C&T

New Alternatives to Paraben-Based Preservative Blends

Klaus Weber
Schülke & Mayr GmbH, Norderstedt Germany

KEY WORDS: *preservative blends, parabens, organic acids, diazolidinyl urea, S&M KoKo test, preservative-based discoloration*

ABSTRACT: *Adding diazolidinyl urea to a blend of organic acids (i.e., sodium benzoate and potassium sorbate) extends this sample blend's applicable pH range up to a pH level of 7, provides protection from discoloration, and offers an alternative to paraben-based preservative blends.*

Ingredients for the preservation of personal care products require high standards of safety and compatibility. Just a few of the numerous well-known and permitted preservatives are used in the majority of products.[1] Among the more widely used materials are the parabens, which have been used successfully in cosmetic preservation for many years. Today, however, parabens are being regarded increasingly critically, both by specialists and by the public.[2] Under certain conditions organic acids can be an ideal replacement.

Organic Acids

Organic acids are becoming popular for the preservation of cosmetics.[3] The antimicrobial efficacy of organic acids is linked to their undissociated, acidic form.[4] With increasing pH, more and more of the acid is transformed into the salt. The salt form of these acids, when used alone, has no antimicrobial efficacy. This effectively limits the use of organic acid preservatives to formulations that have a pH below 6. By combining the organic acid with other preservative ingredients (such as those in Table 1), one can preserve formulations up to a neutral pH. This is important to the formulator because numerous products are formulated within the range of pH 6-7. The failure of acid-based preservatives at pH values over 6 leads to an unfortunate restriction in the use of these systems.

A possible combination partner is diazolidinyl urea (DU), a commonly used preservative effective against Gram-positive and Gram-negative bacteria via the mechanism of denaturation and blocking of the protein functionality by crosslinking.

Diazolidinyl urea is widely used in standard preservative blends in combination with fungicidal components, such as the parabens. Due to their fungicidal efficacy (see Editors' Note), organic acids can replace parabens in these blends.

This article discusses a particular liquid cosmetic preservative[a] that is a combination of diazolidinyl urea, sodium benzoate and potassium sorbate. It is a stabilized aqueous solution, requiring no additional solvents. In this article we will refer to this product as DU/OA to suggest its composition of diazolidinyl urea and organic acids.

Color Stability

Solutions of potassium sorbate and sorbic acid are generally considered to be unstable and not able to be stored.[5] Sorbic acid is also said to have a general tendency to discoloration in cosmetic products. This is one reason why the use of benzoic acid is preferred, because it has less of a tendency to yellow.

Because of its combination of ingredients, DU/OA has a reduced tendency

[a] *Euxyl K 500 (INCI: Diazolidinyl urea (and) sodium benzoate (and) potassium sorbate), Schülke & Mayr, GmbH, Norderstedt, Germany. Euxyl is a registered trademark of Schülke & Mayr.*

Table 1. Preservative blends containing organic acids

Organic acid / salt	Additional active	Efficacy against*	Comments
Benzoic acid; Dehydroacetic acid	Phenoxyethanol	B, Y, M	pH < 6.0
Potassium sorbate	Phenoxyethanol, benzyl alcohol	B, Y, M	pH < 5.5
Sorbic acid	Chlorphenesin, phenoxyethanol	B, Y, M	pH < 5.5
Sodium benzoate	Chloroacetamide	B, Y, M	pH < 5.5
Sodium benzoate, Potassium sorbate	Iodopropynyl butylcarbamate	B, Y, M	pH < 5.5
Sodium benzoate, Potassium sorbate	Diazolidinyl urea	B, Y, M	pH up to 7.0

* B= Bacteria; Y= Yeast; M= Mold

PARABENS VERSUS ORGANIC COMPOUNDS

Parabens

Description: Parabens are alkyl esters of *p*-hydroxybenzoic acid. They are prepared by reacting the desired alcohol (methyl, ethyl, and so forth) with *p*-hydroxybenzoic acid in the presence of an acid catalyst, such as sulfuric acid.

Effectiveness: Effective against a broad spectrum of microorganisms, including most fungi and Gram-positive bacteria. They have low activity against certain bacteria, particularly Pseudomonas.

