG; all from Switzerland. The overall goal is to modify the manufacturing process of cosmetic emulsions to reduce energy consumption and the CO_2 footprint. Modern and skillful process management and the use of innovative methods and recipes can save costs, resources and energy in the manufacture of cosmetic products.

Based on years of research by the authors, five efficiency concepts were identified, precisely defined and applied in this work. These concepts include approaches to optimizing energy consumption in cosmetic production and are: temperature control, hot-warm-cold, cleaning, recipe & formulation and energy management & decarbonization.

In an application-oriented project, these methods were applied, trained and established at the above-mentioned cosmetics companies. The university project team trained the employees of the cosmetics companies on site according to the specific circumstances and accompanied the implementation. Each company set different priorities. On average, three to four of the five possible efficiency concepts were pursued and implemented internally. All planned measures were selected according to potential energy and OPEX (operating costs) savings and low or no CAPEX (capital costs). On-site workshops enabled employees to produce test batches themselves, which were then further processed and analyzed by the universities. The entire team will continue to raise awareness of energy optimization in the future. The knowledge generated will be used for future recipe developments. Great attention was therefore paid to regular and adequate communication between employees on site and remote. In addition, by promoting internal communication, existing industry and company knowledge (empirical values) should be exchanged and recorded, confirmed or corrected on a scientific basis.

After various preliminary discussions with the management and the designated project managers in the companies, the extent of time resources was estimated. One or two standard recipes of the type oil in water (O/W) were determined and scheduling agreements were made based on their production planning.

In a detailed, all-day workshop, the development and production teams were theoretically prepared for their tasks and then given practical training in the operation. This often required a tour of the production department to record the technical parameters of the homogenizers and all the production equipment. So-called "Hydro Test Run" were carried out in preparation for measurements of the energy input on laboratory mixers and production machines. This approach allows understanding various aspects such as energy input or other performance characteristics without using the actual product materials.

The main investigations in the companies' plants were preceded by various preliminary tests and radical experiments in the university laboratories. For example, temperature reductions of 30°C in the water phase (to just 50°C) while maintaining the lipid phase temperature at 80°C, reversals of the mixing sequence (water to oil or vice versa) and variations in the order of emulsifier addition (Continental vs. English method) were part of semester and student work.

Finally, the primary investigations at the partner companies focused on analyzing existing production recipes from the treated O/W emulsions and adapting them for the laboratory plant through a well-defined scale-down procedure. Optimizations were then carried out on the laboratory scale, leading to energy savings. This was followed by a safe scale-up to production sizes (up to a maximum of 2500 kg). Quality measurements confirmed successful improvements.

To facilitate these transitions, a clear scale-down/scale-up methodology and comprehensive quality control procedures were first defined and implemented in the three manufacturing plants. Handouts and spreadsheets were prepared for the companies involved, with the final version included in the appendix to this guideline.

The O/W emulsions treated here had oil phase concentrations between 10 and 30 percent with different amounts of fatty alcohol. The oil phase components were analyzed using differential scanning calorimetry (DSC) to determine the maximum temperature required for heating. To ensure the existing quality in the scale-down process, particle size distributions were determined, rheological and sensory tests (difference tests) were recorded and compared with samples from conventional production for differences.

To ensure the confidentiality of the company's internal data, each company opened its own SharePoint. The measurement data was stored there, which the university partners then analyzed, cleaned and transferred to their data sets in an anonymized form. None of the companies were given access to the other companies' data. The collaboration was concluded in advance in a cooperation agreement between the universities and the individual companies.

Since this project had to be carried out in parallel with the day-to-day business of the companies (personnel resource planning) and the scale-up experiments with modified process parameters required free gaps in the production plan, the average processing time in each company was between 6 and 18 months. The goals achieved in the meantime were presented and discussed upon request to each company. A final presentation with documentation was carried out for all of them so that as many employees as possible were informed and trained again.

After the data sets for the individual companies were prepared, they were reviewed for this document. This document contains detailed background information and concrete examples from the project, particularly in the appendix. The aim is for every reader to be able to implement the concepts in their own company and increase energy efficiency.

At the same time, the dissemination of the findings has begun to reach as many people in the industry as possible. Initial results were presented at the continuing education event of the Swiss Society of Cosmetic Chemists (SWISS SCC) on September 14 2022, in Olten entitled "The Economy of the Future - Energy Efficiency in Development and Production as Part of Sustainability". The possible implementation in the industry was critically discussed: How much sustainability would be possible in individual companies and what could the industry contribute to this? Many questions were asked about energy efficiency in the cosmetics industry. In an ad hoc survey, participants confirmed that, in addition to raw material procurement, sustainability (in second place) and energy security (in third place) were their main concerns. Around half of those surveyed had already implemented general energy optimizations in their company, half of them in production and 15% in development. The other half have not yet taken any measures but are planning to do so. The authors interpret this as a sign of change.

The acceptance of submissions shows that energy efficiency generates interest. Before this document was published, the "Swiss concept" had already been presented at four international conferences. After publication, the guideline will be made available digitally to members of the SWISS SCC in an initial phase.

EFFICIENCY CONCEPTS

The term efficiency concept (EC) is a synonym for a suitable measure to increase efficiency. The following 5 chapters each contain

- Descriptions that explain the EC
- Results
- Instructions for action

The texts and explanations are deliberately kept short. The extensive appendix contains details, background information, theory and case studies ("**cases**").

EC1 TEMPERATURE CONTROL

Usually, "hot" emulsification is used to manufacture cosmetic products. The water and oil phases are heated separately to temperatures in the range of 70 to 80°C and then combined at this temperature in the homogenizer. After completion, the product is cooled. Often a further phase is added at a temperature of around 40 to 50°C. Typically, the emulsion is removed from the mixing container at a temperature of around 25°C, usually stored temporarily and then prepared for filling. Significant energy savings can be achieved by adjusting the temperatures. For details, see appendix A1. Savings of up to 50% in heating and cooling energy are possible!

EC1.1 Maximum temperature

The maximum temperature must be as low as possible Using differential scanning calorimetry (DSC), this maximum temperature can be measured precisely and for each individual product.

EC1.2 Outlet temperature

Should be raised from the usual 25°C to at least 30°C.

EC1.3 Accelerated cooling

Cooling after emulsification is a time-consuming and costly process. This can be checked by a simple test and evaluation using the so-called NTU method (see appendix A1). The determined characteristic value of a heat transfer coefficient illustrates the quality of the heat transfer.

