

Development of a Range of Encapsulated Milk Fat Products

(Encapsulated Milk Fat Products)

Armis No. 4428

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Summary and Conclusions

Microencapsulation is a technique used in a variety of industrial food applications for the protection of sensitive components or the delivery of flavour or an aroma which may be lost during processing or storage. The technology has yet to find application in the dairy industry but from a dairy perspective, a potential outlet exists in the transformation of milk fat into a powdered form using established dairy processes of homogenisation (for dispersing milk fat globules) and spray-drying (for fixation of the globules). The solid matrix or wall material of the powder particles should protect the microparticles or core material from oxidative deterioration. Any microparticle can be encapsulated, but with fat microparticles, the solid matrix must be partly an emulsifier and be capable of dehydration. The dairy industry has excellent emulsifying/dehydratable agents in sodium caseinate and whey proteins. The advantages of microencapsulation are that milk fat can be converted to a stable powder form and better powder flow properties can be obtained by minimising surface fat on the powder particles. This should also facilitate the production of higher fat powders using conventional dryers and of fat powders more stable to oxidation. Fat globule size and size stability over time are of fundamental importance for successful microencapsulation.

Therefore, the aims of this research were to determine the effects of milk composition (fat, whey protein, lactose and salts) and process (homogenisation) factors on the formation of emulsions and microencapsulated powder particles and to relate these to the properties of the powder, especially susceptibility to fat oxidation. The effect of composition, using sodium caseinate and lactose on the production of high fat powders was also studied. Finally, new developments in microencapsulated milk powders were undertaken in collaboration with industry using sodium caseinate and lactose. Overall, the microencapsulation process

should provide a technique to extend the shelf-life of sensitive fats and flavours and to produce high fat powders for a range of end-uses.

The main conclusions were as follows:

- New expertise was developed in microencapsulation technology which is of immediate relevance to industry for the production of novel functional and flavour ingredients.
- Considerable insight was gained into the effect of homogenisation, composition and storage of emulsions on fat globule size and stability prior to encapsulation with whey proteins and lactose. A high homogenisation pressure with 4 passes was required. Increasing lactose and decreasing whey protein levels reduced powder free fat significantly but reduced the surface fat of the powder particles only marginally.
- The physical properties of the powders and their stability to oxidation during storage were related to the levels of the major components in the powders. The only significant composition factor affecting surface fat and thereby the level of oxidation was the fat level in the emulsion.
- High fat (70-90%) powders were made with sodium caseinate and lactose as microencapsulants. The free fat, surface fat and wettability of these powders were controlled by varying composition alone. A powder with 70% fat, 10% sodium caseinate, and 20% lactose had the lowest free fat, with consequent good handling and free-flowing properties during drying and good reconstitution properties in water.
- An FIE award-nominated microencapsulated high fat flavoured ingredient is being successfully produced and commercialised for a variety of applications. The powder maintains good flavour retention during storage and gives good flavour release and functionality when incorporated into food products.

In summary, the major components of the emulsions used to make the microencapsulated powders influenced fat globule diameter and stability, but the minor salt components also affected globule size and stability. Free flowing high fat (70%) powders with sodium caseinate and lactose as encapsulants were manufactured using a tall-form Niro spray dryer with fluidised beds. A flavoured ingredient using a by-product flavoured fat as the flavour agent was made using the same encapsulants. Microencapsulated powders were incorporated into baked goods as multi-functional ingredients. They increased loaf volumes and improved handling and processability of the dough, thereby extending the product range for fat and other dairy ingredients used for baking. Microencapsulated 80% fat blends were manufactured for biscuit formulations to overcome the handling problems associated with bulk fats. This sub-project also gave rise to a leading role in a EU FAIR project on the microencapsulation of fish oil for use in functional foods using milk components as the sole encapsulants.

Research and Results:

Preparation of stable milk fat microemulsions

Good emulsions with small fat globules which were stable over time were easily made with whey protein isolate (WPI) as emulsifier. Increasing whey protein concentrate (WPC) or equivalent salt levels up to 1.90% added to WPI increased the fat globule diameter and instability of the emulsions, as shown in Table 1. A higher number of homogenisation passes counteracted these negative effects.

Table 1: Effect of added salts and 2 or 4 homogenisation passes on the fat globule diameter in emulsions stabilised by WPI, after storage for 2 and 22 min.

	2 Passes		4 Passes	
Added salts	2 min	22 min	2 min	22 min
(%)			Fat globule diameter D(v, 0.9) mm	
0.00	0.76	0.80	0.54	0.54
0.10	0.98	1.04	0.74	-
0.20	0.91	0.99	0.64	-
0.31	1.33	1.61	0.78	0.84
0.63	1.72	2.42	0.62	0.66
1.90	Unstable		Unstable	

a 15% Fat, 12% WPI, 12% Lactose.

Factors affecting storage stability of milk fat powders

An initial range of powders was made for storage stability testing. The minimisation of the emulsion fat globule diameter, free fat and surface fat did not depend to the same extent on the same factors. Milk powders with low free fat but not surface fat could be produced using whey proteins as emulsifier. The inclusion of 50% WPI with WPC-35 (increasing the whey protein ratio) in the emulsion increased the free fat from 3 to 24% in the 40% fat powders. Increasing WPC-35 (increasing the lactose ratio) resulted in reduced free fat in the powders. The surface fat values of the powders were high, ranging from 38 to 52% of the surface area of the powder particles. The powders with high (40%) fat and 50% WPI inclusion had the highest surface fat values (53%) compared to 43% surface fat for the remaining powders. Emulsion fat percentage was the only significant factor that raised the surface fat of the powders. WPC-35 (in effect a combination of whey proteins and lactose) compared to WPI, did not affect the surface fat level significantly.

