18.6 Emulsifiers

Due to their polar character, emulsifiers have interactions with most ingredients of wheat flour. Fig. 128 summarizes the effects of emulsifiers in baking.

It has been shown that the flour's own polar lipids – mainly phospholipids (lecithin) and galactolipids already have a positive effect on the volume yield (MacRitchie and Gras, 1973).

Tab. 91: Effect of alternan and alternan sucrase on the Farinogram

Dosage per 100 kg of flour	**WA** %	**Stability** min	**Softening** FU
No addition	62.0	9.5	10
100 g Alternan	62.3	9.5	10
300 g Alternan	62.6	8.5	20
500 g Alternan	63.3	8.5	25
1 g Alternan sucrase	62.0	9.5	10
1 g Alternan sucrase, 100 g malt extract	62.2	9.5	15
10 g Alternan sucrase, 100 g malt extract	62.7	10.0	15
100 g Malt extract	61.8	9.5	10

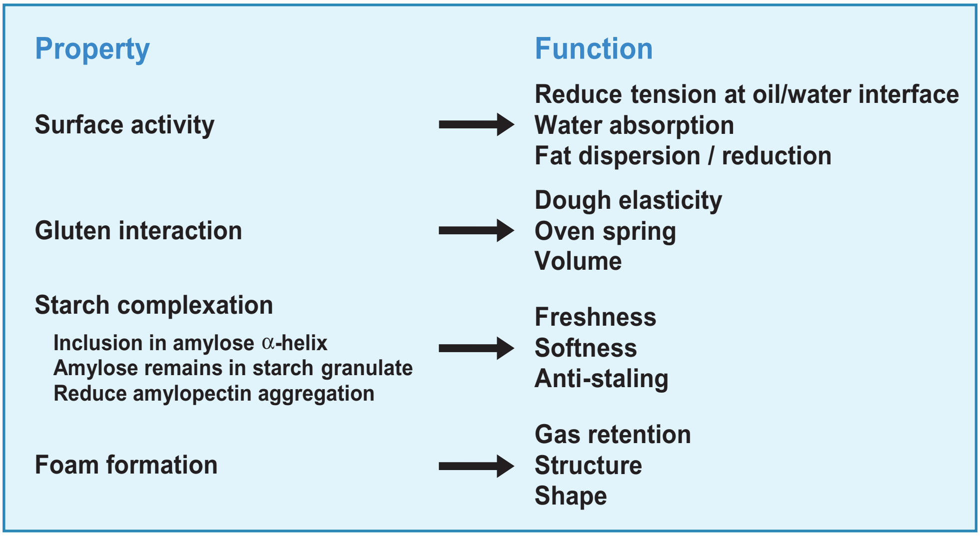

Fig. 128: Properties of emulsifiers in bread baking

54 Flour from which all lipids had been extracted only showed an improvement in volume yield when the polar lipids (or all lipids) were re-added, but not with non-polar lipids (i.e. oil) alone (Fig. 129).

It is probable that all emulsifiers build complexes with gluten, as shown in Fig. 130 for lecithin. On the one hand they increase the binding forces between the protein chains, but on the other hand they act as a kind of lubricant, improving the gliding of the protein layers over each other.

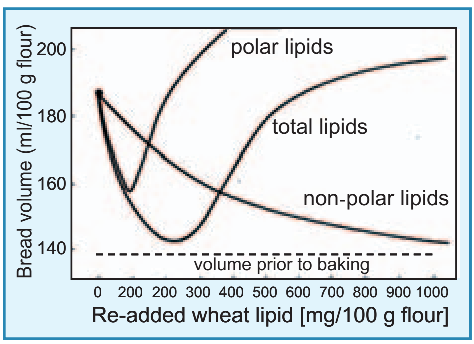

Fig. 129: Effect of wheat lipids on volume yield of defatted wheat flour (modif. from MacRitchie and Gras, 1973)