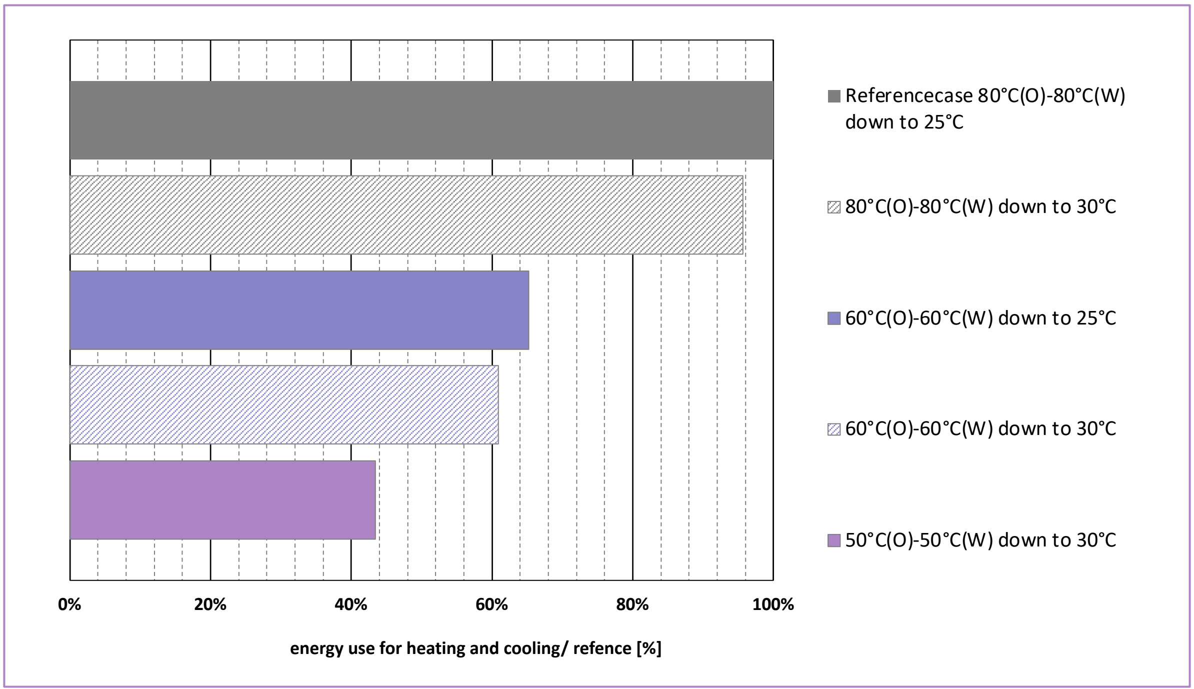

Figure 4 Concrete energy saving potential for a modified temperature setting from the original 80°C for oil and water phase to up to 50°C, as well as for an increased outlet temperature of 30°C instead of 25°C.

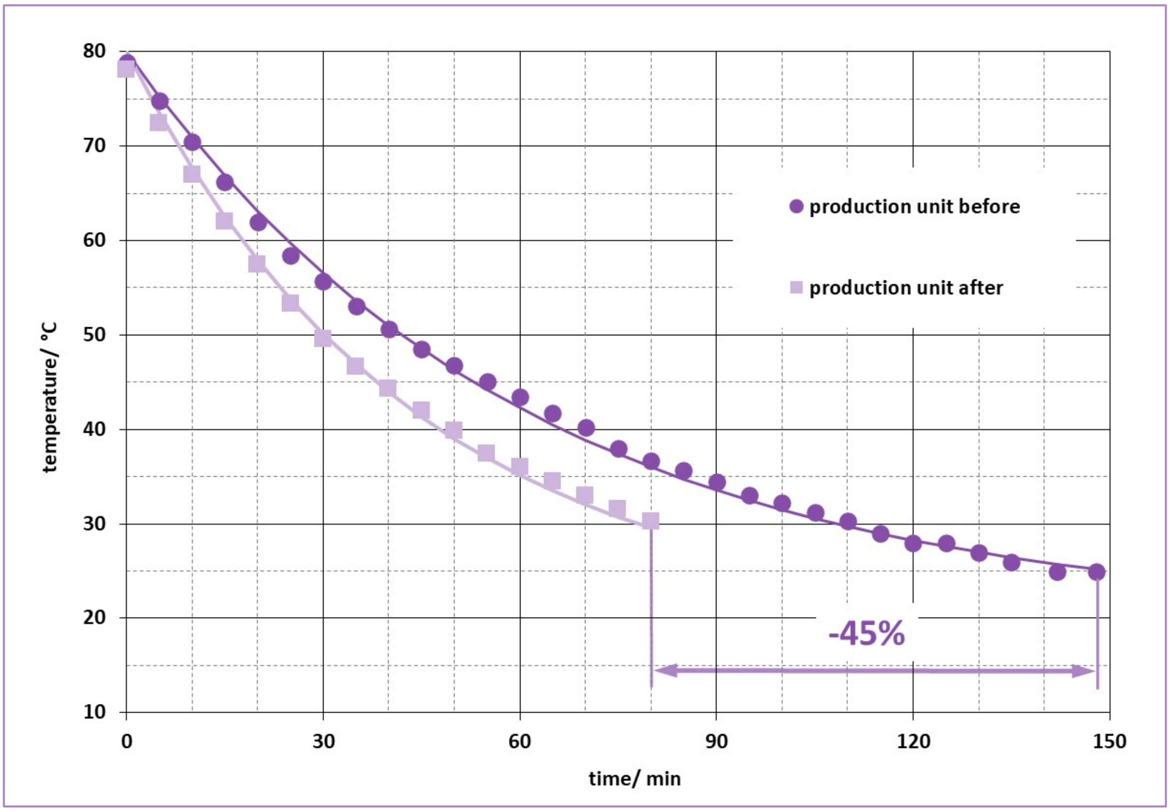

Figure 5 45% time saving by increasing the outlet temperature from 25°C to 30°C and improved temperature control. Data points/squares: measured temperatures of the product in the container. Lines: model calculation (NTU method).

Instructions for action

- ✓ Measurement of melting points of all ingredients using DSC
- ✓ Measurement of melting temperature and melting enthalpy with DSC
- ✓ Eliminate high-melting components wherever possible
- ✓ Reduction of maximum temperature
- ✓ Increasing the outlet temperature
- ✓ Improve chiller configuration

Detailed instructions, theory, cases and templates can be found in the 12-page appendix A1.

EC2 HOT-WARM-COLD

In addition to the general temperature optimization according to efficiency concept 1, there is also the possibility of heating only the water phase, or parts of it, to a lesser extent and then emulsifying it. This is a well-known method, which is widely used under the name Hot-Cold or Cold-Hot, because the oil phase is kept at a constant high temperature (Hot) and the water phase is not heated; thus it remains cold (Cold).

