Manufacture and Properties of Synthetic Toilet Soaps[1]

M. HOLLSTEIN, Zschimmer & Schwarz GmbH, PO Box 2179, 5420 Lahnstein, West Germany, and **L. SPITZ**, 5225 Old Orchard Road, Skokie, IL 60077

ABSTRACT

The manufacture of syndet bars requires special machinery and somewhat different processing steps than those used for normal toilet soap production. Fully synthetic bars are higher priced specialty products which offer special properties not available in normal soaps. Syndet bars: are free from alkali; they can be neutral or adjusted to pH levels below 7; are used for skin problems; lather and clean very well at various water hardnesses without forming a curd or precipitate; are compatible with a large variety of additives; and use less perfume than normal soaps.

INTRODUCTION

Soap is mankind's oldest body cleansing agent. Its physical and chemical properties have been improved through the ages, resulting in the top quality bars of today. While soap-based laundry products have been replaced almost completely by synthetic surfactants during the last few decades, toilet bars have not been affected in a similar way. There are three main reasons for the survival of fatty acid-based toilet bars: they are economical, have good usage properties and are easy to manufacture. But there is a special field of application in which the synthetic substitute has become an interesting alternative: the synthetic toilet bar.

A syndet bar contains only synthetic surface-active materials and no soap. The "combo bars," combinations of soap and synthetic surfactants, are not discussed here.

COMPOSITION

A general composition range for syndet bars is (parts): surfactant (30-70); plasticizer/binder (10-30); filler (10-30); additives (0-20); and water (3-10).

Surfactants

Surfactants are the components responsible for the cleansing and lathering properties of the bar. Patent literature describes, rather optimistically, almost every existing surfactant as a possible active ingredient of quality syndet bars. Some examples, published during the last 15 years, have been chosen to illustrate the state of the art.

Table I shows the multiplicity of surfactants for syndet bar formulation. Fatty alcohol sulfates, alkane sulfonates and, in particular, acyl isethionates are the favorite ingredients, either alone or in combination with other surfactants. Besides these and other anionics, nonionics, cationics and amphoterics are also proposed.

Many authors claim special and additional properties resulting from their formulations. Good skin tolerance, low sloughing and wear rate, as well as increased slip, are directly attributable to certain surfactants. Lowered sloughing is obtained with the addition of calcium or magnesium α-olefin sulfonates (20) alkane sulfonates (5) and alkoxy hydroxy propane sulfonates (7). An increased slip results from sugar esters (4), whereas alkyl phosphates seem to be especially tolerable to skin (23).

The availability of a large number of detergent raw materials and their use in wide concentration ranges make syndet bar formulation a rather difficult task.

Plasticizers and Binders

To obtain good processability and usage properties, the surfactant part of the syndet bar is stabilized with plasticizers and binders. A proper differentation between the two is difficult. A plasticizer can be defined as substance which lowers the viscosity at the manufacturing temperature; thus, a plasticizer helps both plodding and stamping.

A binder prevents the separation of macroscopic aggregates, caused by local stresses, which in turn promote cracking tendencies. It is an obvious advantage of natural soap that the surfactant itself acts as plasticizer simultaneously. Plasticizers and binders strongly influence the lathering, wear and sloughing characteristics of the bar. Thus, they should be selected very carefully, not simply as processing aids. According to patent literature, there is an almost unlimited freedom of choice among different materials. Table II gives some typical examples. The substances studied most intensively are the fatty acids and their derivatives such as alkanolamides, esters of polyvalent alcohols and even natural soap. They are followed by fatty alcohols and paraffin. A remarkable increase of plasticity is claimed for the addition of fatty alkyl ketones (12) and the combination of hydrogenated triglycerides with fatty acids or alcohols (27). Most plasticizers and binders serve simultaneously as emollients.

Fillers

Solid fillers are used frequently to improve the internal structure and hardness of the finished product and, above all, to reduce the bar cost since most fillers are rather cheap. The most widely used fillers are listed in Table III. Talcum powder is used against sloughing (18), puffed borax for lower wear and density (30). It is important not to exceed certain maximal concentration levels, since most fillers impart a rough surface feel to the bar, plus loss of slip and a less attractive overall appearance.

Additives

The additives used in syndet bar formulations are substances added in rather low quantities to impart or improve certain desired properties and to suppress undesired ones. Overall appearance, performance, dermatological and germicidal effects are enhanced by additives.

Colors are used as in normal soaps. Titanium dioxide

[1]Based on a paper presented at the AOCS Meeting in New Orleans, May 1981.

