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Energy-efficient Cosmetics Production

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The first step on the road to decarbonization is to increase energy efficiency. To this end, three Swiss cosmetics companies, Lucerne University of Applied Sciences and Arts (HSLU), Zurich University of Applied Sciences (ZHAW) and Kinematica AG, have developed guidelines in a two-year project with the support of SWISS SCC and SwissEnergy. This resulted in a set of instructions, which is available online as a document in German, English and French for interested parties in the cosmetics industry at **Projects – Swiss SCC** (www.swissscc.ch/leistungen/projekte).

Cosmetic products and their manufacturing processes are complex. The authors have compiled the many years of experience of the experts involved and clearly sorted the approaches for optimizing energy consumption and resource use in cosmetics production into five efficiency concepts (EC). An introductory procedure for safe scale-up was established at the cosmetics manufacturing companies. This was accompanied by a three-stage quality check. Energy savings of around 30% were immediately achieved in the companies. These were achieved without investment and were also associated with productivity and cost savings. The companies involved to date have comprehensively expanded their internal communication between development and laboratory. SOPs now contain additional process parameters, such as shear rate and energy input. All three participating companies have significantly increased their sustainability in production as part of this project and are on the way to fully CO_2-neutral production.

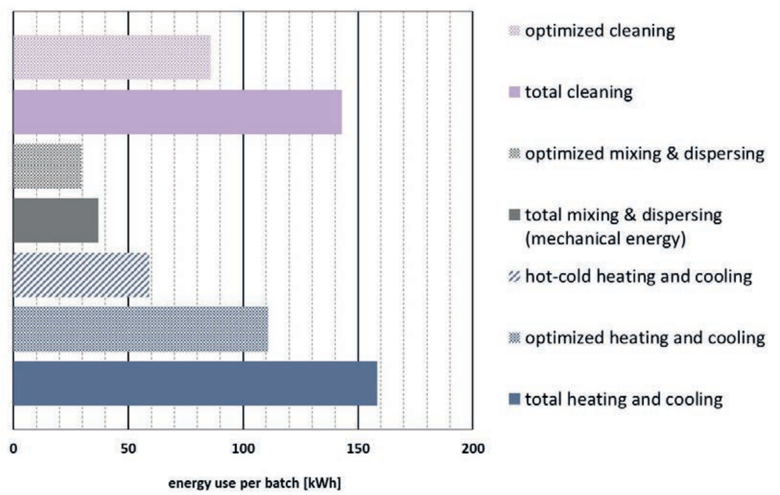

Fig. 1 Concrete savings potential for a batch of 1000 kg.

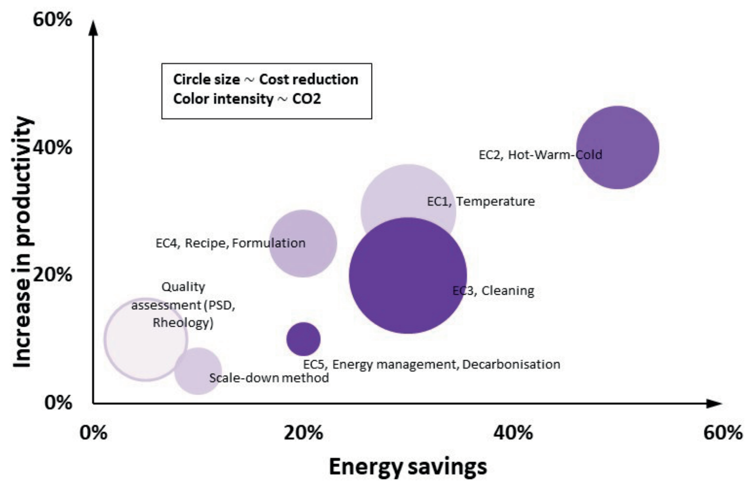

Fig. 2 Overview of the potential energy savings and productivity increases with the efficiency concepts documented in this guide (EC). The bubble size symbolizes the "amount" of possible cost savings and the color intensity reflects the potential for CO_2 savings; the darker, the greater.