Mechanism: Their antimicrobial activity comes from paraben's interaction with key metabolic pathways in the target organisms.

Organic Compounds

Description: Organic acids and their salts. Examples include benzoic acid, sorbic acid, sodium benzoate and potassium sorbate.

Effectiveness: These organic compounds are mostly active against fungi (molds and yeasts), showing only minimal effectiveness against bacteria.

Mechanism: The undissociated acid molecules interact with the cell wall of the target organisms.

Source: "Beginning Cosmetic Chemistry", Allured Publishing

to discolor, both in the concentrated commercial form and in the preserved cosmetic product. We studied a shampoo formulation containing different concentrations of DU/OA compared with amounts of sorbic acid and benzoic acid that are sufficient for preservation. The discoloration after storage at 40°C for 4 weeks and 8 weeks is shown in Figure 1.

Both sodium benzoate and potassium sorbate show concentration-related discolorations at the levels tested. No such relation is observed with the combination product DU/OA, illustrating the color stability of the stored shampoo preserved with DU/OA.

Microbiological Test Methods

S&M KoKo test: The effectiveness of various preservatives in comparison with DU/OA was tested in the S&M KoKo test. This is a repetitive challenge test over a period of six weeks. A mixed suspension of Gram-positive and Gram-negative bacteria, yeast and mold is used for inoculation (Table 2).