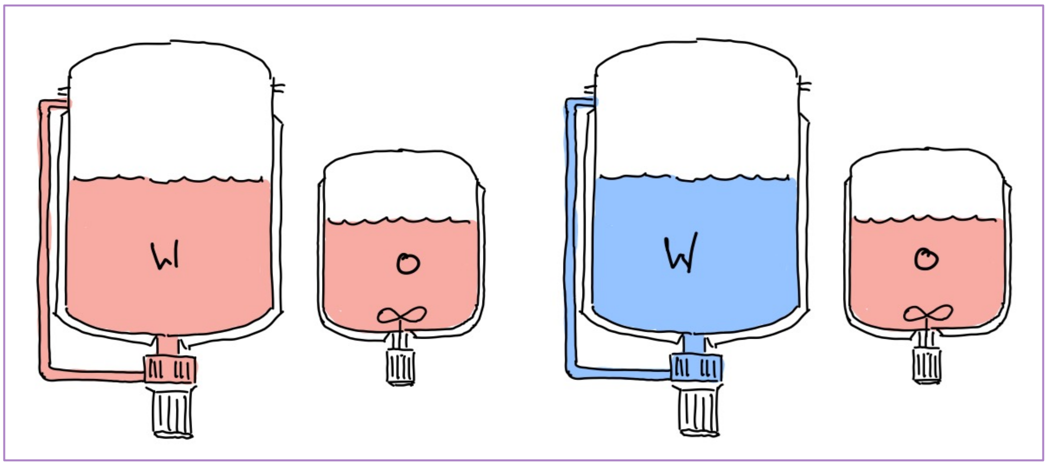

Figure 6 Schematic representation of the usual Hot-Hot process (left) compared to the optimized Hot-Cold process (right). W stands for the water phase, O stands for the oil phase.

When using the Hot-Cold process, it is crucial to ensure that the melting point of the oil phase (with wax) is not compromised at the critical moment of emulsification so that the droplet disintegration of the oil phase can proceed unhindered. To enable this, the water phase should either have a sufficiently high temperature, as in the Hot-Hot process, or the water to oil phase ratio at the moment of emulsification should be chosen in a way that there is significantly less water. The mixing temperature is then still above the melting temperature of the most critical component. In principle, therefore, as little water phase as possible should be present at the moment of emulsification. In the case of an O/W emulsion and at the moment of emulsification, however, the oil content should be kept below 70% (even better below 50%), otherwise there is a risk of phase inversion. With water-in-oil (W/O) emulsions, this is generally less of a problem than with oil-in-water (O/W) emulsions.

Figure 7 Laboratory device: The oil phase is fed directly to the homogenizer via an inlet (white pipe).

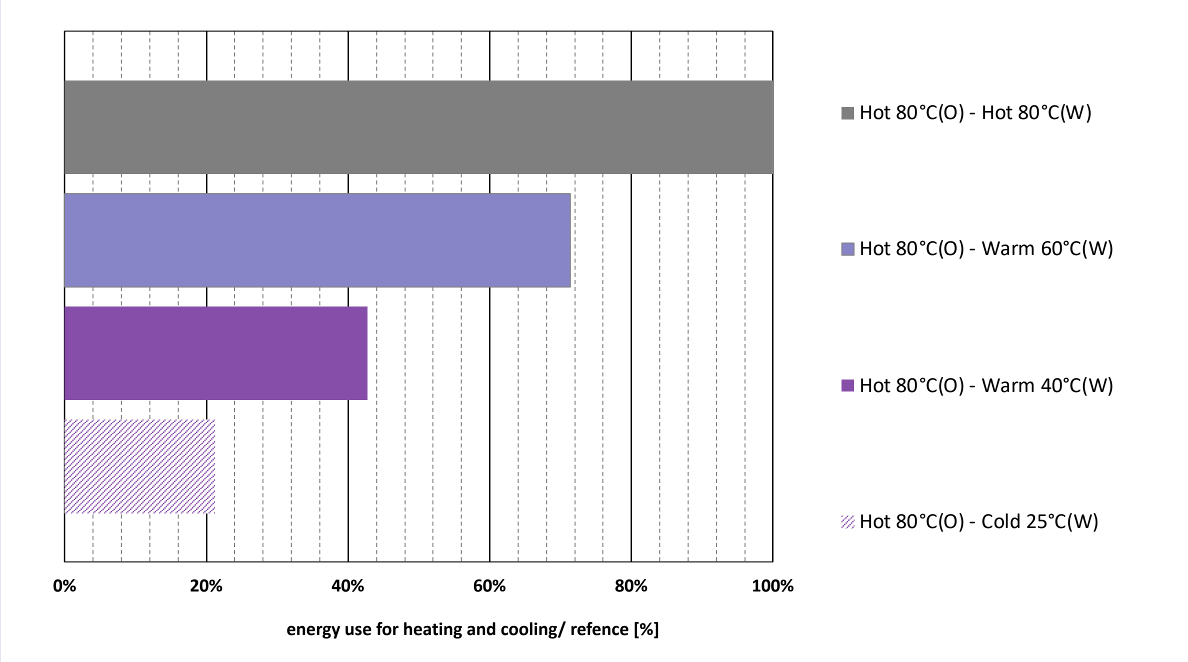

Figure 8 Concrete savings potential for Hot-Warm-Cold. The oil phase always remains at 80°C. The water phase is gradually (less) heated to 60°C, 40°C or room temperature 25°C.

Instructions for action

- ✓ Ensure that the oil phase can be fed directly to the homogenizer in the production plant
- ✓ Think Hot-Cold when developing the formulation and develop it in the laboratory
- ✓ Extension of the laboratory equipment to include a direct feed of the oil phase to the location of the homogenizer
- ✓ Screening can be carried out as before using the Hot-Hot method

Detailed instructions, theory and cases can be found in the 8-page appendix A2.

EC3 CLEANING

After a batch of product has been produced, the mixing tank is emptied. Product residues remain on the agitators, on the tank wall and in the recirculation line, if present. Depending on the machine type and product viscosity, 1 to 3% of the product usually remains in the machine; for highly viscous products, up to 10%. The recirculation line in particular often still contains large quantities of product. This is disadvantageous for two reasons: a) the product would be ready for sale and is just lost, and b) the remaining product causes effort and costs for cleaning and wastewater treatment.

The system needs to be cleaned. The cleaning process is expensive, and the costs are often underestimated. A cost analysis can bring the company great financial savings and environmental improvements. Costs and energy losses in the cleaning process include:

- Time: Several cleaning steps with filling and emptying.
- Product loss: Most significant in terms of value.
- Water costs: Reverse osmosis water costs an industry average (2023) of around 0.2 CHF/kg and should be used sparingly.
- Energy for heating water: This can sometimes exceed the energy required for the actual production.