Milk fat powders made with WPC-35 and WPI

During storage at 20°C, the powders made with WPC-35 showed a significant level of oxidation immediately after manufacture, which indicated that the fat present in the WPC was already oxidised. This trial was therefore repeated at 2 levels of fat and 3 ratios of

WPI:lactose to avoid the use of WPC, in order to determine the effect of these components on the rate of oxidation of the fat during storage. At the low WPI ratios, the emulsion globule size, powder free fat and reconstituted emulsion globule size were reduced, but the rate of oxidation was not affected, because the surface fat levels were probably not reduced, as in the initial trial. At the higher fat level, the level of oxidation after 2 months at 20°C was higher. A final confirmatory trial was carried out to determine the effect of fat level and the same ratios of whey protein:lactose on powder free fat, surface fat and oxidised off-flavour stability. As the fat, free fat and surface fat levels of the powder increased, the level of metallic off-flavour was the same, but a sour off-flavour was detectable 6 weeks earlier in the highest fat (50%) powder.

High fat powders microencapsulated using sodium caseinate and lactose

Powders were produced at fat levels ranging from 70 - 90% (w/w) with sodium caseinate levels of 1 to 15% (w/w) and lactose levels of 5 to 29% (w/w). High pressure homogenisation (45 MPa) and 4 passes were used for these trials. Decreasing sodium caseinate to <5% (w/w) gave a dramatic increase in fat globule diameter irrespective of fat level. Increasing the fat level increased the free fat from 4 to 80% and surface fat from 60 to 99%. Increasing the lactose level from 5 to 20% (decreasing sodium caseinate) decreased free fat by 52%. There was an inverse relationship ($r = -0.77$) between free fat and wettability and surface fat increased with increasing free fat (Table 2).

Table 2: Fat, free fat and surface fat of microencapsulated powders A, B and C and a regular cream powder D.

Powder	Fat	Free Fat	Surface Fat
	(%)	(%)	(%)
A	70	4.7	59.1
B	80	43.0	69.7
C	70	85.7	98.9
D	73	50.7	73.4

Microstructural analysis by confocal scanning laser microscopy (CSLM) (Fig. 1) and scanning electron microscopy (SEM) (Fig. 2) supported the results of the physical properties of the powders.

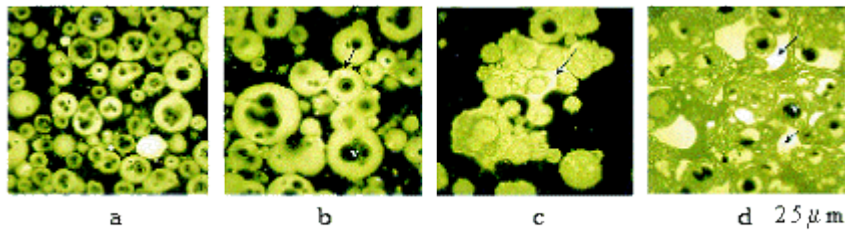


Fig. 1: Confocal scanning laser micrographs of powders stained with 0.01% (w/w of fat) Nile Red. (a) microencapsulated powder with a free fat of 4.7% (b) microencapsulated powder with a free fat of 43% (c) microencapsulated powder with a free fat of 83% (d) regular cream powder with a free fat of 50%. Fat appears yellow/white against a dark background. Arrows indicate surface fat. v = vacuole.

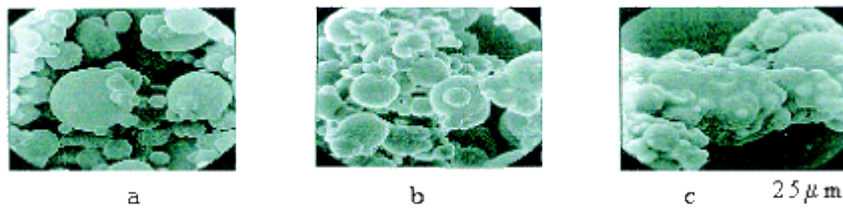


Fig. 2: Scanning electron micrographs of encapsulated high fat milk powders. (a) powder with a free fat of 4.7% (b) powder with a free fat of 43% (c) powder with a free fat of 83%.

Commercial developments

1. A fat by-product from a bacon processing facility was microencapsulated using sodium caseinate and lactose to give a natural smoky bacon flavoured ingredient. The microencapsulated powder showed good flavour and odour retention on storage at 16°C and gave good flavour release and functionality when incorporated into food products. The powder is now commercialised and marketed as a natural meat flavour enhancer. It is used as a replacement for commonly used artificial meat flavour enhancers such as mono-sodium glutamate (MSG).
2. Microencapsulated milk fat (70% fat) powder with low free fat (6%) was produced for a dairy processor. The powder exhibited good flow and handling properties and is undergoing commercial evaluation by the processor.
3. The assessment of microencapsulated powders in bread and other baked products as multi-functional ingredients (i.e. addition of the fat in powder form with protein as the emulsifier) indicated that bread made with the microencapsulated powder was superior to breads made with traditional margarine shortening. The functionality tests used were loaf volume, texture and colour.
4. A high fat (80%) microencapsulated fat powder was manufactured for a biscuit producer with the aim of incorporating fat into biscuit formulations without the handling problems associated with bulk fats. The powder was preferred to bulk fat by the bakers from a handling and processing point of view, but microencapsulation increased the cost of the fat.