Introduction

The overall aim of the project was to modify the manufacturing process for cosmetic emulsions in order to reduce energy consumption and the CO_2 footprint. Costs, resources and energy can be saved in the manufacture of cosmetic products through modern and clever process management and the use of innovative processes and formulations.

The potential energy savings were calculated for an example batch size of 1000 kg and without investment and are shown in **Figure 1**.

Based on years of research by the authors, five efficiency concepts were identified and precisely defined and applied in this work. These concepts include approaches for optimizing energy consumption in cosmetic production and are as follows: Temperature Control, Hot-Warm-Cold, Cleaning, Recipe & Formulation and Energy Management & Decarbonization **(Figure 2)**.

Material and method or procedure

On-site workshops at the companies 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 about energy optimization in the future. The knowledge generated is to be used for future recipe developments. For this reason, great attention was paid to regular and adequate communication with employees both on site and online. In addition, the existing industry and company knowledge (empirical values) should be exchanged and recorded, confirmed or corrected on a scientific basis by promoting internal communication. One or two standard formulations of the oil in water (O/W) type were selected in each case and scheduling agreements were made based on their production planning.

In an initial, detailed, full-day workshop, the development and production teams were prepared for their tasks in theory and then given practical training. It often required an inspection of the production department to record the technical parameters of the homogenizers and the entire production equipment. So-called "Hydro Test Run" were carried out in preparation for measurements of the energy input on laboratory mixing equipment and production machines. This approach makes it possible to test and understand various aspects such as energy input or other performance characteristics without using the actual product materials.

The main tests in the companies' plants were preceded by various preliminary tests and radical experiments in 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.

Finally, the main investigations at the partner companies focused on analyzing existing production formulations of the treated O/W emulsions and transferring them to the laboratory plant using a clear scale-down procedure. Optimizations that lead to energy savings were then carried out on a laboratory scale. 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 method and comprehensive quality control procedures were first defined and implemented in the respective manufacturing companies. Handouts and spreadsheets were created for the participating companies, the final version of which can be found in the appendix of this guide.

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

Results: the 5 EFFICIENCY CONCEPTS

EC1 – TEMPERATURE CONTROL

"Hot" emulsification is usually used in the manufacture of 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 finishing, the product is cooled down. A further phase is often added at a temperature of around 40 to 50°C. Typically, the emulsion is discharged from the mixing vessel 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. 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 calorimetry, this maximum temperature can be measured precisely and individually for each product.

EC1.2 – Outlet temperature

The 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 cost-intensive process. It can be checked by a simple test and evaluation using the so-called NTU method. The determined characteristic value of a heat transfer coefficient illuminates the quality of the heat transfer.

EC2 – HOT-WARM-COLD

In addition to the general temperature optimizations according to efficiency concept 1, there is also the option of heating only the water phase, or parts of it, to a lower temperature and then emulsifying it. This is a well-known method known as hot-cold or cold-hot, as the oil phase is kept at the same high temperature (hot) and the water phase is not heated, i.e. remains cold.

In the hot-cold process, it must be ensured that the melting point of the oil phase (e.g. with wax) does not fall below the critical temperature in the moment of emulsification so that the droplet decomposition of the oil phase proceeds unhindered. Instructions and tips are given in the above-mentioned guide.

EC3 – CLEANING

After a product batch has been produced, the mixing container is emptied. Product residues remain on the agitators, on the container wall and in the transfer line, if present. Depending on the machine type and product viscosity, usually 1 to 3 % of the product remains in the machine; with 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 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 major financial savings and ecological improvements. Cost and energy losses during the cleaning process:

- Time: Several cleaning steps with filling and emptying.
- Product loss: Most significant in terms of value.
- Water costs for reverse osmosis water: this should be used sparingly.
- Energy for water heating: This may exceed the energy required for the actual production.

EC4 – RECIPE AND FORMULATION

Every recipe that is already commercially available offers **potential savings during production due to its manufacturing specifications and raw materials. New developments offer the opportunity to make formulation adjustments (including ingredients) to select structuring raw materials with lower melting points. This applies, for example, to the selection of waxes, emulsifiers and co-emulsifiers. The influence of process changes such as a lower maximum temperature or a higher outlet temperature on the O/W emulsions treated here must be clarified (Figure 3). Quality parameters** such as particle

Fig. 3 Changed process conditions for formulations must first be tested on a small scale. (Credits ZHAW)

size distribution and rheology must **remain identical**. In the case of visco-elastic comparisons, there may or can be accepted differences to a limited extent.