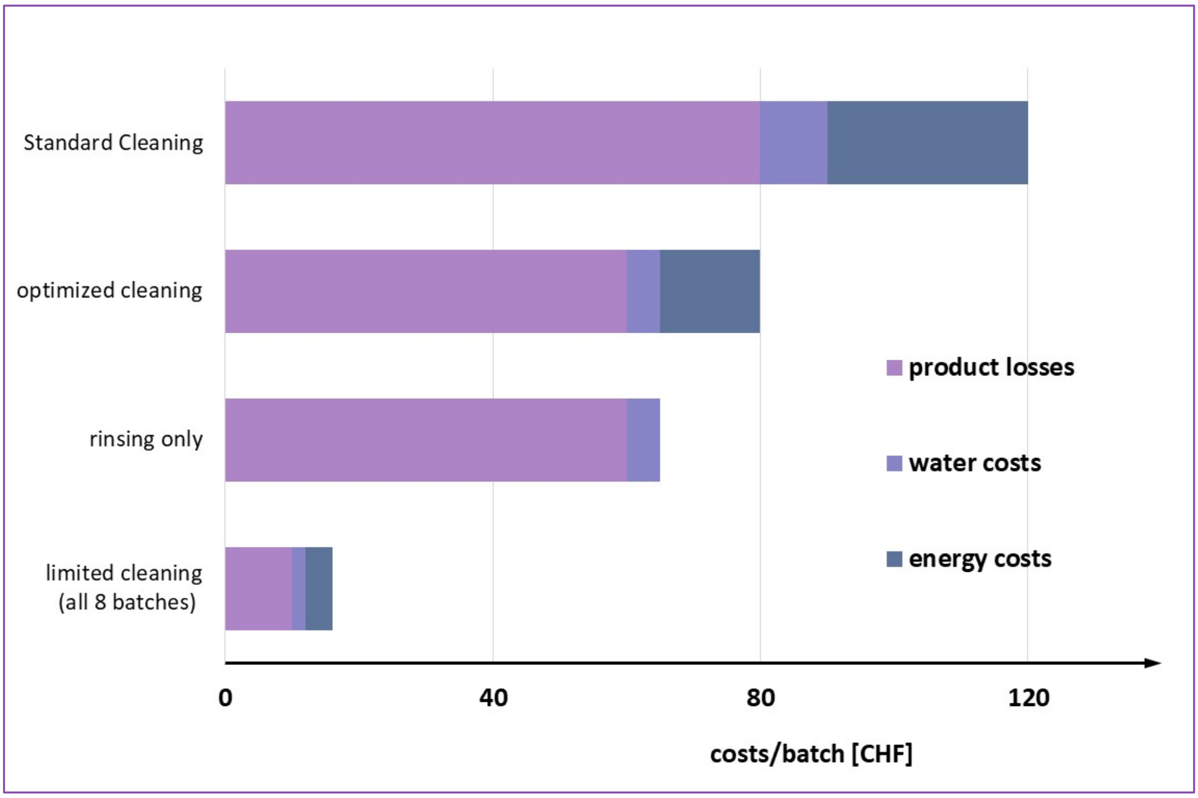

Figure 9 Example of cleaning costs based on a 1000 kg batch.

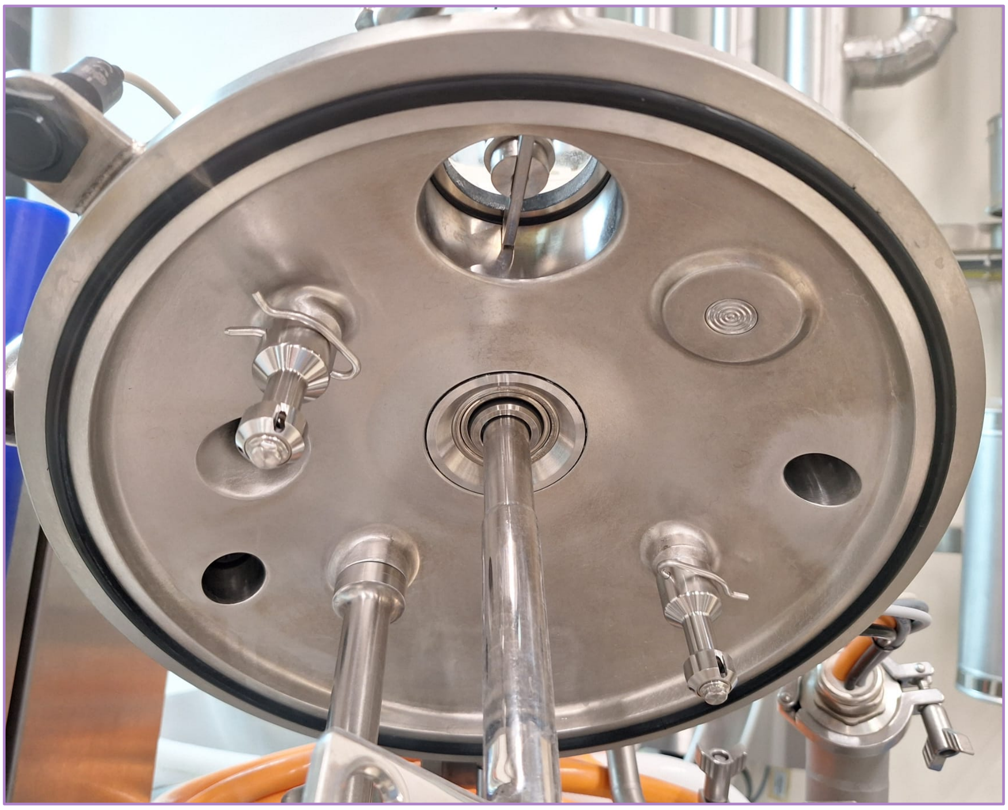

Figure 10 Photo of a clean lid after a thorough cleaning.

Instructions for action

- ✓ Transparent and honest cost analysis!
- ✓ Optimize logistics and production planning so that more campaigns are run that do not require intermediate cleaning
- ✓ Adjust water quantities and temperatures for cleaning
- ✓ Cleaning validation according to ISO standard 22716
- ✓ Solve the hygiene problem of the system on the "machine" by replacing components and not trying to "cure" it with cleaning

The subject of hygiene and cleaning is a sensitive and very important topic. A detailed treatment would be worth a book of its own. Tested instructions, theory, cases and further literature can be found in the 7-page appendix A3.

EC4 RECIPE AND FORMULATION

Every recipe that is already available on the market already offers **potential savings in production due to its manufacturing instructions and its raw materials**.

New developments offer the opportunity to make adjustments to the recipe (including ingredients) in order to select structuring raw materials with **lower melting points**. This applies, for example, to the selection of waxes, emulsifiers and co-emulsifiers.

It must be clarified what influence process changes such as a lower maximum temperature or a higher outlet temperature have on the O/W emulsions discussed here. **Quality parameters** such as particle size distribution and rheology **must remain identical**. There can/may be limited differences in viscoelastic comparisons.

It must be ensured that the formulation remains physically stable in the period between production and application (usually over 30 months), as has been the case up to now. Predictive estimates of the long-term stability of an emulsion system are advantageous (rheology, stability under strong centrifugal forces, etc.). However, they do not yet replace the "gold standard" of in-house long-term stability testing.

