Jungbunzlauer

From nature to ingredients®

facts

Multifunctional ingredients for a minimalist deodorant: CITROFOL® AI and Zinc Lactate

Introduction

For many people, using a deodorant routine to prevent unpleasant underarm odour is an elementary part of their daily hygiene routine. Deodorants are therefore a key product category for the personal care market. This year, the global market for deodorants is estimated at 25 billion US dollars and is expected to grow further.[1] In the deodorant sector, as in the entire personal care market, there is an increasing demand for natural ingredients, with many consumers viewing conventional active ingredients for deodorants critically. This applies especially to products that contain aluminium and/or alcohol, which are associated with negative health consequences. As a result, interest in and demand for aluminium-free deodorants has increased significantly.

The minimalist trend

In recent years, there has been an ongoing consumer trend towards reducing complexity in daily life in order to focus on what is truly important. This minimalist lifestyle trend is also apparent in the cosmetic industry, where the trend is to limit the number of ingredients in any one product and to launch high-quality and natural cosmetics. For deodorants, alcohol-free, paraben-free, aluminium-free, organic and natural are important criteria, representing increasingly popular claims that fit perfectly into the minimalist concept.[2] Multifunctional ingredients play an important role in keeping the ingredients lists of minimalist cosmetic formulations as short as possible. Zinc lactate and CITROFOL® AI, which are discussed in this article as active ingredients for deodorants, both demonstrate multifunctional properties which make the development of a minimalist deodorant formulation easier.

Preference for aluminium-free deodorants

The safety of aluminium salts in deodorants has been controversially discussed for many years, with individual studies suggesting an increased risk of breast cancer or Alzheimer's disease associated with the aluminium absorbed by the skin. So far there is no scientific evidence that exposure to aluminium from deodorants has a negative health effect.[3] However, consumers are cautious and an increasing number would prefer to avoid deodorants containing aluminium.

Sweat is not just sweat

The main function of sweat is thermoregulation of the body. This occurs when the surface of the skin cools as sweat evaporates. But humans have two types of sweat glands: eccrine and apocrine. The eccrine sweat glands that can be found all over the body are responsible for lowering body temperature. Eccrine perspiration consists mainly of water in which salts and small organic compounds are dissolved.[4] Apocrine sweat glands, in contrast, are only present in specific body regions like the armpit and the genital area and become active during puberty. They do not play a role in thermoregulation, but produce a secretion that contains among other things long-chain fatty acids, sulphur-containing amino acids and hormones. It is the bacterial degradation of these organic molecules in apocrine perspiration that produces volatile odour compounds and is therefore responsible for the typical axillary malodour.[4,5] However, while eccrine perspiration does not, in itself, cause malodour, it does provide a moist environment suitable for bacterial growth and enable apocrine sweat to spread.[4]

How do deodorants combat malodour?

Commercial deodorants contain a combination of ingredients that act to reduce or even prevent axillary malodour. A subgroup of deodorants, the antiperspirants, also reduces the amount of sweat formed in the armpit. Antiperspirants typically contain a water-soluble aluminium salt as active ingredient (for example aluminium chloride, aluminium chlorohydrate complexes or aluminium zirconium complexes). This antiperspirant substance dissolves in the moisture on the surface of the skin of the armpit and forms a gel, which creates a small temporary "plug" near the top of the sweat gland, significantly reducing the amount of sweat that is secreted to the skin surface. However, this gel can only plug eccrine sweat glands, as apocrine sweat glands have much wider pores that cannot be blocked by the aluminium salts.[5]

So while antiperspirant active ingredients do reduce the amount of moisture, they have only a minor effect on axillary odour itself. Antiperspirant agents are therefore not strictly necessary deodorant ingredients and are always used in combination with ingredients that target the bacteria or the odour directly.

An overview of all the different active ingredients and their mode of action is given in figure 1.