As before, it must be ensured that the formulation remains physically stable in the period between production and its application (usually over 30 months). Predictive estimates of the long-term stability of an emulsion system are advantageous (rheology, light centrifuges, etc.). However, they do not yet replace the "gold standard" of in-house long-term stability testing.

In our test cases, all emulsions were physically stable; rheological measurements after 8, 12 and 18 months showed no significant deviations from the initial sample.

EC5 – ENERGY MANAGEMENT AND DECARBONIZATION
Sustainability and CO_2-neutral products are mandatory in today's world. Increasing transparency and comparability on the market will increase pressure from consumers to implement these criteria in the cosmetics industry as well. Energy requirements must be reduced to a technically feasible level. The remaining energy must be CO_2-neutral. Energy consumption and the CO_2 footprint can be significantly reduced with just a few measures:
"Heat pumps should be used to eliminate fossil fuels. This is advantageously achieved through heat recovery with the aid of thermal storage".

Conclusions

In the project presented here, the participants succeeded in achieving financial savings and greater sustainability in production while maintaining practically the same quality in the products examined. This is only successful in the long term if it is actually implemented for all new products and **actively continued**. This is why, in addition to the technical and economic aspects, it is particularly important to strengthen the skills of employees!

Effects on sustainability and the economy: Energy savings of 20-30% were achieved in all companies, resulting in a correspondingly lower CO_2 footprint. In addition, productivity was also increased by 20-30%. This was achieved through greater flexibility in production, shorter production times and savings in material costs by optimizing the cleaning process. The implemented efficiency concepts did not require any investment.

The authors and participating companies were amazed at how great the savings potential is, especially in cleaning. The costs, especially due to product loss, are high and can easily be reduced without investments in the order of CHF 50 or more per batch.

Competence enhancement: The workshops at the start of the project raised awareness of the topic among management, development and production and subsequently encouraged them to implement what they had learned through appropriate coaching. Communication between the individual departments and regular exchanges were encouraged. Implicit empirical knowledge was collected from the employees, some of whom had been with the company for many years, in an appreciative manner. Communication between the departments about products and challenges is now based on facts and KPIs **(Figure 4)**. The knowledge of energy input, shear rate and homogenization times expands the discussion about "time and speed, a lot and a little". The metrological determination of quality parameters extends the previous (go/no-go) for product release.

Fig. 4 Constant communication between the development department and the production team is crucial to the successful implementation of a product or process adaptation. (Credits ZHAW)

The follow-up showed how "stubborn" habits and traditional knowledge can be. The previous habits: "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 agitator should be set to slow" and many others, could be revised. This can be achieved with fact-based knowledge.

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

Preparation checklist:

- Download the guide (English, German or French version) under **Projects – Swiss SCC** www.swissscc.ch/leistungen/projekte
- Select a product that can be practiced on without too much risk. Preferably O/W with an oil content above 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 of a production plant and a laboratory plant to learn and check your own practice to date and conformity with the scale-down concept from this guide.
- Checking the technical requirements, such as direct feed of oil phase onto rotor-stator in production and laboratory.
- Access to DSC, rheometer, laser diffraction analysis and sensory analysis available?
- Raw material availability for sample production (at least 10 batches of laboratory masstable, at least 2-3 batches of scale-up) should be ensured.
- Are resources available for the project work? A project duration of 6 months should be expected, and the management must want the project. Goals should be set and successes communicated!

The authors are also available to provide individual support on site.

Note:
The recommendations for the manufacturing industry have been summarized in a practical guide. The main section of this guide can be used free of charge in German, English and French for internal company implementation purposes. The Swiss Society of Cosmetic Chemists (SWISS SCC) and the authors exclude any liability.