Figure 11 Raw materials for emulsions; especially raw materials of the oil phase such as waxes, emulsifiers and co-emulsifiers offer potential for better energy efficiency.

In our test cases, the emulsions were physically stable; rheological measurements after 8, 12 or 18 months showed no significant deviations from the initial sample (laboratory batch or production).

To be able to optimize the resulting quality of the recipes as best as possible before or after process changes (e.g. lowering the temperature), different aspects must be checked at the laboratory level in advance or as a subsequent corrective measure. When using laboratory approaches, attention must be paid to the best possible **standardization and reproducibility of the tests**.

The temporal synchronization of homogenization (shear duration), temperature control (rapid initiation of cooling after phase union) and the influence of the phase inversion temperature PIT are important parameters in a manually produced laboratory batch.

In addition, the following points a) to e) should be tested in a laboratory experiment and their degree of influence on the emulsion in question should be assessed:

Temperature-dependent influencing factors:

a. Maintaining the phase temperature of the fat and oil phase during entry into the water phase
b. Mixing temperature after completion of phase combination

Time-dependent influencing factors:

c. Cooling kinetics (duration)
d. Consideration of PIT (only applies to non-ionic emulsifiers)
e. Energy input by shear input during cooling (post-homogenization)

Instructions for action

- ✓ Addition of emulsifiers to the oil phase (continental method)
- ✓ Pre-phase combination of all oil and fat components (utilize the effects of "eutectic systems")
- ✓ Simplifying the process steps (e.g. timing of addition of raw materials)
- ✓ Checking the influence of shear rate/duration on optimal particle size distribution and sensorial characteristics or profile?

Detailed instructions, theory, cases and background on PIT can be found in the 15-page appendix A4.

EC5 ENERGY MANAGEMENT AND DECARBONIZATION

Sustainability and CO_2 neutral products are mandatory in today's world. With increasing transparency and comparability on the market, pressure from consumers will increase to implement these criteria in the cosmetics industry as well. Energy requirements must be reduced to a technically reasonable level. The remaining energy must be provided in a CO_2 neutral manner. Energy consumption and CO_2 footprint can be significantly reduced with just a few measures:

"Heat pumps should be used to eliminate fossil fuels. This is best achieved through heat recovery with the help of thermal storage."

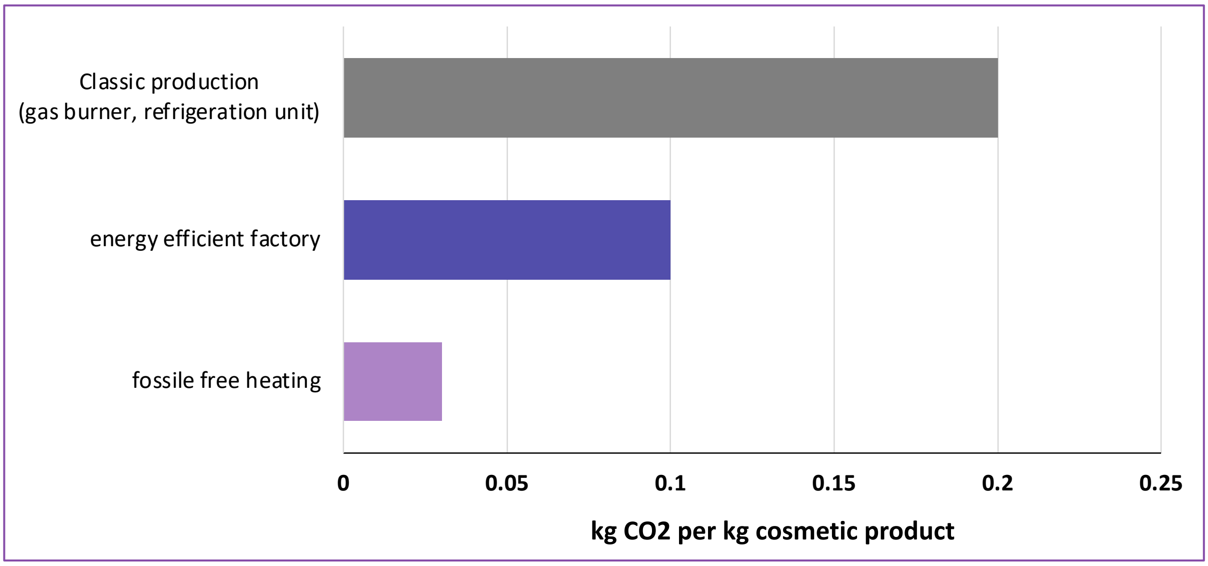

Figure 12 The calculated CO2 footprint to produce a cosmetic product. Approximate values from various surveys by the authors.

Instructions for action

- ✓ Analyze heating and cooling requirements
- ✓ Reduce cooling and heating requirements and implement efficiency concepts
- ✓ Install cold storage and heat storage
- ✓ Immediately eliminate fresh water as a source of cold
- ✓ Provide heat pumps to combine heating and cooling supply
- ✓ Eliminate fossil fuels
- ✓ Photovoltaics, PV installation

Detailed instructions, theory and cases can be found in the 8-page appendix A5.

QUALITY AND SCALE-UP

0 INTRODUCTION QUALITY

In the area of cosmetic emulsions, we distinguish two levels to define the term quality:

- The **best possible quality**. This includes a wide range of parameters.
- After a product is launched and available on the market, we ensure that its **quality remains consistent**.

Occasionally, a special situation arises where a process improvement makes it possible to achieve "better quality", for example a narrower and finer droplet size distribution. However, this also means a deviation in other properties (for example in viscosity) and thus a change in quality.

For a product on the market, a "changed quality" is usually equivalent to a lower/poorer quality. In addition, with emulsions we are dealing with thermodynamically unstable systems. The products have a lifespan, the viscosity changes very significantly between production and filling and continues to change over the course of the storage period, albeit more slowly. As part of this project, we have developed a three-stage quality concept to ensure "the same quality" for two products, standard and sample.