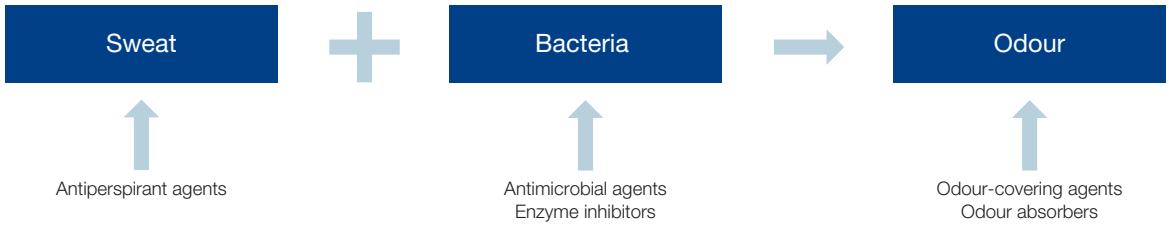


Figure 1: Deodorants – mode of action

Agents such as perfumes disguise bad odours, while odour absorbers bind or remove the volatile compounds that cause them. Both antimicrobial agents and enzyme inhibitors reduce odours by preventing the breakdown of organic compounds by bacteria. Popular deodorant ingredients to reduce microbial activity include alcohol and triclosan, but both of these are viewed with suspicion by some consumers.

Preservatives in deodorants

Consumers are also increasingly concerned about the preservatives contained in deodorants. Until recently, parabens were the preservatives of choice for cosmetic products and were also used for deodorants. These esters of 4-hydroxybenzoic acid are efficient against a broad spectrum of microorganisms and exhibit good solubility, no odour, temperature stability and antimicrobial activity over a broad pH range.[6] Unfortunately, they have recently come under suspicion of having a negative effect on human health. Although parabens with a short alkyl chain are still permitted for use under the European cosmetic regulation (Regulation (EC) No 1223/2009), some parabens are classified as endocrine-disrupting chemicals that may eventually lead to hormone-related health effects.[6,7]

Nowadays deodorants usually contain organic alcohols and acids as preservatives. Most of these are safe but may be limited in respect of pH range. However, the use of above mentioned triclosan, a prominent representative of this group, is indeed now restricted in the EU and the USA.[6]

The claim “preservative free” is used to indicate the absence of substances classified as preservatives in Annex V of the European cosmetic regulation. The alternative term “self-preserving” is actually more appropriate. Self-preserving formulations often incorporate multifunctional cosmetic ingredients as a way to improve product stability and consumer safety. Besides their main function such ingredients are able to deliver antimicrobial activity (alone or in combination with other ingredients) that can substitute for that of conventional preservatives.[7] Promising multifunctional cosmetic ingredients with known antimicrobial properties include zinc salts, lactic acid and triethyl citrate.

Multifunctional ingredients for a minimalist deodorant

This article describes an example of an effective aluminium-free deodorant which contains neither alcohol nor triclosan. The formula consists of two active ingredients with differing modes of action: CITROFOL® AI (triethyl citrate) works as an enzyme inhibitor, while zinc lactate is known to have antimicrobial properties. They represent a gentler alternative to conventional antimicrobials. CITROFOL® AI is already established in the deodorant market and its effectiveness has been described and proven.[8] This article is therefore primarily intended to examine whether zinc lactate can boost the performance of CITROFOL® AI to deliver an even more effective deodorant.

The use of zinc in deodorants

Zinc plays an important role in many different biological processes and is a cofactor in over 1000 enzymatic reactions in the human body. Elemental zinc and its salts have long been used in topical preparations for therapeutic purposes and their anti-inflammatory and wound-healing properties have been confirmed in many different studies.[9–11] Zinc salts are also popular ingredients for daily-use skin care products because of their skin-conditioning and soothing effects.

Besides the properties mentioned above, zinc salts are also known to have an antimicrobial effect. High concentrations of Zn^{2+} ions in microbial cells disturb the Zn^{2+} homeostasis and cause destabilisation and enhanced permeability of the cell membrane, leading to the death of the cell.[12,13] This antimicrobial activity makes them likely candidates as active ingredients for deodorants. Water-soluble zinc salts are already known to act as odour absorbers and are used in this function in deodorants to obtain a longer-lasting effect. Organic zinc salts are usually used for this application.[14,15] The effect is most probably the result of the high reactivity of the zinc ion with sulphur and amine groups in the low-molecular-weight organic compounds that are produced by the bacteria.[12]

Zinc lactate

Zinc lactate is the zinc salt of lactic acid and offers many benefits for cosmetic formulations. Due to its antimicrobial properties and its ability to reduce the formation of dental plaque, zinc lactate is often used in oral care products. It is established as a safe ingredient in the food and beverages industry, as well as in skin care products. The antimicrobial properties of zinc lactate in cosmetic products have been substantiated in various studies. As a multifunctional ingredient, zinc lactate also offers skin-soothing and anti-inflammatory benefits. Zinc lactate is a white odourless powder with a high solubility of 55 g/L in water (equivalent to 12.7 g zinc per L) and is compatible with natural cosmetic standards such as ECOCERT/COSMOS or NATRUE.