TABLE I

Surfactants Used in Syndet Bar Formulations

	Composition (%)	Ref.
Acyl isethionate ↓	(25-60)	1
	(40-53) + fatty alcohol sulfate (55-60)	2
	(20-70) + sugar ester (5-30)	3
	(30-70) (7-24) + alkane sulfonate (3-20), (45-65)	4,5
	(30-70) + alkoxy hydroxy propane sulfonate (1-10)	6
	(10-20) + alkyl sulfoacetate (10-20)	7
	(20-27) + α-sulfo fatty acid (30-50)	8
	(30-80) + acyl N-methyl taurate (0-2)	9
Fatty alcohol sulfate ↓	(40-74)	10,11,33
	(13-33) + fatty acid monoglyceride sulfate (47-67)	12
	(50-54) + alkyl phenol polyethylene glycol ether (17-23)	13
Alkane sulfonate ↓	(60-85)	14
	(40-80) + α-olefin sulfonate (20-60)	15
	(15-49) or α-sulfo fatty acid ester (10-15) + iminopropionate amphoteric (14-21)	16
Sulfo phenol fatty acid ester (25-80) + phenol sulfonate (10-55)		17
Alkylbenzene sulfonate (18-21)		18
α-Olefin sulfonate (95-100)		19,20
Monoalkyl sulfosuccinate (60-75)		21
Acyl glutamate (95)		22
Acyl taurate (10-20)		33
Alkyl phosphate, mono + di (100)		23
Fatty alcohol polyglycol ether (10-35) + ethylenediamine EO/PO (20-40)		24
Quaternary ammonium salt (55-100) + amine oxide (>10)		25
Imidazolyl amphoteric (50)		26

TABLE II

Plasticizers and Binders in Syndet Bar Formulations

	Composition (%)	Ref.
Fatty alcohol ↓	(5-25)	2,8,12,14,33
	(16) + stearic acid monoglyceride (4)	11
	(5-10) + hydrogenated triglycerides (22-28)	27
Fatty acid ↓	(5-30)	5,8,14,17
	(10-40) + soap (6-28)	1
	(10-20) + fatty acid ethanolamide (10-20)	25
	(27-30) + hydrogenated triglycerides (5-10)	27
Fatty alcohol (10-20) and/or fatty acid (15-38) and/or hydrogenated tallow (5-20) + fatty alkyl amide (0.4-21)		9
Soap (13-16)		10
Fatty acid ethanolamide (21-26)		13
Fatty acid (30-35) + PEG 600 (20-40)		24
Diethylene glycol monostearate (3-15)		28
Glycerol monostearate (5)		16,21
Glycerol monostearate + fatty alcohol + hydrogenated castor oil (total 20)		29
Hydrogenated tallow (18)		16
Fatty alkyl ketone (0.5-10)		12
Paraffin (10-30)		7,16
Polyoxyethylene glycol (65-70)		33

TABLE III

Fillers in Syndet Bar Formulations

Composition (%)	Ref.
Na_2SO_4 and similar salts (20-25)	10
$CaHPO_4$ (1-40) + talcum (5-19)	18
$MgHPO_4$ (1-40) + talcum (5-19)	18
NaH_2PO_4 (16-70)	16
Puffed borax (10-50)	30
Starch (5-10)	16,27
Starch (5-10) + dextrin (10-30)	7
Mannitol (50)	26

may be added for uncolored bars (9,21).

Fragrance can be used in lesser quantities, since in syndet bars, perfumes do not have to mask certain odors prevalent in normal soaps. Also, most perfumes show greater stability in syndet bars.

Some of the negative in-use properties of syndet bars such as high solubility and sloughing are improved by adding inorganic salts together with dimer linoleic acid (31) (see Table IV). Aluminum triformate is also very effective and will be discussed later.

The cracking tendency has much less importance for natural soaps and it is mainly controlled by properly formulated plasticizer/binder and filler systems. Reduced

TABLE IV

Miscellaneous Additives in Syndet Bar Formulations

Composition (%)	Effect	Ref.
TiO_2 (0.4-2)	Whitener	9,21
Na_2SO_4 (4) + NaCl (3) + dimer linoleic acid (3)	Antisloughing	31
Na-α-sulfo palmitate (up to 5)	Antiscum, curd	17
Zn-stearate (up to 7.5)	Better slip	17
Mineral oil (2-5)	Regreasing	14
Glycerine (4)	Moisturizer	9
PEG 600 (0.25)	Moisturizer	17
EDTA (8-20)	Moisturizer	28
Acyl glutamate (5-55) + lactate (12-20)	Moisturizer	32
Iodophors (3-20)	Germicidal	33

curd formation is obtained with α-sulfo palmitates and zinc stearate has been claimed to impart better slip (17).