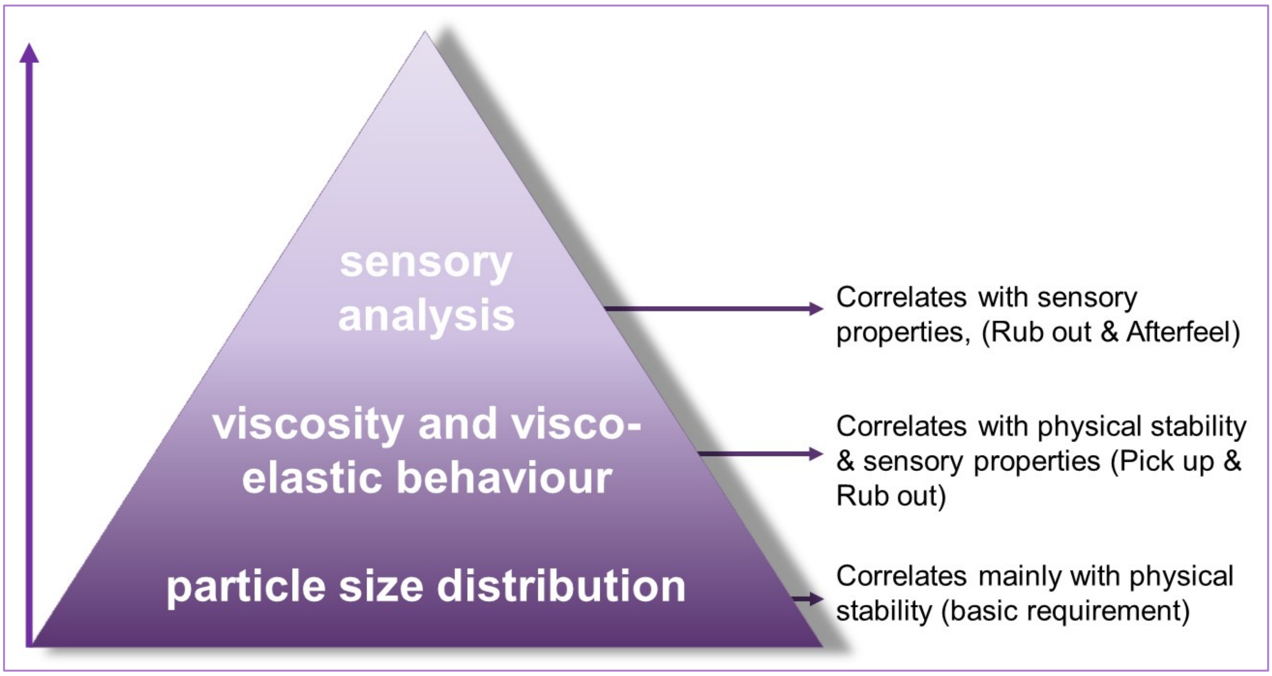

Figure 13 "Pyramid of the quality matrix"; hierarchy of the measurement methods used and their quality parameters.

Instructions for action

- ✓ The particle size distribution must be the same for samples to compare
- ✓ Viscosity must be tested shear rate dependent and must be equal
- ✓ Viscoelasticity must be measured by Dynamic Mechanical Analysis (DMA) and oscillation tests & storage modulus and loss modulus or their ratio should be equal
- ✓ The equality of sensory quality from the user's point of view must be confirmed by means of a triangle test

Each company is free to set the tolerance/specification values for the above parameters. Ultimately, this is also a question of cost.

Detailed instructions and theory can be found in the 4-page appendix B0.

1 SCALE-UP/ SCALE-DOWN

The term **scale-up** describes the process in product development in which it is determined how a product initially developed in the laboratory should be transferred to the production scale. Transferring the current process settings of the production device to the dimensions of the laboratory device is known as scale-down.

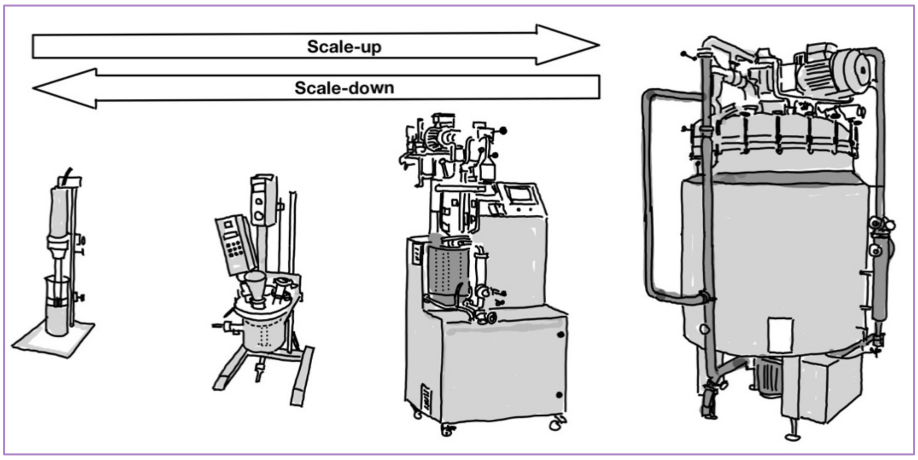

Figure 14 Scale-up: From laboratory scale to production scale. Scale-down: From production scale to laboratory scale.

Scale-down is based on the performance of the production systems. These are measured. This ensures that the **results can** be transferred to the laboratory equipment. By adhering to the operating parameters determined in this manner (speed and shear time) during formulation development, consistent product quality can be ensured in the production system. Less piloting is necessary, and the risk of faulty batches is drastically reduced. Transfer from any laboratory equipment to any production system (in-house production as well as external) is possible.

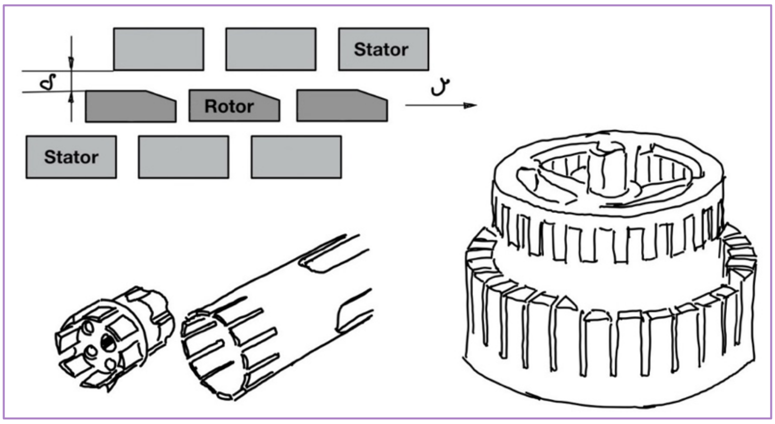

Figure 15 The calculated shear rate and the applied shear energy of a rotor-stator homogenizer must be kept the same for laboratory equipment and production plant!

Detailed instructions, theory and templates can be found in the 13-page appendix B1.

2 PARTICLE SIZE

In practice, it is common to evaluate particle sizes using microscopy. This is useful in terms of quality assurance. In the current project, the exact distribution was also measured using laser diffraction and different patterns were compared with each other.

- ✓ The particle size distribution (PSD) must be determined using analytical methods
- ✓ Conclusions about potential problems can be drawn from the shape of the particle size distribution
- ✓ The distribution must be identical
- ✓ It is advantageous to have a standard representation of the volume density distribution q3

Figure 16 Measurement of a PSD at the HSLU: left laser diffraction, right optical centrifuge.