CITROFOL® AI

CITROFOL® AI (INCI name Triethyl Citrate) is widely used in personal care applications for its multiple functions. It is well established as a solvent, diluent and fixative in perfumes. In cream formulations, it can function as an emollient to improve skin feel by moisturising and softening. Additionally, CITROFOL® AI is an excellent deodorising agent that inhibits the enzymatic decomposition of sweat components and therefore prevents body odour. A 100% bio-based material produced by esterification of fermentative-based citric acid and ethanol, CITROFOL® AI is COSMOS-approved by ECOCERT as well as NATRUE-approved for use in natural cosmetics.

CITROFOL® AI as enzyme inhibitor

The mode of action of CITROFOL® AI is shown in figure 2. When a deodorant containing CITROFOL® AI is applied to the skin, a deodorising cycle reaction will take place. Enzymatic hydrolysed triethyl citrate will form ethanol and citric acid. Citric acid will lower the skin pH, which deactivates bacterial lipase enzymes. The decomposition of sweat and degradation of skin products, which causes malodour, is thus reduced. The natural buffer function of the skin slowly neutralises the citric acid. This leads to an increase in skin pH and the reactivation of enzymes. When the bacterial process is reactivated, the deodorising cycle with triethyl citrate starts again.[8]

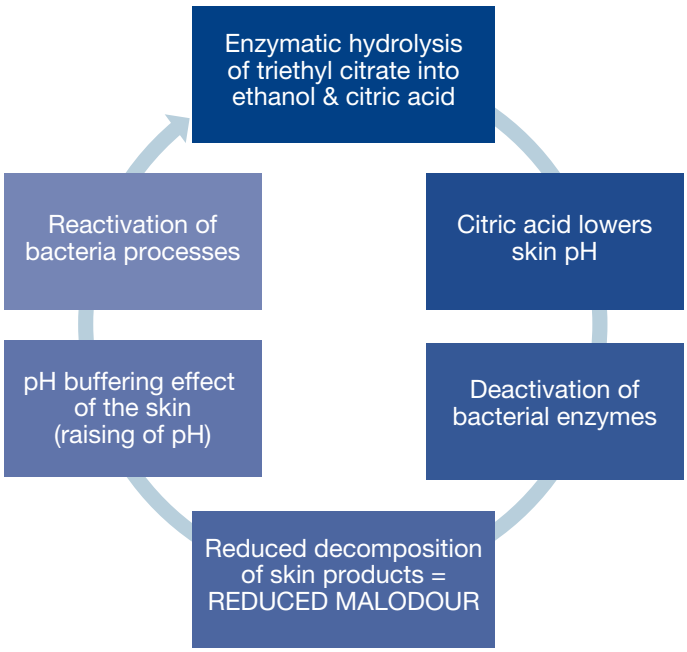
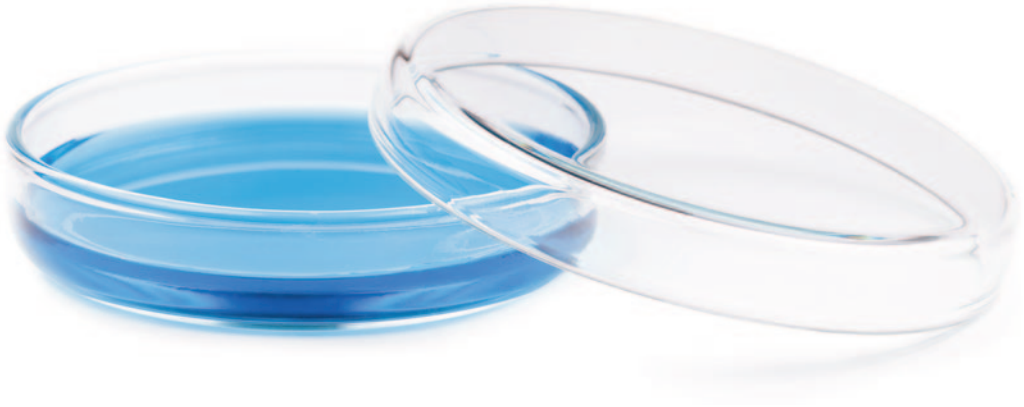


Figure 2: Axillary deodorising cycle reaction with CITROFOL® AI[8]



Experimental part

A test was designed to evaluate the ability of Jungbunzlauer's zinc lactate to boost the deodorant efficacy of its established deodorising ingredient CITROFOL® AI. The chosen formulation satisfies the growing demand for minimalist products, with a limited number of ingredients in a plain roll-on deodorant. The deodorising efficacy was evaluated according to standardised tests as described below.