Good dermatological properties are very important for valid marketing claims. A variety of additives has been studied in this regard. Emollience and humectancy of the skin mainly determine the subjective postwash "after feel" registered by the syndet bar user. Mineral oil has been described as a regreasing agent for improving emollience (14), but there are better alternatives. Methyl glucose ethers and lanolin derivatives have been found to be effective emollients in natural soap (34) and should perform correspondingly well in syndet bars. Comparative sebumeter studies gave high emollient recovery values between 4.0 and 6.7 units against -1.2 for isopropyl myristate (34).

Glycerine, fatty acid mono-diglycerides and ethoxylated isostearyl glycerides are other efficient emollience-enhancing additives in well approved syndet formulations. Humectancy of the skin results from moisturizer additives. Polyethylene glycols (17), EDTA (28) and mixtures of glutamates with lactates (32) are described in patent literature for this use. Products based on hydrolized collagen are also very effective in this respect.

The group of germicidal additives comprises deodorants and disinfectants, already known from natural soap formulations. Many of them have been banned or restricted in application during the last few years for consumer safety reasons. Tetramethyl thiurame disulfide, tetrachloro salicylic acid anilide (TCSA), elementary iodine (33), tribromosalicylanilide (TBS) and hexachlorophene are examples. Besides the light-stable trichlorocarbinilide (TCC) and its less important trifluoro methyl derivative, trichloro hydroxydiphenyl ether shows broad bacteriostatic and fungistatic activity ranges, good tolerance and rather low toxicity. Concentrations of about 1% are normally sufficient. A herbal-based deodorant additive for a wide bacterial and fungal spectrum is usnic acid. The recommended concentration level is 0.1%.

MANUFACTURE OF SYNDET BARS

The production of syndet bars is more difficult than the manufacture of conventional toilet soaps, the main problem being the plasticity of the syndet base. Soap plasticity stays rather constant in the normal 30 to 45 C temperature operating range, whereas syndet plasticity changes from very hard to very soft in the same processing range. Standard toilet soap finishing lines are used for syndet bar manufacture but product appearance and line productivity are seldom satisfactory. The best syndet bar line is the "Dual-Function Finishing Line" with "prerefining."

Syndet Bar Line

Over the last decade, toilet soap finishing lines have been standardized into a few well defined types. Unfortunately, syndet bar lines have not received the same attention and there are many types, mostly based on toilet soap finishing methods.

The "Dual-Function Prerefining Syndet Bar Line" (Fig. 1) illustrates two manufacturing routes using the same processing steps and the same machinery. The difference is in the possibility of using either a Twin-Worm Simplex Refiner and/or the Three Roll Mill for the prerefining and refining steps. The prerefining concept, the dual-function manufacturing flexibility and some specialized equipment should be part of any well functioning syndet bar line.

Twin-worm plodders have superior conveying, pelletizing and extruding capabilities. The superior performance of the twin-worm vs single-worm plodders is achieved with the two counter-rotating, touching but not intermeshing, special profile worms. The syndet bar worms are of different design than the normal soap worms. Syndet bars with a limited number and small quantity of additives can be produced with single-worm plodders, but it is always recommended to use the special worms to facilitate processing.

PROCESSING STEPS

Prerefining

A prerefining step is the best assurance for trouble-free syndet bar processing. The low moisture content, cold syndet base material is usually very hard, but when it is subjected to mechanical work with a refiner or a roll mill, it is easily plasticized into a rather soft and somewhat sticky consistency. The plasticized base mixes easier with the solid and liquid additives in the mixing stage than a nonplasticized base. The subsequent refining and extruding steps are also performed better.

Mixing

The prerefined solid syndet base is mixed with all the other additives in a standard batch-type soap amalgamator (mixer). The optimal mixing time depends on the product formulation and the batch size used. Overmixing should be avoided since it will cause product discharge difficulties from the amalgamator and conveying problems to the refining stage.

Refining

Refining the entire product mixture into a homogeneous, uniform, optimal quality finished product is performed with a roll mill or a Simplex refiner and with the first stage of the Duplex Vacuum Plodder, which is always a refining stage.