At weekly intervals, a sample of the test product is streaked out onto nutrient

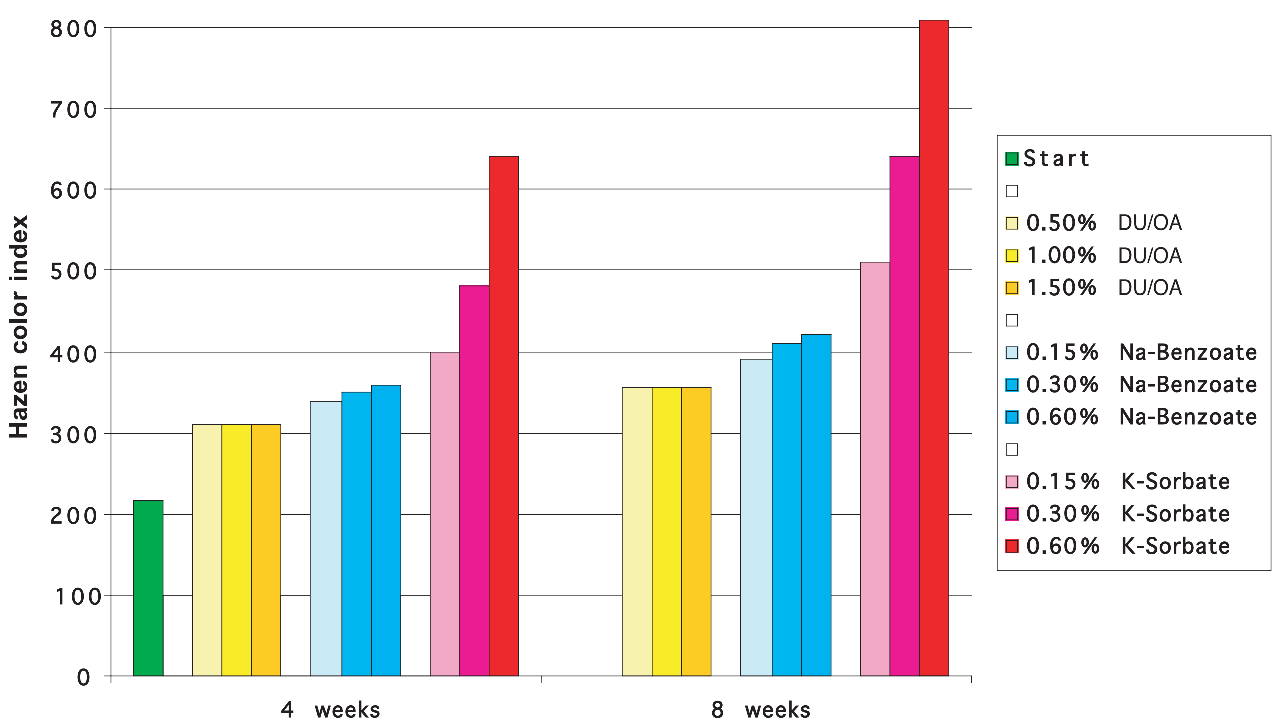

Figure 1. Color stability of stored shampoo

Table 2. Test organisms in the S&M KoKo test

Organism	Gram behavior	Family	Species	ATCC no.
Bacteria	positive	Staphylococcaceae	Staphylococcus aureus	6538
Bacteria	positive	Micrococcaceae	Kocuria rhizophila	9341
Bacteria	negative	Enterobacteriaceae	Enterobacter gergoviae	33028
Bacteria	negative	Enterobacteriaceae	Escherichia coli	11229
Bacteria	negative	Enterobacteriaceae	Klebsiella pneumoniae	4352
Bacteria	negative	Pseudomonaceae	Pseudomonas aeruginosa	15442
Bacteria	negative	Pseudomonaceae	Pseudomonas fluorescens	17397
Bacteria	negative	Pseudomonaceae	Pseudomonas putida	12633
Yeast		Saccheromycetaceae	Candida albicans	10231
Mold		Trichocomaceae	Aspergillus niger	6275
Mold		Trichocomaceae	Penicillium funiculosum	36839

Table 3. Concentration (in %) of the preservatives with equivalent content of diazolidinyl urea, for use in the S&M KoKo test

DU	DU/Parabens	DU/OA
0.10	0.33	0.50
0.15	0.50	0.75
0.20	0.67	1.00
0.30	1.00	1.50

Formula 1. Basic shampoo (unpreserved)

	% w/w
Sodium laureth sulfate, 70% soln	11.40
Cocoamidopropyl betaine, 30% soln	10.00
Hydrolyzed wheat protein (and) hydrolyzed wheat gluten	2.00
Sodium chloride	0.10
Citric acid/sodium hydroxide (pH-Value adjusted to 6.0)	ca 0.05
Water (aqua)	qs

Formula 2. Basic O/W lotion (unpreserved)

		% w/w
A.	Water (aqua)	83.5
	Propylene glycol	2.0
B.	Paraffinum liquidum (mineral oil)	9.5
	Cetearyl alcohol	3.0
	Ceteareth-25	2.0
		100.0

media, incubated, and evaluated semi-quantitatively. The first streaking out is to detect possible contamination of the test product prior to inoculation. After each streaking out, the test product is inoculated with 108-109 CFU/g of the suspension. Thus, a microorganism load of 105-106 CFU/g of each organism is produced.

The evaluation scheme differentiates between four levels of microbial growth. In addition, the growth is classified according to three types of microorganism (bacteria, yeast or mold). The test ends after six inoculation cycles or is discontinued earlier after several cases of "massive" microbial growth.

If a sample survives all six inoculation cycles (i.e., if no growth is observed after this repeated inoculation), it can be regarded as safe with regard to microbiological stability.

Test formulations: Two unpreserved test formulations were used in the S&M KoKo test to check the effectiveness of the preservative. These formulations were a shampoo that contains hydrolyzed wheat protein (Formula 1) and an oil-in-water lotion (Formula 2).

Preservatives: The test series was performed with three different preservative systems:

- DU (diazolidinyl urea)
- DU/Paraben (diazolidinyl urea/parabens)
- DU/OA (water, diazolidinyl urea, sodium benzoate, potassium sorbate)

In order to get information on the share of efficacy provided by the organic acids, the tested concentrations of the different preservatives contained comparable amounts of diazolidinyl urea (Table 3).