To substantiate performance, a sniff test that accurately reflected actual usage conditions for deodorants was performed. A deodorising efficacy over 24 h was proven for the tested deodorant formulation, which contained 5% CITROFOL® AI at a pH of 4.5.[8] In a subsequent test, the effectiveness of CITROFOL® AI was substantiated for 48 h with the same setup.[16]

Formulation development

Table 1 shows the minimalist formulation, which has the appearance of a slightly opaque gel and thus can be sold in clear packaging. The formulation contains 5% CITROFOL® AI as an enzyme inhibitor. The pH value of the total formulation was set at 4.5. Zinc lactate as the antimicrobial ingredient was tested at concentrations of 1% and 3%.

Table 1: Composition of deodorant formulation

Phase	Ingredients	INCI	Function	Supplier	CITROFOL® AI only %	CITROFOL® AI and Zinc Lactate%
A	Water demin.	Aqua	Solubiliser		Qs to 100%	Qs to 100%
B	**Xanthan Gum FNCSP-PC**	**Xanthan Gum**	**Thickener**	**Jungbunzlauer**	1.3%	1.3%
C	**Zinc Lactate Dihydrate**	**Zinc Lactate**	**Deodorising ingredient**	**Jungbunzlauer**		1% / 3%
D	**CITROFOL® AI Extra**	**Triethyl Citrate**	**Deodorising ingredient**	**Jungbunzlauer**	5%	5%
E	**L(+)-Lactic Acid 90% Heat stable Personal Care Grade**	**Lactic Acid**	**pH regulation**	**Jungbunzlauer**	Qs	Qs

Preservation support

The preservation efficacy of the Jungbunzlauer ingredients CITROFOL® AI and zinc lactate, which had already been substantiated in rinse-off and leave-on skin care products,[17,18] was tested by means of the well-established European pharmacopoeia (Ph. Eur.) test 5.1.3.. Both zinc lactate and CITROFOL® AI demonstrated preservation activity in deodorant applications.

The test setup was originally designed to test topical cosmetic or pharmaceutical preparations for their microbial stability. This norm determines how to test the preservation efficacy of preservative systems.[19]

In accordance with Ph. Eur. 5.1.3., the relevant sample is inoculated with 10^5 to 10^6 colony-forming units (CFU) of selected microorganisms per millilitre. The microorganisms comprise *Staphylococcus aureus* (Gram positive coccus), *Pseudomonas aeruginosa* (Gram negative bacillus), *Escherichia coli* (Gram negative bacillus), *Candida albicans* (yeast), and *Aspergillus brasiliensis* (mould). The prepared samples are stored at room temperature away from light and the concentration of CFU/mL is determined after predefined times (2, 7, 14 and 28 days). The observed decline in the number of microorganisms and the (non-) occurrence of growth sets the criterion A or criterion B needed to pass the test.[19] The criteria for evaluation of antimicrobial activity are given in table 2.

Criterion A is difficult to achieve for gentle formulations, which can be claimed as preservative free at a slightly acidic pH. The log reduction required for criterion B is either lower than criterion A or can be achieved at a later point in time. The test is failed if neither criterion A nor criterion B is satisfied.

Table 2: Criteria of acceptance for Ph. Eur. 5.1.3. test[19]

	Test criteria	Log reduction			
		2 d	7 d	14 d	28 d
Bacteria	A	2	3	-	NI
	B	-	-	3	NI
Fungi	A	-	-	2	NI
	B	-	-	1	NI

To evaluate the optimal zinc lactate concentration for preservation efficacy, the blank formulation with 5% CITROFOL® AI only, a combination of 5% CITROFOL® AI and 1% zinc lactate and a formulation with 5% CITROFOL® AI and 3% zinc lactate were tested. The results are shown in table 3.

Table 3: Test results of deodorant formulation with CITROFOL® AI and zinc lactate according to Ph. Eur. 5.1.3.