The operating variables for the refining units are: cooling

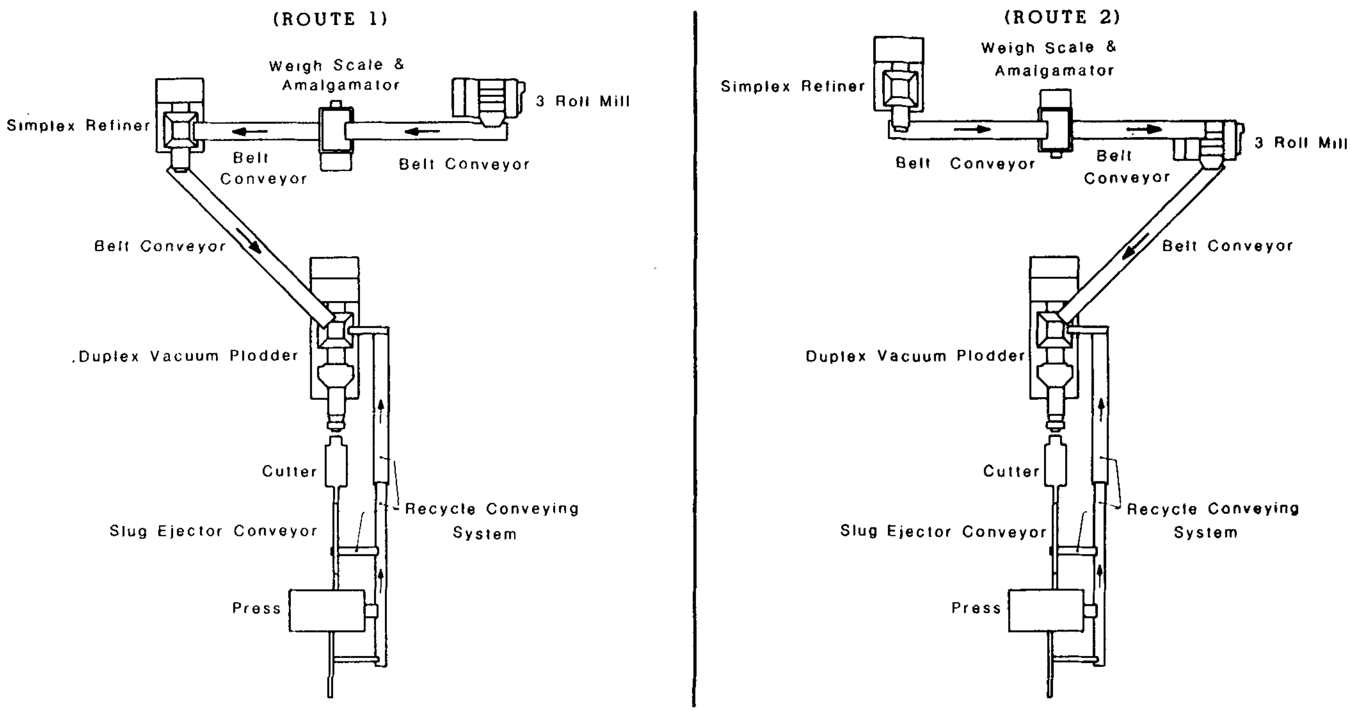

FIG. 1. Dual-function prerefining syndet bar line.

water temperature for the refiners and/or roll mill; and refining screen size for the refiners.

The cooling water temperature is very critical, depending largely on the water content of the product and to a lesser degree on the line capacity, type and size or refining equipment used.

In the refiners, refining screens of European mesh number 18, 22, 30 or in certain cases even 55 (U.S. mesh number 16, 20, 28 or 50) can be used. The proper size depends on the product formulation, i.e., the quantity and type of additives.

Extruding

All modern finishing lines have a Duplex Vacuum Plodder for the final refining, compacting and air-free extrusion of the product. These units consist of two plodders mounted in tandem and connected by a vacuum chamber. Twin-worm Duplex Vacuum Plodders are the best for syndet bar lines. It is very important to note that the preliminary stage of the Duplex Vacuum Plodder is a refining stage whereas the final stage is for extrusion only. After passing the preliminary stage, which is the last refining stage, the product must be fully refined.

The extrusion stage must always be free from any screens and pressure plates to allow unrestricted, uniform extrusion. The extrusion head temperature ensures a smooth surface finish to the extruded slug (billet). The optimal temperature, anywhere between 60 and 90 C, depends on the line output and product formula.

Cutting

The continuously extruded slug which leaves the Duplex Vacuum Plodder is cut into individual slugs of predetermined length. Standard soap chain cutters with the chain movement assisted by an air motor are most suitable.

Conditioning

The purpose of conditioning is to harden the slug surface before stamping. Since most syndet bar formulations are somewhat soft and sticky, even the use of refrigerated (chilled) stamping dies does not always help to achieve acceptable stamping rates.

Due to the cost and size of conditioning tunnels, they should be considered only for 200 bars/min and faster lines and for very difficult-to-stamp products. Since conditioning tunnels are seldom used, optional equipment, they are not shown in Figure 1.