Discussion

Quality: The best possible quality is desired. This includes a wide range of parameters. Including those that we measure. As soon as a product is released and on the market, we ensure that the same quality is guaranteed. Occasionally, the special situation arises that a process improvement makes "better quality" possible, for example a narrower and finer drop size distribution. However, this also means a deviation in other properties (e.g. viscosity) and therefore a change in quality. For a product on the market, a "changed quality" is generally a poorer quality. In addition, emulsions are thermodynamically unstable systems. The products have a lifespan, the viscosity changes very significantly between production and filling and continues to change, albeit more slowly, during the storage period. As part of this project, we have developed a three-stage quality concept to ensure "the same quality" for two products, standard and sample.

- The particle size distribution must always be the same.
- Viscosity must be tested depending on the shear rate and must be the same.
- 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 the sensory quality from the user's point of view must be confirmed through adequate conduction of triangle tests.

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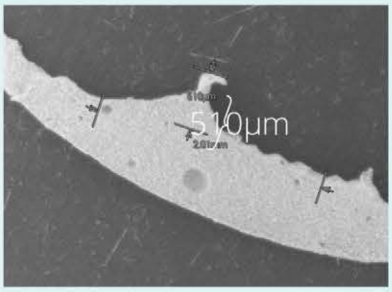
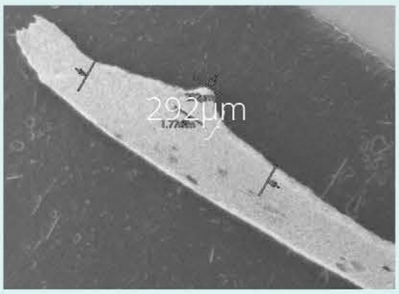


Before

DeltaD reduction (%)

-42,00%



After

DeltaW reduction (%)

-10,34%

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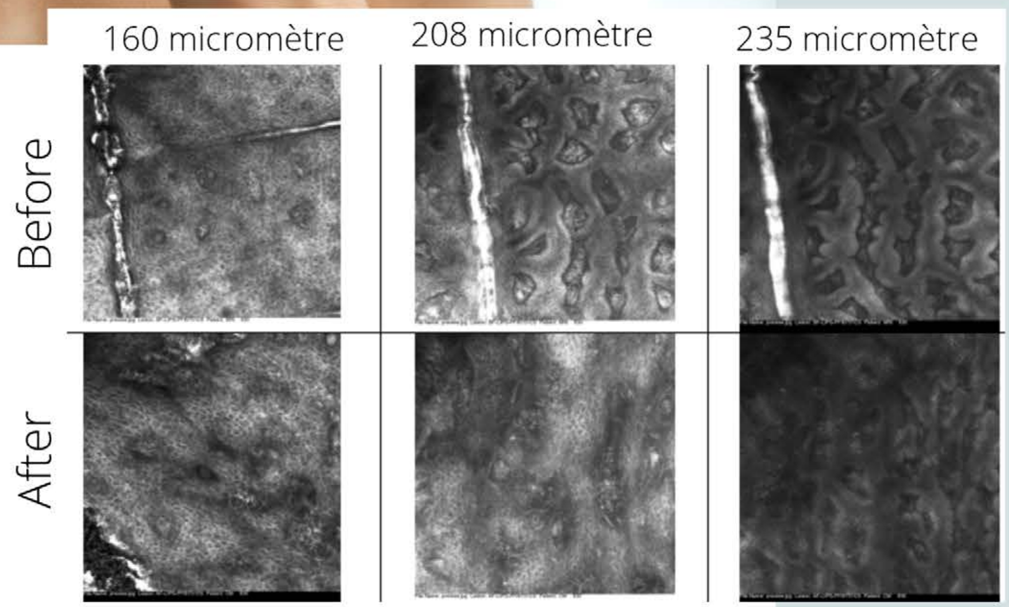
Lip Balm Safety SPF 100 + UVImune® technology

- Photostable and Oxygen stable LipBase® helps.
- VegeLeam® smoothes lip surface for optimum SPF 100+ (PA++++) using novel
- Creasperse® THX Lip Max Protect, organic free and so non-invasive and safest.
- Tested ISO 24443:2 and In Situ DLCMicroscopy imagery.



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