	Deodorant formulation pH 4.5		
Test germ	**5% CITROFOL® AI**	**Combination of 5% CITROFOL® AI 1% Zinc Lactate**	**Combination of 5% CITROFOL® AI 3% Zinc Lactate**
E. coli	A	A	A
P. aeruginosa	A	A	A
S. aureus	B	A	A
C. albicans	A	A	A
A. brasiliensis	F	F	B
Total test results	**F**	**F**	**B**

The blank formulation with 5% of CITROFOL® AI failed the test because of insufficient efficacy against *A. brasiliensis*. To ensure microbiological stability, an additional ingredient to support preservation is needed in this formulation.

The addition of 1% zinc lactate only boosted the performance against *S. aureus*. However, when 3% of zinc lactate was added, the test was passed with criterion B. The formulation was microbiologically stable and no additional preservative was needed. Therefore testing was continued with the combination of 5% CITROFOL® AI and 3% zinc lactate.

Test for antimicrobial effectiveness

To ensure microbial effectiveness of the deodorant formulation against microorganisms which cause body odour, an *in vitro* disinfection kinetics test was performed in accordance with Ph. Eur. 5.1.3. Four specific microorganisms, which cause body odour in general, in armpits or on feet, were tested.[5,20]

The goal was to achieve only a moderate reduction of microorganisms so as to avoid a negative effect on the overall skin microbiome. Times of testing were defined as 15 min, 30 min, 1 h, 2 h, and 24 h. The results are shown in figure 3.

For claim substantiation and proof of synergistic effect, formulations containing either 5% CITROFOL® AI alone, 3% zinc lactate alone or a combination of both, 5% CITROFOL® AI and 3% zinc lactate, were tested.

The first germ tested for disinfection kinetics was *Staphylococcus epidermis*. It is responsible for malodour in armpits and body odour in general.[5] When evaluating the results, the formulation with zinc lactate alone showed a faster reduction of CFU per gram sample. After 24 h, all formulations displayed comparable performance.

The second test germ was *Corynebacterium xerosis*, which causes malodour in armpits.[5] For this test germ, the formulation with CITROFOL® AI alone performed slightly better compared to the other formulations.

Two other test germs that cause malodour in armpits and feet were also tested.[5] For *Brevibacterium epidermis*, the formulation with CITROFOL® AI alone and the combination showed a comparable performance. The formulation with zinc lactate alone performed slightly worse after 24 h.

The last germ tested was *Corynebacterium acnes*, which is also known as *Propionibacterium acnes*.[5] At the beginning of the disinfection kinetics for this test germ, the formulation with zinc lactate and the combination showed a faster reduction of CFU/g and therefore a better performance. After 2 h and 24 h, the results for all formulations were comparable.

A combination of 5% CITROFOL® AI and 3% zinc lactate is therefore recommended to improve deodorant performance and optimise activity of the formulation against test germs which cause body odour.