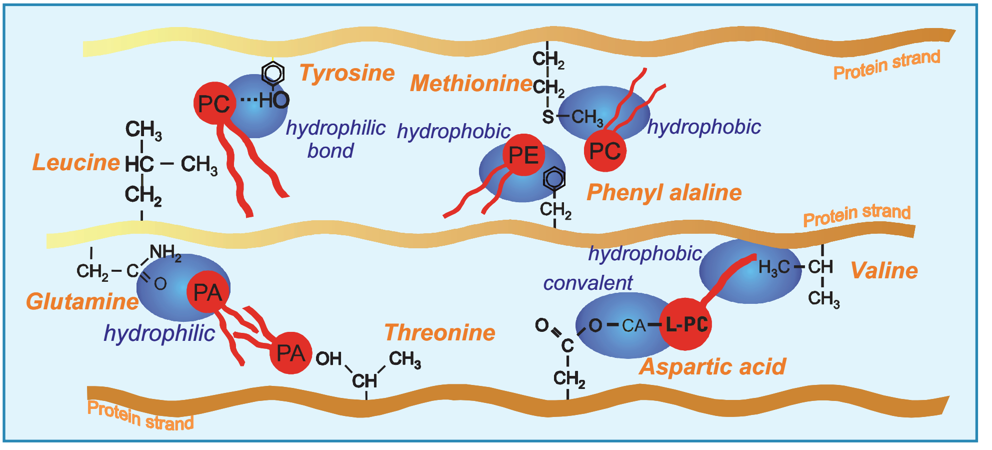

Fig. 130: Formation of lipoprotein complexes by emulsifiers

Some emulsifiers with long non-polar, linear chains, such as monoglycerides, form complexes with starch (Fig. 153; chapter 18.11), preventing the recrystallization of the gelatinized starch upon storage and thus prolonging shelf-life.

18.6.1 Lecithin

Bakers, especially, have been familiar with lecithin longer than with any other emulsifier. At first it was mainly the effect of lecithin from egg yolk that was used to distribute large amounts of fat evenly in the product and achieve a finer crumb and higher baked volume, but now concentrated lecithin from soybeans is available for this purpose. In its deoiled form it is also well suited for use in mills. The most obvious benefit of lecithin is probably the noticeably reduced stickiness of the dough; bound up with this is better machinability, that is also a result of greater smoothness. The interaction of lecithin with the starch and its ability to bind water also prolong the shelf-life of the crumb. Lecithin also has a positive effect on volume yield, but in this respect it tends to fall behind synthetic emulsifiers such as diacetyl tartaric esters of mono- and di-glycerides (DATEM). A consumer trend towards slightly lower volume yields observed in some parts of Europe is likely to increase the use of lecithin again, if the problem with raw material from genetically modified (GM) organisms is finally solved. There are already effective IP[29] systems for sourcing non-GM soybean lecithin. Moreover, lecithin fractions are available that offer the advantage of being natural emulsifiers with properties specially adjusted to specific applications. There is a fraction with a very low HLB[30] value (hydrophobic) and one with a very high HLB (hydrophilic); this makes one more suitable for emulsification of water in oil and the other for emulsification of oil in water.

The dosage of lecithin for flour treatment is in the range of 30 - 150 g to 100 kg of flour. Such low doses mainly have the effect of improving the processing characteristics of the dough,

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29 IP = Identity Preservation. IP is an active process in which actions are taken to preserve the identity of a higher value product as it moves through the chain to a specific end market. Keeping apart or segregating raw materials is one of the consequences of applying an IP system. Consumer demand for non-GM or GM free food provides an economic incentive for farmers, processors and distributors to supply such products, which require IP to be accepted by the consumer (modif. from Codex Alimentarius Commission, 2001).

30 HLB = hydrophilic-lipophilic balance; the theoretical values of HLB range from 1 to approximately 50. The more hydrophilic emulsifiers have HLB values greater than 10, while the more lipophilic emulsifiers have HLB values from 1 to 10. As a general rule, emulsifiers with HLB values in the range of 4 to 6 promote water-in-oil emulsions; values between 8 to 18 promote oil-in-water emulsions.

whereas a considerably larger dose increases the stability of the dough, crumb structure, fermentation tolerance, and shelf-life.

18.6.2 Mono- and Diglycerides

Mono- and diglycerides are produced by splitting off a single or two fatty acids from edible fats and oils. By selecting the fatty acids remaining on the glycerol backbone it is possible to produce emulsifiers with greatly differing properties. For flour treatment there is mainly a demand for the mono- and diglycerides with good anti-staling properties. These are attributed to linear, saturated fatty acids that interact well with starch and thus slow down the staling process. The best monoglyceride for this purpose is glycerol monostearate (GMS). Although GMS and other mono- or diglycerides show their best functionality when hydrated, i.e. as paste, and can therefore only be used in the bakery, they are also suitable for use in milling when in a fine powder form. The large surface: volume ratio results in fast hydration, and thus almost the same efficacy.

In other respects, too, these emulsifiers have similar effects to lecithin, namely a finer crumb and a greater volume yield. With fat-rich products, especially, the dose required may be up to 1% of the flour.