As a result of the use of the more water-soluble salts of the acids, DU/OA causes a slightly alkaline reaction and leads to changes in the pH value of the formulation, especially when added at the end of the production process. (The addition of DU/OA at the end of the process is critical if the pH has already been adjusted at an earlier stage and no further check is scheduled.) After it has

Table 4. Results of challenge tests on the basic shampoo formulation before inoculation (cycle 0) and during six inoculation cycles (one cycle per week for six weeks)

- = free of microbial growth
+ = slight growth
++ = moderate growth
+++ = massive growth
./. = test stopped
B = bacteria
Y = yeast

	pH	0	1	2	3	4	5	6
Unpreserved shampoo	6.0	-	+++B	+++B	./.			
+ 0.10% DU	6.0	-	-	+++Y	+++BY	./.		
+ 0.15% DU	6.0	-	-	-	-	-	-	-
+ 0.20% DU	6.0	-	-	-	-	-	-	-
+ 0.33% DU/Parabens	6.0	-	+++Y	+++BY	./.			
+ 0.50% DU/Parabens	6.0	-	-	+Y	+Y	+++BY	+++BY	./.
+ 0.67% DU/Parabens	6.0	-	-	-	-	-	-	-
+ 0.50% DU/OA	6.0	-	-	-	-	+Y	+Y	++Y
+ 0.75% DU/OA	6.0	-	-	-	-	-	-	-
+ 1.00% DU/OA	6.0	-	-	-	-	-	-	-
+ 0.10% DU	6.5	-	++Y	+++Y	+++BY	./.		
+ 0.15% DU	6.5	-	-	-	-	+Y	++Y	+++Y
+ 0.20% DU	6.5	-	-	-	-	-	-	-
+ 0.33% DU/Parabens	6.5	-	+++BY	+++BY	./.			
+ 0.50% DU/Parabens	6.5	-	-	-	+++Y	+++BY	./.	
+ 0.67% DU/Parabens	6.5	-	-	-	-	+++Y	+++Y	./.
+ 0.50% DU/OA	6.5	-	-	-	++Y	+++Y	+++Y	./.
+ 0.75% DU/OA	6.5	-	-	-	-	-	+B	+B
+ 1.00% DU/OA	6.5	-	-	-	-	-	-	-
+ 0.10% DU	7.0	-	++Y	+++BY	+++BY	./.		
+ 0.15% DU	7.0	-	-	-	++Y	+++BY	+++BY	./.
+ 0.20% DU	7.0	-	-	-	-	+Y	+Y	+Y
+ 0.33% DU/Parabens	7.0	-	+++BY	+++BY	./.			
+ 0.50% DU/Parabens	7.0	-	+Y	+++Y	+++BY	./.		
+ 0.67% DU/Parabens	7.0	-	+Y	++Y	+++B	+++B	./.	
+ 0.50% DU/OA	7.0	-	+Y	++Y	+++BY	+++BY	./.	
+ 0.75% DU/OA	7.0	-	-	-	+Y	+++Y	+++Y	./.
+ 1.00% DU/OA	7.0	-	-	-	-	-	-	-

been incorporated into the cosmetic product, the pH value must be adjusted (e.g., with citric or lactic acid). Microbiological challenge tests were performed at pH 6.0, 6.5 and 7.0 to find the efficacy limit of the acids.

Table 4 shows the results of challenge tests on the basic shampoo formulation. The DU/Paraben blend failed at all concentrations and at all pH values that were tested. Diazolidinyl urea itself provides sufficient efficacy up to pH 6.5, but is outperformed by DU/OA at pH 7.0. The addition of organic acids leads to an adequately preserved formulation at the same level of diazolidinyl urea, even under neutral conditions.

Mold fungi play a much more important role in the preservation of leave-on cosmetics. For this reason, diazolidinyl urea will fail to preserve these products without the addition of a fungicide. Table 5 also shows the limitation of DU/OA. Up to pH 6.5, sufficient amounts of free fungicidal organic acids are present for effective preservation. At pH 7.0, only the DU/Paraben mixture controlled the microbial growth in this comparative study. However, the growth of yeast was not controlled by this blend adequately to meet the pass criteria of this study at all levels and pH values tested.