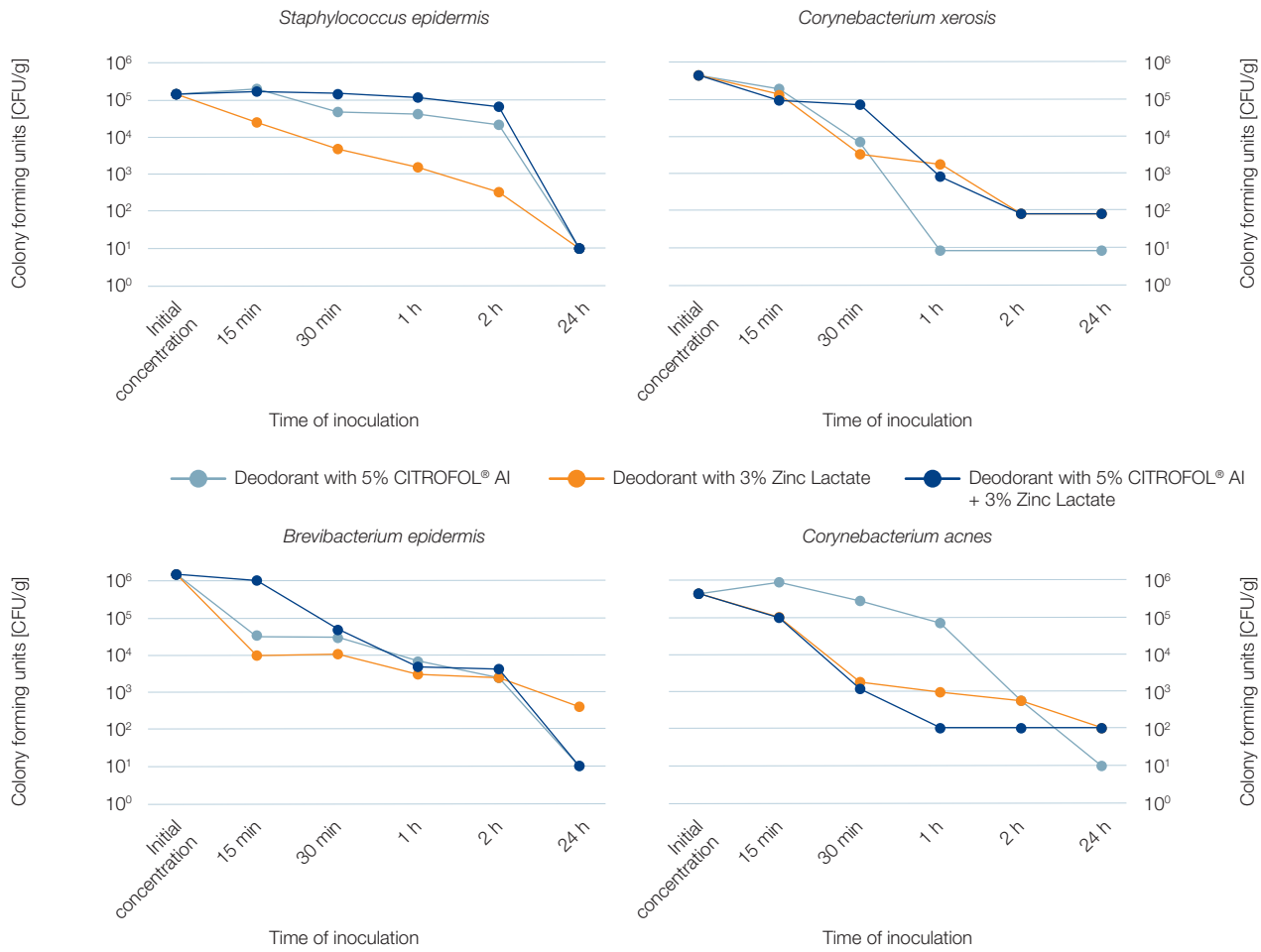


Figure 3: Test results for *in vitro* disinfection kinetics of deodorant formulation pH 4.5.

External panel test to evaluate deodorant performance

In addition to the microbiological *in vitro* trials, a panel test was conducted to evaluate *in vivo* deodorant performance and show how zinc lactate can boost the effect of CITROFOL® AI. No sniff test was conducted in this context, because CITROFOL® AI alone had already demonstrated efficacy for 48 h.[16] The sniff test could not therefore reveal any additional benefits of zinc lactate.

The test was performed at the Dermatest® institute. During this external panel test, 20 male and female persons used the deodorant products over a period of two weeks. For direct comparison the deodorant formulation with 5% CITROFOL® AI alone was applied to the left armpit and the formulation with the combination of CITROFOL® AI and zinc lactate was applied to the right armpit. The panellists used the products daily and as required. At the end of the test participants completed a questionnaire to reveal whether the addition of zinc lactate has a performance-boosting effect. Additionally, the products were dermatologically tested.

After the performance evaluation, the panellists were asked to rate every single attribute for each formulation as good, neither good nor bad, or bad. The results are summarised as a bar chart in figure 4.