18.6.3 Emulsifier Complexes

In many cases it is possible to enhance the properties of an emulsifier by combining it with another emulsifier. An example of this is the mono- and diglycerides, that achieve their optimum suitability for use in flour treatment through combination with lecithin. The lecithin improves their solubility and dispersion, and clearly their interaction with constituents of the flour as well. Well-known and widely used organic flour improvers fall into this category. The combination makes it possible to reduce the dose necessary for optimum effect to 100 - 300 g with 50% emulsifier in the complex.

Diacetyl tartaric esters of mono- and diglycerides are also receptive to enhancement with lecithin: the addition of as little as 10% lecithin improves their emulsifying effect and also reduces the vinegar smell.
The above combinations are only effective if the emulsifiers are mixed before being converted into their powdered form. Interestingly, it is not sufficient just to mix the individual powdered components.

18.6.4 Diacetyl Tartaric Acid Esters of Mono- and Diglycerides (DATEM)

One very effective group of emulsifiers in respect of volume yield is mono- and diglycerides of edible fats esterified with mono- and diacetyl tartaric acid. DATEM is a heterogeneous mixture of molecules derived from esterification of acetic acid, tartaric acid and fatty acids (bound to glycerol). Some of the resulting emulsifier molecules are more active than others. The structures shown in Fig. 131 were the most efficient in bread baking trials (Köhler, 1999). Both molecules were derived from glycerol monostearate. But most probably the other molecules do have a co-emulsifying effect, which means that the mix is more effective than a single, purified emulsifier. DATEM is one of the main constituents of most baking improvers, especially when the aim is to produce voluminous baked goods with a crisp crust. DATEM is not often used in flour treatment; its main application is in bread improvers utilized in bakeries. The optimum dose is about 300 - 400 g to 100 kg, but for reasons

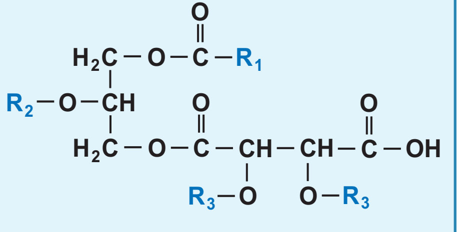

Fig. 131: Hypothetical structure of the most baking-active components of DATEM

of cost the dosage is often reduced to as little as 150 g.

18.6.5 Sodium and Calcium Stearoyllactylate (SSL and CSL)

These emulsifiers are made from the fatty acid stearic acid esterified with a double ester of lactic acid. The remarks concerning DATEM also apply to these, but with the difference that SSL and CSL are especially suitable for baked goods with a soft crust. Furthermore, they have a better effect on the retention of crumb softness.

18.6.6 Other Emulsifiers

Tab. 92 summarizes the emulsifiers suggested for baking. Sucrose esters seem to be interesting since they are produced in a wide range of HLB (hydrophilic or lipophilic). The high-HLB variants, especially, have a good effect on volume yield and crumb structure at quite low dosages, but the price is still much higher than that of conventional baking emulsifiers.

Tab. 92: Suggested emulsifiers with potential use in baking applications

Emulsifier	Common abbreviation	HLB	Application and benefit
Acetyl esters of monoglycerides	AMG	2.5-3.5	Whipped cakes, volume
Calcium stearoyl lactate	CSL	7-9	Bread, shelf-life, volume
Diacetyl tartaric esters of monoglycerides	DATEM	9.2	Bread, shelf-life, volume
Ethoxylated mono- and diglycerides (polyglycerates)	EMG	12-13	High-fibre bread; shelf-life (combined with monoglycerides)
Glycerol monostearate (non self-emulsifying)	GMS	3.7	Shelf-life
Glycerol monostearate (self-emulsifying)	GMS	5.5	Shelf-life
Lecithin	LC	3-4	Shelf-life, dough properties
Lactyl esters of monoglycerides	LMG	3-4	Whipped cakes, volume
Mono- and diglycerides	MDG	2.8-3.8	Bread, cakes, cookies, volume
Polyglycerol ester	PGE	12-13	Whipped cakes, volume
Propylene glycol monostearate	PGMS	1.8	Whipped cakes, co-emulsifier
Polysorbate 60	PS 60	14.4	Whipped cakes, co-emulsifier
Succinyl monoglyceride	SMG	5-7	Yeast leavened baked goods; volume
Sorbitane monostearate (e.g. SPAN 60)	SMS	4.7-5.9	Whipped cakes, volume
Sodium stearoyl lactate	SSL	18-21	Bread, shelf-life, volume
Sucrose esters	SUE	7-13	Bread, cake, volume