Summary

The personal care industry has come under increasing regulatory, scientific and public pressure. Fewer preservatives are now acceptable for use in these products. As a result, new blends of

Table 5. Results of challenge tests on the basic O/W lotion formulation before inoculation (cycle 0) and during six inoculation cycles (one cycle per week for six weeks)

- \- = free of microbial growth
- \+ = slight growth
- ++ = moderate growth
- +++ = massive growth
- ./. = test stopped
- B = bacteria
- Y = yeast
- M = mold

	pH	0	1	2	3	4	5	6
Unpreserved lotion	6.0	-	+++BMY	+++BMY	./.			
+ 0.10% DU	6.0	-	+++MY	+++MY	./.			
+ 0.20% DU	6.0	-	+++Y	+++Y	./.			
+ 0.30% DU	6.0	-	+++Y	+++Y	./.			
+ 0.33% DU/Parabens	6.0	-	+++MY	+++MY	./.			
+ 0.67% DU/Parabens	6.0	-	+++Y	+++Y	./.			
+ 1.00% DU/Parabens	6.0	-	-	++Y	++Y	++Y	++Y	++Y
+ 0.50% DU/OA	6.0	-	+++M	+++BMY	./.			
+ 1.00% DU/OA	6.0	-	-	-	-	-	-	-
+ 1.50% DU/OA	6.0	-	-	-	-	-	-	-
+ 0.10% DU	6.5	-	+++BMY	+++MY	./.			
+ 0.20% DU	6.5	-	+++BMY	+++MY	./.			
+ 0.30% DU	6.5	-	+++Y	+++Y	./.			
+ 0.33% DU/Parabens	6.5	-	+++MY	+++MY	./.			
+ 0.67% DU/Parabens	6.5	-	+++MY	+++MY	./.			
+ 1.00% DU/Parabens	6.5	-	-	-	+Y	+Y	+Y	+Y
+ 0.50% DU/OA	6.5	-	+++M	+++MY	./.			
+ 1.00% DU/OA	6.5	-	++Y	+++Y	+++Y	./.		
+ 1.50% DU/OA	6.5	-	-	-	-	-	-	-
+ 0.10% DU	7.0	-	+++MY	+++MY	./.			
+ 0.20% DU	7.0	-	+++MY	+++MY	./.			
+ 0.30% DU	7.0	-	+++Y	+++Y	./.			
+ 0.33% DU/Parabens	7.0	-	+++BMY	+++BMY	./.			
+ 0.67% DU/Parabens	7.0	-	+++Y	+++Y	./.			
+ 1.00% DU/Parabens	7.0	-	-	++Y	++Y	++Y	++Y	++Y
+ 0.50% DU/OA	7.0	-	+++BMY	+++BMY	./.			
+ 1.00% DU/OA	7.0	-	+++Y	+++Y	./.			
+ 1.50% DU/OA	7.0	-	+Y	+++Y	+++Y	./.		

antimicrobial actives are being investigated. The combination of organic acids and diazolidinyl urea shows interesting properties.

In contrast to simple combinations of organic acids, one proprietary combination containing diazolidinyl urea, sodium benzoate and potassium sorbate can successfully be used under acidic to neutral conditions. This combination also provides protection from discoloration often caused by sorbic acid and benzoic acid in cosmetic products. This new cosmetic preservative blend is a reasonable alternative to classical combinations containing parabens and solvents.

References

Address correspondence to Klaus Weber, c/o Editor, *Cosmetics & Toiletries* magazine, 362 South Schmale Road, Carol Stream, IL 60188-2787 USA; or e-mail: CT_author@allured.com

1. D Steinberg, Frequency of use of preservatives 2001, *Cosmet Toil* 117(4) 41-44 (2002)
2. T Branna, A preservative update, *Happi* 41(5) 89-92 (2004)
3. K Weber and J Siebert, Organic acids - a modern alternative for preservation of cosmetics, *SÖFW-Journal* 129(6) 44-50 (2003)
4. T Eklund, The antimicrobial effect of dissociated and undissociated sorbic acid at different pH levels, J Appl Bacteriol 54(3) 383-389 (1983)
5. HP Fiedler, *Lexikon der Hilfsstoffe für Pharmazie, Kosmetik und angrenzende Gebiete*, Editio Verlag Aulendorf 5 Aufl (Bd 2) 1560-1563 (2002) ■

Reprint from January 2005 ***Cosmetics & Toiletries*** magazine, Vol. 120, No. 1, p. 57-62.