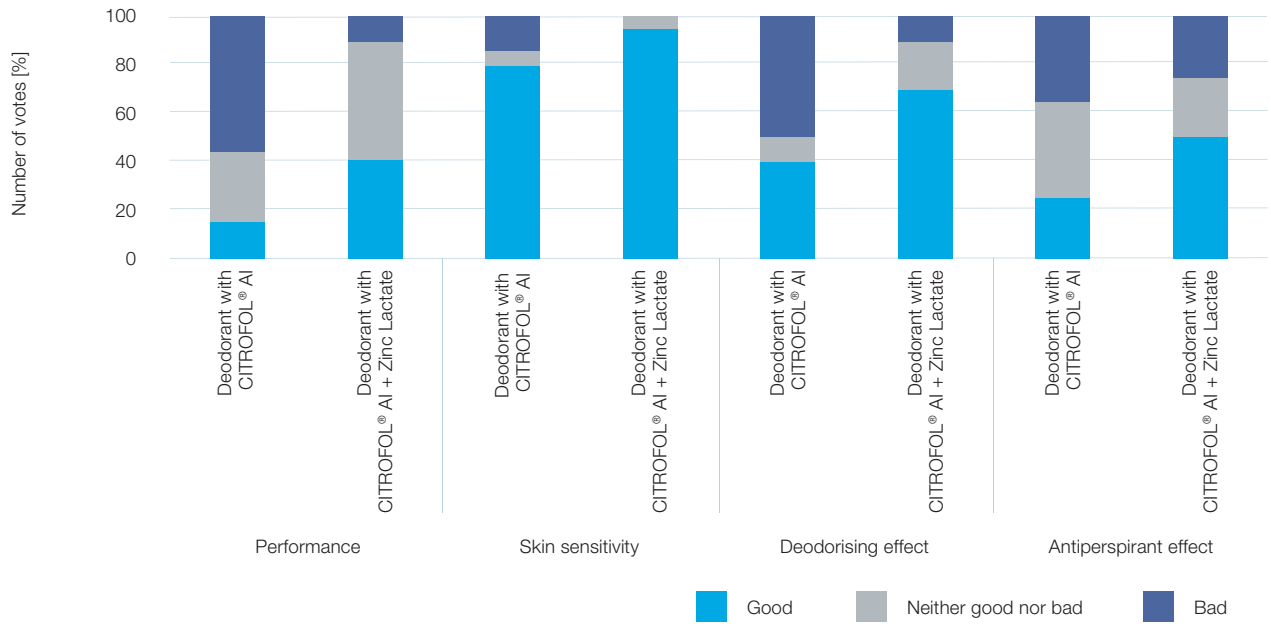


Figure 4: External panel test of deodorants – evaluation of attributes

First, the overall performance was evaluated. For the deodorant with CITROFOL® AI alone, around 15% of the panellists rated the formulation as good and 30% as neither good nor bad. More than half of the panellists (55%) regarded the performance of the formulation as bad. In direct comparison, the formulation with zinc lactate and CITROFOL® AI was ranked as good by 40% of all panellists, 50% as neither good nor bad and only 10% of the panellists rated the deodorant performance as bad. Hence the perception of overall performance can be significantly improved by adding zinc lactate.

A very good result was obtained for skin sensitivity. Only small differences between the formulations were detectable. This was to be expected because the minimalist formulation with only natural and multifunctional ingredients is in itself very skin sensitive.

When evaluating the deodorising effect, around 40% of all panellists rated the deodorant with CITROFOL® AI as good and about 50% as bad. In direct comparison, 70% of all panellists rated the formulation with CITROFOL® AI and zinc lactate as good, 20% as neither good nor bad and only 10% as bad. Hence it was shown that the addition of zinc lactate boosts deodorising performance significantly too.

In addition to deodorant performance, the antiperspirant effect was evaluated. It should be said that to the best of our knowledge, there was no reason to expect CITROFOL® AI and zinc lactate to produce an antiperspirant effect at the concentrations tested. This parameter served merely as an indication of the subjective feeling of the panellists and is not suitable for scientific claim substantiation. Direct comparison of the two formulations showed that the addition of zinc lactate also improved this attribute.

Overall, the addition of zinc lactate to a formulation already containing CITROFOL® AI boosted its performance significantly. The improvement was especially obvious in respect of the perception of deodorising and antiperspirant performance.

At the end of the performance test, the panellists were asked to scale in direct comparison for the attributes of preference, longer performance, recommendation and buying intention. They were asked whether they would choose the formulation with CITROFOL® AI alone, the optimised formulation with added zinc lactate or neither. The results are shown in figure 5.