Stamping

The use of refrigerated, chilled stamping dies in the automatic soap presses has become standard practice for soap and syndet products alike. The optimal temperature at which the syndet bars best release from the dies depends on the product formula and line speed, as well as on the bar shape and the humidity in the operating area. The temperature range varies from -30 to +10 C.

Die-releasing agents are also used. They are applied to the surface of the slugs or sprayed directly onto the stamping dies. The silicone-based product ZS 2945 is a very effective die-releasing agent.

Product Reprocessing

Extruded unstamped slugs (billets), stamped bars (tablets) and all trimmings and flashing from the stamping operation must be reprocessed *immediately* because syndet products reharded very quickly. Just like toilet soap finishing lines, all syndet lines must be provided with a continuous product rework, recycle conveying system. With high speed lines and very difficult products, it is best to repelletize all the rework material through a small plodder before recycling it to the preliminary stage of the Duplex Vacuum Plodder.

PROPERTIES

Lathering characteristics, wear rate, sloughing and toxicity are the most important properties of syndet bars.

TABLE V

Foam Height and Stability at Different Concentration Levels of Ethoxylated Isostearyl Monoglyceride (0.2% Solution, According to DIN 53902, Part 1)

Concentration (%)	1	2	3	4
Foam height	500-420	235-190	200-160	150-120

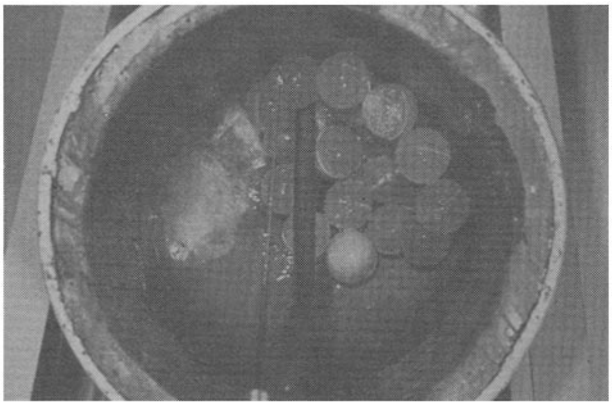

FIG. 2. Apparatus for wear evaluation.

TABLE VI

Chemical and Physical Data of ZETESAP 813 A

	Parts
Composition	
Sodium lauryl sulfate	25
Sodium monoalkyl sulfosuccinate	25
Corn starch	20
Cetearyl alcohol	15
Paraffin	10
Water	2-5
Titanium dioxide	0.1
Analytical methods	
Active anionic detergent matter	*p*-toluidine method, average molecular weight: 260 (37)
Moisture	Karl Fischer titration (38)
Physical data	
pH of 10% solution	6-7
Physical form	White noodles
Specific gravity, 293 K	1.16 g/cm^3
Bulk density	500 g/L

Lather

Fast forming, stable and creamy lather is always a desirable characteristic of products in bar form. Syndet bars lather very well, even in hard water and in sea water, whereas normal soaps lose most of their lathering ability under the same conditions. This lathering advantage is one of the most significant properties of syndet bars. Certain hydrophobic additives, even at low concentrations, adversely affect the foaming characteristics. Table V shows decreasing foam height and foam stability with increasing quantities of an ethoxylated isostearyl monoglyceride.

Wear Rate

Wear rate or erosion is not very sensitive to formula changes. The plasticizer and filler ratios mainly determine bar hardness and, therefore, the wear rate. Wear can be determined quantitatively with the unit shown in Figure 2 (35). The cylinder is filled with a ball-shaped piece of the syndet bar material and soft plastic balls of the same diameter (1-1/2 in.). It rotates around a longitudinal axis inclined by 45°. Constant-temperature water flows through the device simultaneously. After 8 min, the weight loss of the syndet ball is determined. For the syndet bar material presented in Table VI, the wear amounts to about 15% at 20 C and to about 26% at 37 C.

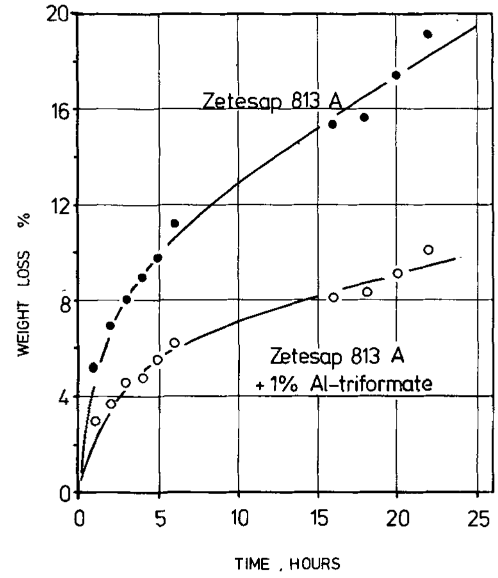

FIG. 3. Sloughing weight loss vs time.