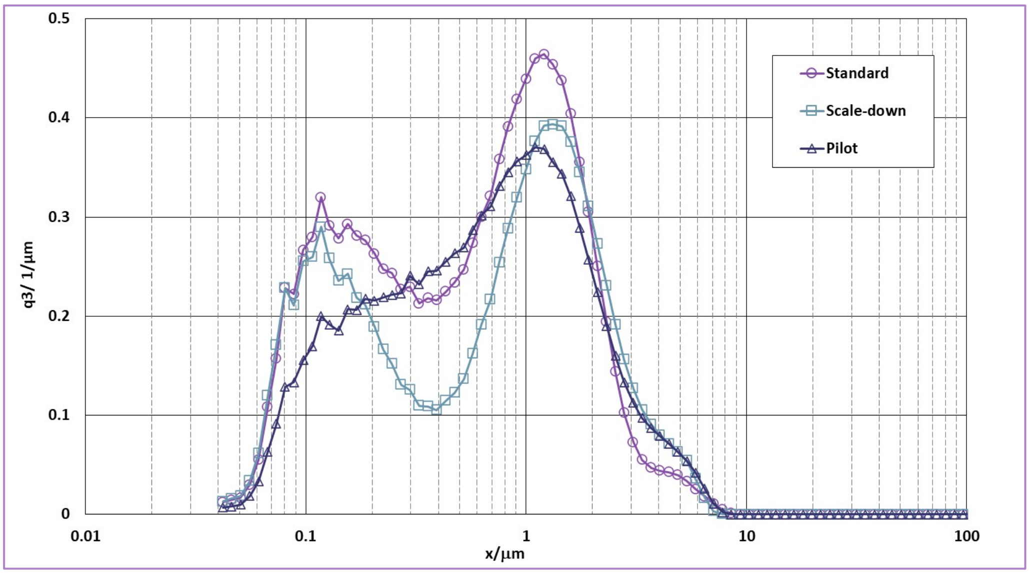

Figure 17 Particle size distribution of a standard product compared to laboratory and pilot batch with a modified temperature setting. (Example from appendix A1)

Detailed instructions, theory and cases can be found in the 8-page appendix B2.

3 RHEOLOGY

Rheological measurement methods are used to characterize the quality of emulsions. Under certain conditions, they can also provide information on long-term stability or sensory behavior. The rheological measurements presented here were carried out using the A. Paar MCR 302 rheometer. They are plate/plate measurements that were carried out in rotation mode or oscillation mode.

3.1 Viscosity

Viscosity is an important and easy-to-determine quality parameter. Cosmetic emulsions are shear-thinning. The finer the particle size of the disperse phase, the more viscous the product becomes due to interactions at a high packing density. The viscosity of a product is significantly influenced by the type and amount of the liquid-crystalline phase formed, which is created by adding the emulsifier and other structure-giving lipid components. The arrangement of the lipid crystals in the emulsion plays a decisive role.

3.2 Viscoelastic properties (elasticity and yield point)

In contrast to viscosity measurement, the viscoelastic properties are measured in a non-texture-destroying area below the yield point. The storage modulus G' indicates the elastic part, the loss modulus G'' indicates the viscous or fluid part. The length of the linear-viscoelastic (LVE) range is a plateau value. The measuring range is limited by the yield point.

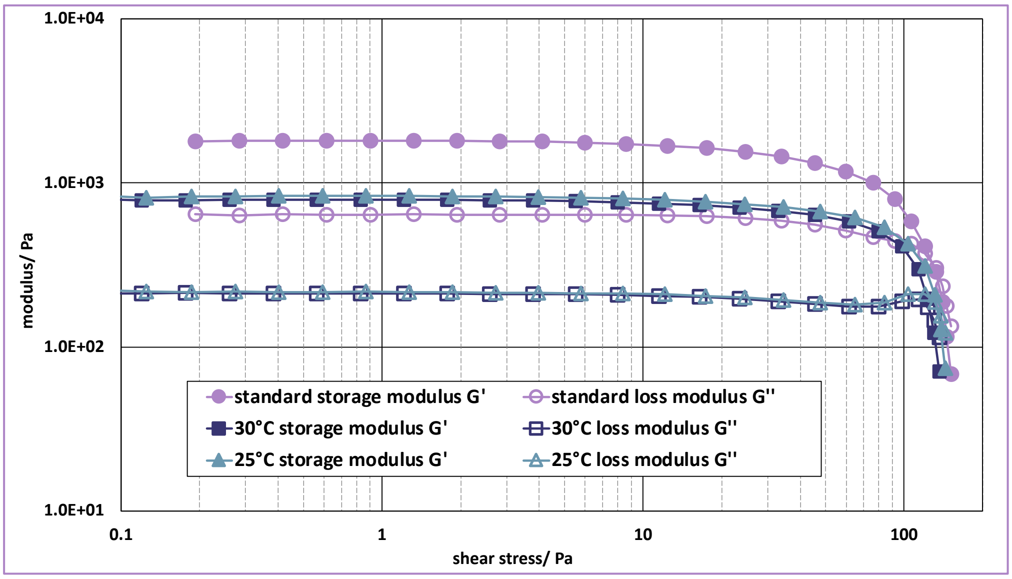

Figure 18 Representation of the viscoelastic properties of 3 samples with outlet temperature 30°C (new), 25° (conventional) versus older standard.

Detailed instructions, theory and cases can be found in the 10-page appendix B3.

4 SENSORY ANALYSIS

Sensory Analysis makes macro- or microscopic product properties "tangible". When this happens in a scientific setting, we speak of the scientific discipline of "sensory science". While untrained users are more likely to provide information about the acceptance or preference of a product, in descriptive testing methods, trained expert panelists use a test protocol to evaluate the intensities or differences of the individual product properties (attributes). Both trained and untrained people can take part in a test as described below.

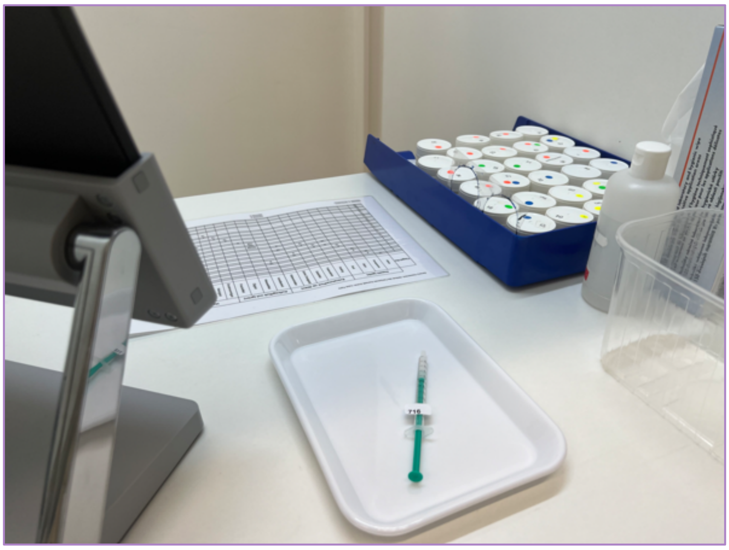

Figure 19 View into a test booth that was set up for a sensory descriptive test (profiling) of cosmetics (ZHAW Wädenswil).