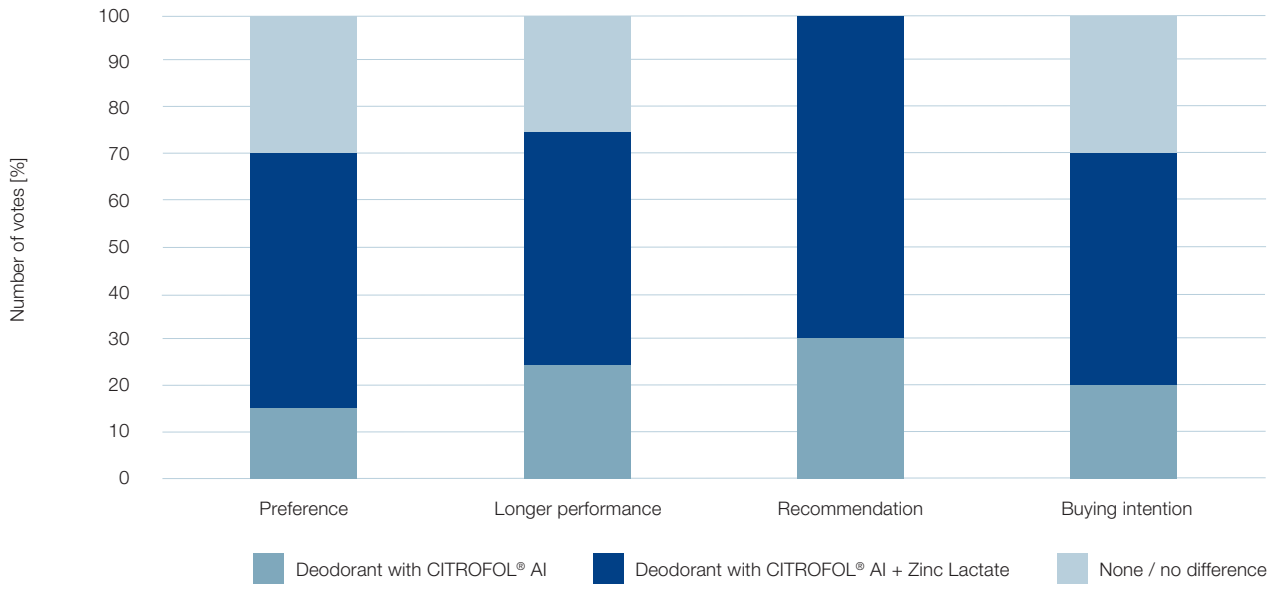


Figure 5: Evaluation of overall deodorant performance – direct comparison

When evaluating the first parameter, preference for the deodorant with the combination of zinc lactate and CITROFOL® AI was significant.

For the attribute longer performance most panellists also chose the formulation with zinc lactate.

Seventy percent of all panellists would recommend the deodorant with zinc lactate while 30% would recommend the formulation with CITROFOL® AI alone.
The last attribute was buying intention. Thirty percent of the panellists said they would not buy either of the products, around 20% would buy the product with CITROFOL® AI alone and 50% would buy the product formulated with a combination of CITROFOL® AI and zinc lactate.

In summary, the external performance test clearly showed that the addition of zinc lactate boosts the performance of the deodorant formulation significantly. Overall the product with zinc lactate was preferred to the deodorant with CITROFOL® AI alone because it provided a longer-lasting deodorant effect.

Zinc lactate was thus proven to exhibit an excellent boosting effect in deodorant formulations.

Summary

Summing up, the microbiological and performance trials showed that zinc lactate is an efficient boosting ingredient to improve the deodorant efficacy of CITROFOL® AI.

CITROFOL® AI is a well-known natural ingredient, which acts as enzyme inhibitor to ensure excellent deodorising properties.

Zinc lactate is a superior antimicrobial agent that reduces bacteria on skin and therefore acts as a supplementary active ingredient in deodorants. Besides its antimicrobial activity, zinc lactate has the added benefit of skin-soothing and anti-inflammatory properties, combining the benefits of zinc and lactate ions.

Additionally, the well-established Ph. Eur. test 5.1.3. provided proof that use of zinc lactate and CITROFOL® AI allows formulation of self-preserving deodorants. Thus, the level of preservative function offered by these two multifunctional ingredients makes it possible to avoid the use of conventional preservatives in deodorant products.

Hence zinc lactate and CITROFOL® AI from Jungbunzlauer, which are both COSMOS and NATRUE approved, demonstrate multifunctional activities that enable the formulation of deodorants with a cleaner label and shorter ingredient list to fit perfectly with the minimalist trend.

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About Jungbunzlauer

Jungbunzlauer is one of the world's leading producers of biodegradable ingredients of natural origin. We enable our customers to manufacture healthier, safer, tastier and more sustainable products. Thanks to continuous investment, state-of-the-art manufacturing processes and comprehensive quality management, we are able to provide outstanding product quality.

Our mission "From nature to ingredients®" commits us to protecting people and their environment.

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