Sloughing

Sloughing, slushing or mushing is a very typical negative property of most syndet bars and it is difficult to correct without reducing some positive properties. Sloughing is determined by dipping the bars into water for a certain time and calculating weight loss, which is then plotted vs time as in Figure 3. After an initial nonlinear increase for the first 4 hr, an almost constant 5%/hr loss occurs.

As mentioned before, there are many suggested additives for the reduction of sloughing. We found out that a small amount of aluminum triformate reduces considerably the slushing tendency. Figure 4 illustrates that a 3% addition yields a reduction of about 1/4 of the original value. Lathering power and wear rate did not change significantly in this experiment. It was also shown that the reduced pH value was not responsible for this effect.

Irritancy and Toxicity

Evaluation of effective skin and eye irritation for syndet bars is an extremely difficult task for several reasons. The widely used Draize test method, the Duhring chamber and other patch tests have exposure times which do not correspond to practical usage conditions. For this reason, syndet bars have more unfavorable ratings than natural soap. This leads to a recommendation concerning comparative tests. Half of the panel should be adapted to syndets before starting the actual testing, because most people are used to natural soap, and very seldom to syndets. Draize tests of our company's syndet-based material ZETESAP 813 A scored the rating "nonirritant" for the primary dermal irritation (0.75% aqueous solution) and "slightly irritant" for the eye irritation. A more realistic and practical test was performed over 6 months under clinical conditions

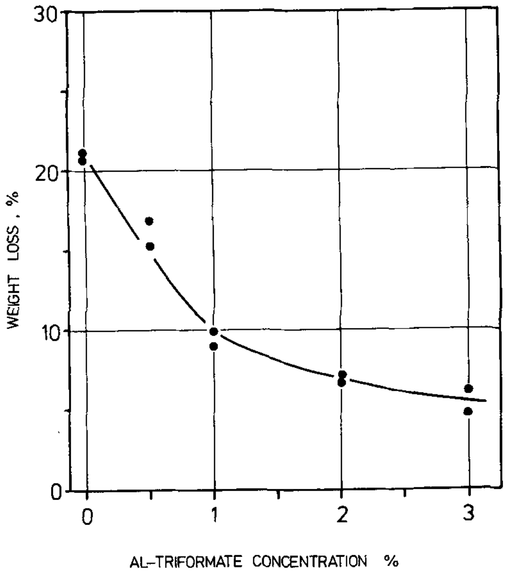

FIG. 4. Sloughing weight loss vs Al-triformate concentration.

with a panel of more than 100 persons. No irritations or other negative effects could be observed; the subjective judgment was predominantly positive (36).

LD_{50} levels generally are so high that "low" or "non-toxic" ratings may be stated. The material was tested according to FDA procedure and gave an LD_{50} of 5,800 mg/kg in rats.

PRACTICAL EXAMPLES

Base Material

More than 10 years ago, Zschimmer and Schwarz developed Zetesap, an easy-to-handle premix of constant composition which offers side formulation flexibility and versatility. The Zetesap syndet base is available in 2-mm diameter pellet form. Its composition and other data are shown in Table VI. Laboratory equipment extrusion is illustrated in Figure 5.

Formulations

The following formulas are two of the many formulation possibilities that exist with Zetesap-based products. Sensitive-skin bar: Zetesap 813 A, 93.0%; Amphoteric-2 (50%), 6.0%; perfume and color, 1.0%; dry-skin bar: Zetesap 813 A, 95.0%; lanolin, 2.0%; water, 2.0%; perfume and color, 1.0%.

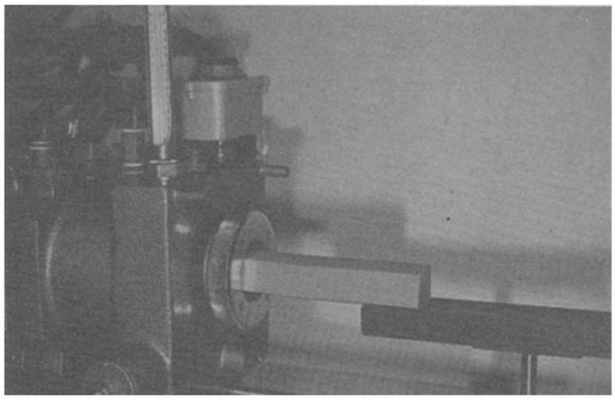

FIG. 5. Laboratory-scale extrusion.