Difference test is specifically used for very similar products. The **triangle test** used here determines whether there is a perceptible sensory difference or similarity between the samples.

In addition, a difference can be determined based on a single or multiple sensory properties (attributes). All further information can be found in ISO 4120:2021, Sensory analysis - Test methods - Triangle test.

The required selectivity defines the number of assessors or test runs. The test for a difference can be carried out with 24-30 assessing persons. With a significance level of α=5%, this is equivalent to a "strict" selection procedure.

Detailed instructions, theory and cases can be found in the 7-page appendix B4.

IMPLEMENTATION

DISCUSSION

In the past, companies and authors (including the authors of this guideline) have repeatedly looked at the economic side of producing emulsions. The focus here was on shortening the process time, reducing residual quantities during emptying, improving the mixing effect and increasing flexibility.

In the project, we managed to achieve financial savings and greater sustainability in production with the products examined while maintaining practically the same quality. This can only be successful in the long term if it is actually implemented for all new products and **actively continued**. Therefore, in addition to the technical and economic aspects, strengthening the skills of employees is particularly important!

Figure 20 Constant exchange is crucial to successfully implement a product or process adaptation.

The goals achieved (and to be achieved) can be assessed in two categories.

Effects on sustainability and economy: All companies achieved energy savings of 20-30% and thus a correspondingly smaller CO_2 footprint. In addition, productivity was increased by 20-30%. This was achieved through greater flexibility in production, shorter production times and savings in material costs through optimization of the cleaning process. The efficiency concepts implemented did not require any investments.

Increased competence: The initial workshops raised **awareness** of the topic among management, development and production. During the implementation, they were repeatedly encouraged to implement what they had learned through appropriate coaching. Communication between the individual departments and regular exchange were encouraged. Implicit knowledge from experience was collected in an appreciative manner from employees, some of whom had been with the company for many years. Communication between departments about products and challenges is now based on facts and KPIs. Knowledge about energy input, shear rate and homogenization times expands the discussion to include what was previously "time and speed". The metrological determination of quality parameters expands the previous (go/no-go) for product release.

In retrospect, it became clear how stubborn habits and traditional knowledge can be. Previous habits such as "process temperatures in the hot-hot process should be at least 15-20°C higher than the highest melting point of the ingredients," or "for microbiological reasons, the outlet temperatures should be kept as low as possible," or "when cooling the product in the mixer, the stirrer should be set to slow" and many others had to be revised. This could be achieved with fact-based knowledge.

In this project, we were able to demonstrate that, despite lower process temperatures, physically stable products with fine sensory properties can be produced. The project partners did not receive any negative feedback regarding microbial contamination (total germ count determination) at the higher outlet temperatures.

During the course of the project, formulations (multimodal systems) were "detected" that do not necessarily correspond to the ideal particle size distribution of a cosmetic emulsion. But perhaps despite or precisely because of these anomalies, these are valued and unique products on the market that nevertheless represent physically stable systems. Such emulsions could also be optimized through the adapted processes.

While the methodology for scale-down and quality control is now standardized, the information on recipes and formulations is very individual and is based on the product ranges of each company. This also applies to the topics of decarbonization and energy efficiency and the description of production systems. All of this follows the individual company equipment and depends on the energy integration on site.

The authors do not claim completeness in this guideline. However, the case studies and theoretical backgrounds described here have been prepared with great care to the best of our knowledge and based on scientific findings.

GET STARTED

The authors recommend the following tips for getting started and implementing them in your own company:

Preparation checklist:

- ✓ Select a product that can be practiced without too much risk. Ideally O/W with oil content over 20% and viscosities above 10 Pas and below 100 Pas at a shear rate of 5/s.
- ✓ Training and workshop with employees from the laboratory and production. Creating a common experience and language.
- ✓ Start with scale-down from one production plant and one laboratory plant to learn and test your own previous practice and conformity to the scale-down concept from this guideline.
- ✓ Checking the technical requirements, such as direct oil phase feed onto the rotor-stator in production and laboratory.
- ✓ Access to DSC, rheometer, laser diffraction analysis available?
- ✓ Raw material security for sample production (at least 10 batches on laboratory scale, at least 2-3 batches on scale up) should be ensured.
- ✓ Are resources available for the project work? You should expect the project to last 6 months and the management must support the project. Goals should be set and successes be communicated!

The authors are happy to provide individual support on site.

SUCCESSFUL PRESENTATION/DISSEMINATION

The project has already been presented at the following events:

Olten, Switzerland, September 15, 2023, continuing education event of the Swiss Society of Cosmetic Chemists SWISS SCC, https://www.swissscc.ch/wp-content/uploads/2022/05/Programm_SWISSSCC_Weiterbildung_Sept_2022.pdf ,
Title: First findings - Project energy efficiency in the cosmetics industry; Testimonials from the project partners - Implementation in the industry; First steps towards more energy efficiency in your company

Cambridge, UK, July 5, 2023, SCS UK-Society of Cosmetic Chemists Annual Conference, L. Fischer, Petra Huber, Title: Energy efficient production of cosmetics.

Barcelona, Spain, September 4-7, 2023, International Conference of the IFSCC: Petra Huber, L. Fischer, Title: The path to zero CO_2, using formulation and process expertise – a time and energy saving journey.

Berlin, Germany, October 26, 2023, SEPAWA Congress, L. Fischer, Petra Huber, Title: Reduce to the max - making emulsion with reduced energy, process time and costs.

Paris, France, April 18, 2024, Incosmetics, L. Fischer, Petra Huber, Title: Energy efficient cosmetics production.

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As the main sponsor, EnergieSchweiz is subject to public law. This means we meet their requirements for transparent communication and knowledge transfer. The authors have no economic ties to the companies involved and no conflicts of interest. This document is available free of charge to Swiss companies in the cosmetics industry. There are plans to continue the project with additional companies.

We would like to thank the board members and those responsible, as well as the support of our industrial partners La Prairie AG, Frike Group, Steinfels Swiss and Kinematica AG and the open and stimulating dialogue during our research work. We would also like to thank the employees and students at HSLU and ZHAW for their support with analytics and the creation of the graphics.

Initiating a paradigm shift requires time and continuous incentives, but above all motivated and visionary employees and managers who are already ready to rethink and keep trying new things - proactively and without external regulatory pressure. That is innovative entrepreneurship! Our future generations will thank you.

With this in mind, we wish you every success!

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