Syndet Bars in the U.S. and Western Europe

During the last 10 years, syndet bars have gained increased consumer acceptance as medicated, sensitive-skin and luxury toilet bars. Table VII lists some of the most important brands now sold in the U.S., France, West Germany and Italy. The volume of syndet bars is less than 1% of the total toilet bar market in the U.S. and about 1-2% in Europe.

ACKNOWLEDGMENT

Special thanks to V. Martin, K. Beisicht and K. Maeckel of the Zschimmer & Schwarz laboratory staff for their contributions.

REFERENCES

1. Ger. Patent 2,402,223 (1974).
2. Gatti, L.J., Brit. Patent 1,294,754 (1972).
3. Machin, D., Ger. Patent 2,901,070 (1979).
4. Prince, L.M., Ger. Patent 2,461,139 (1975).
5. Prince, L.M., U.S. Patent 3,989,647 (1976).
6. Tokosh, R., and A. Cahn, U.S. Patent 4,180,470 (1979).

TABLE VII

Some U.S. and Western European Syndet Bars

Country	Brand	Surfactant base[a]
USA	Lowila	Alkyl sulfoacetate + sulfosuccinate
	Redken	Acyl isethionate
	Jhirmack	Alkyl sulfate + sulfosuccinate
	Buf	Alkyl sulfate + acyl isethionate
France	Dodie	Acyl isethionate
	Dermo-Pain	Alkyl sulfate + sulfosuccinate
	Lactacyd	Alkyl sulfate
	Vichy	Acyl isethionate
Germany	Dermichthol	Alkyl sulfate
	Eubos	Alkyl sulfate + sulfosuccinate
	Kräuter-Seife	Alkyl sulfate + sulfosuccinate
	Sebamed	Alkyl sulfate
Italy	Bioderma	Alkyl sulfate + sulfoacetate + sulfosuccinate + acyl isethionate
	Lactacyd	Alkyl sulfate
	Mitigal	Alkyl sulfate
	Pane del Bambino	Alkyl sulfate + sulfosuccinate

[a]According to labeling.

7. O'Roark, J.R., U.S. Patent 4,100,097 (1978).
8. Farmer, C.H., and M.A. Wells, Ger. Patent 2,403,895 (1974).
9. Morshauser, F., Intl. Publ. WO 80/02154, 1980.
10. Schumann, K.A., K.H. Schumann and J. Brueckl, DDR Patent 32,812 (1965).
11. Tuan, T.A., Fr. Patent 96,188 (1972).
12. Hewitt, G.T., U.S. Patent 3,350,320 (1967).
13. Orshitzer, P., and A. Macander, U.S. Patent 4,012,341 (1977).
14. Norton, C.J., U.S. Patent 3,622,517 (1971).
15. Alsbury, A., U.S. Patent 3,812,060 (1974).
16. Barnhurst, J.D., G.M. Leigh and J.A. Monick, U.S. Patent 3,442,812 (1969).
17. Miller, R.O., and L.A. Mattano, U.S. Patent 3,503,888 (1969).
18. Bishnu, P.S., U.S. Patent 4,150,001 (1979).
19. Sweeney, W.A., and G.L. Woo, U.S. Patent 3,705,114 (1972).
20. Woo, G.L., and R. House, U.S. Patent 3,867,317 (1975).
21. Brit. Patent 1,153,303 (1969).
22. Yoshida, R., M. Takehara, A. Kanagawa, O. Hitoshi and Y. Usuba, Ger. Patent 2,010,303 (1970).
23. Belg. Patent 851,806 (1977).
24. Hooker, D.T., U.S. Patent 3,312,626 (1967).
25. Cheng, W.M., A.N. Morrison, M. Barnes, T. Richards, D.A. Rosser and P. Thurairajan, Brit. Patent 1,296,351 (1972).
26. Shelmire, J.B., U.S. Patent 3,975,313 (1976).
27. Chakrabarti, P.M., and F.S. Morshauser, Ger. Patent 2,737,739 (1978).
28. Steinhauer, A.F., Ger. Patent 2,432,161 (1975).
29. Fr. Patent 1,183,960 (1960).
30. Compa, R.E., C.F. Fischer, R.T. Hunter and R.C. Odioso, U.S. Patent 3,708,425 (1973).
31. Prince, L.M., and J.P. Furrier, Brit. Patent 1,477,897 (1977).
32. Johnston, G.F., A. Martin and A.D. Tomlinson, Brit. Patent 1,487,552 (1977).
33. Halpern, A., U.S. Patent 3,687,855 (1972).
34. Pavlichko, J.P., A.M. Fleischner and A. Seldner, Cosmet. Technol. 3:40 (1981).
35. Stoesser, K.V., Fette Seifen Anstrichm. 59:972 (1957).
36. Tronnier, H., Muench Med. Wochenschr. 117:913 (1975).
37. Based on Marron, T.U., and J. Schifferli, Ind. Eng. Chem. Anal. Edn. 18:59 (1946).
38. Official and Tentative Methods of Analysis of the American Oil Chemists' Society, revised 1974, Method Ca 2e-55.

[Received November 17, 1981]

Synthesis and Bacteriostatic Properties of Acylarylureas and Alkylarylureas

T.J. MICICH, Eastern Regional Research Center[1], Philadelphia, PA 19118

ABSTRACT

Fatty substituted ureas (RNHCONHR') were prepared where R is an aliphatic acyl or alkyl group and R' is a substituted phenyl group or a thiazole group. The benzene ring was generally substituted with chlorine, nitro, hydroxy, or a combination of these groups. The compounds were ineffective against gram-negative microorganisms but a number of samples inhibited the growth of *Staphylococcus aureus* at 1 ppm. Bacteriostatic activity was generally observed where the acyl or alkyl group contained 6-10 carbon atoms and where R' is 4-nitrophenyl, 4-chloro-3-nitrophenyl or a thiazole group derived from 2-amino-5-nitrothiazole. Scattered activity at 1 ppm was observed where R' is 3-nitrophenyl, 2,4- and 3,5-dichlorophenyl, 2-hydroxy-5-chlorophenyl, 2-hydroxy-5-nitrophenyl, 3-nitro-4-hydroxyphenyl, 3,5-dinitrophenyl and 2-nitro-4-chlorophenyl. The alkylureas appear to be more active than the acylureas.

INTRODUCTION

Three basic types of sanitizing agents have been used in the food processing industry and various health institutions for the last several decades. These include the halogens or hypohalite solutions, halogenated aromatic compounds and quaternary ammonium salts. The halogens usually used as hypohalite solutions are exceptional broad spectrum germicidal agents by virtue of their high chemical reactivity. This characteristic is disadvantageous, for the halogens will react with organic substrates, thereby readily losing their activity. The low stability and high chemical reactivity of halogen-derived agents is associated with destructive oxidative reactions of organic substrates. Halogenated benzene derivatives such as hexachlorophene and trichlorocarbanilide are compatible with anionic and nonionic surfactants and have been used in cleaning formulations, surgical scrub soaps and soap bars. These totally aromatic bactericides possess the disadvantages of high toxicity, allergic sensitization and possible structural instability. Quaternary ammonium compounds are excellent broad spectrum germicides which are deactivated by soap, organic matter and polyvalent cations.

Beaver and coworkers studied substituted urea derivatives to relate structure with bacteriostatic properties (1). They concluded that very small changes in chemical structure lead to profound changes in antimicrobial activity. Of the 10 bridging functions examined, the urea bridging group conferred the highest bacteriostatic activity. The most active compounds were 3,4,3'-, and 3,4,4'-trichlorocarbanilides. Further studies of nitrodiarylureas indicated that meta nitro-substituted derivatives showed very high activity against *Staphylococcus aureus* (2). The rather conspicuous activity of the 3,4-dichloroaniline derivatives stimulated specific studies of this function, resulting in the publication of two patents (3,4). Schenach et al. (5) synthesized a series of N-alkyl-N'-3,4-dichlorophenyl ureas and found that compounds of alkyl groups containing 5-10 carbon atoms were most active with minimal inhibitatory concentrations (MIC) against *S. aureus* of < 1 ppm. This activity is comparable to that of the trichlorocarbanilides. Included in this study were alkylene α,ω-bis (3,4-dichlorophenylureas) with methylene bridges containing 0-8 carbon atoms that had MIC values greater than 5 ppm. A similar study of N-acyl-N'-3,4-dichlorophenyl ureas by Zakaria and Taber (6) indicated that MIC for these compounds in soap were 20 ppm with no sharp deviations in activity for acyl groups containing 2-13 carbon atoms. Work by Baker et al. (7) and a patent (8) obtained by Jerchel showed that aliphatic amides derived from 2-hydroxy 5 chloraniline and various halonitroanilines are active bacteriostats against *S. aureus.* A recent study of fat-based N-aryl-substituted amides (9) at this laboratory confirmed these results and indicated that high activity against *S. aureus* was conferred by a variety of substituted phenyl derivatives. These results and the absence of a general study of acylarylureas, prompted the present program to prepare bacteriostats that are useful with surfactants and effective against gram-negative and gram-

[1] Agricultural Research Service, U.S. Department of Agriculture.