Investigation of the Contribution of Dairy Ingredients to Chocolate Rheology, Texture and Flavour with Special Reference to Understanding the Optimum Form and Functionality of the Ingredients

(Dairy Ingredients in Chocolate)

Armis No. 4223

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Summary and Conclusions

Conventionally, chocolate crumb is the source of milk solids used in the chocolate-making process in the UK and Ireland (37,000 tonnes used in 1992), while whole milk powder is used in continental Europe (40,000 tonnes used in Germany in 1992). Chocolate manufacturers prefer roller dried powder to spray dried powder, because roller dried powder gives acceptable flow characteristics especially low viscosity to chocolate at the conching stage of chocolate making. Regular spray dried powder gives a higher viscosity to chocolate at this stage. This is attributed mainly to the free fat levels of the powders. Roller dried has up to 90% free fat compared to less than 10% in regular spray dried powder. However, preparing a batch of chocolate with skim milk powder and anhydrous milk fat to give 100% free fat does not result in the same flow characteristics as roller dried powders. The chocolate industry consider that both the high free fat and unique particle structure of roller dried powder control the rheology of chocolate. Problems in making high free fat in powders are reported at certain times of the year, but in particular, the control of particle structure in the production of spray dried powders and the effects on chocolate are poorly understood.

Therefore, the main objective was to assess and control the contribution of various ingredient components to chocolate behaviour and to optimise ingredients for specific chocolate applications. A key aim, therefore, was to understand the role of composition and particle structure and to produce spray dried powders with a functionality in chocolate as close as possible to roller dried powders. By demonstrating how the powder properties affect chocolate, it should be possible to control the functional properties of the powders to meet

any powder or chocolate specification. Novel powder compositions indicated by this work should also be useful to chocolate makers.

The main conclusions were as follows :

- Preliminary chocolate batches were made on the new pilot scale plant at Moorepark using spray dried regular whole milk powder, a purchased high free fat powder and blended skim milk powder and anhydrous milk fat. Powders with higher free fat resulted in chocolate with lower viscosity at conching.
- Spray dried powders with the variable attributes necessary for testing their effects on the chocolate properties were made in MTL. The free fat of the powders was directly related to the milk protein and curvilinearly to the solid fat at 10°C, reaching a minimum at 48% solid fat. The powder particle size was also curvilinearly related to the solid fat at 10°C and reached a maximum at the same solid fat content.
- Chocolates were made using these high free fat powders to determine the influence of powder composition and particle structure on the chocolate properties. The viscosity of the chocolate at conching was reduced as the free fat and particle size of the powders increased while the yield value was reduced by the solid fat at 10°C and increased by the vacuole volume. The results show that milk powders can be selected to produce chocolates with viscosity and yield values required for various end-uses.

In summary, the ability to make chocolate under test conditions and to assess the role of milk powders or other ingredients has been put in place for the first time in Ireland. Previous knowledge of milk seasonality and of powder technology has provided a basis for understanding variations in milk powder functionality in chocolate. Spray dried powders with mean free fat values of 50 to 94%, particle sizes of 30 to 65 mm and vacuole volumes of 0.0 to 3.9 ml/100g were produced from milks of varying composition but under the same processing conditions. Advances were made in analysing powder structure through microscopy, particle size and occluded air measurement. Valuable new information has been generated on the changes in free fat, solid fat content, particle size and occluded air in powders. Explanations were provided for the first time for the complex effects of these properties on chocolate viscosity and yield value. This information will also make a positive contribution to other projects in the milk powder area. Good contacts have been established with multinational manufacturers and with producers of milk powder for chocolate.

Research and Results:

The process, evaluation methods and preliminary trials

After setting up the process and evaluation methods, preliminary chocolate batches were made using regular spray dried whole milk powder and a purchased high free fat powder. Chocolates were made with powders ranging from 10 to 98% free fat. As expected, the chocolate containing high free fat milk powder had a lower viscosity and yield value than the chocolate containing regular milk powder, at the conching stage (Fig 1). The hardness of the moulded chocolate was also at a minimum at the highest free fat level. Chocolate particle size was controlled within a narrow range, so that changes in chocolate rheology could be attributed solely to varying free fat levels. The microstructure of some chocolate samples was also examined using a confocal scanning laser microscope. Chocolate made with roller dried or high free fat spray dried powders had more visible free fat than that made with 10% free fat powder. In the chocolate made with low free fat powder, most of the fat was seen encapsulated in the protein.

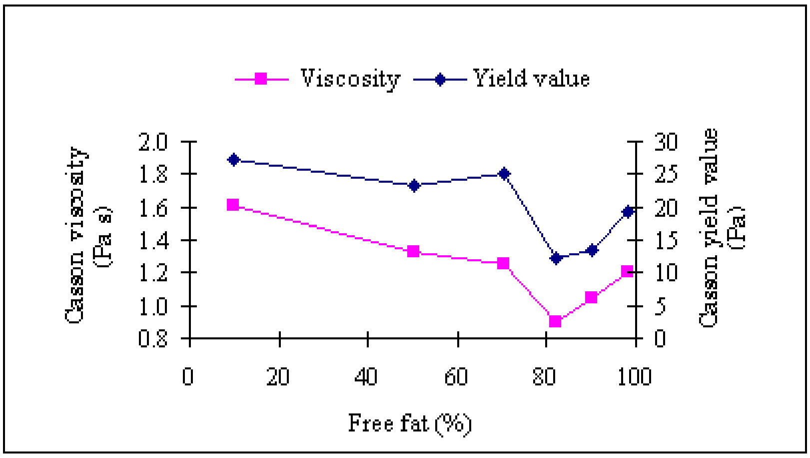

Figure 1: Effect of free fat on viscosity and yield value of conched chocolate.

Making high fat spray dried powders in MTL

Twenty high fat powders and skim powders were made over the year from spring and autumn herd milks, by drying high fat concentrates and blending with the skim milk powder to give a fat content of 26%. In addition to herd type, the protein (%) of the milks and the solid fat at 10°C (%) of the milk fat were evaluated in a quadratic design. The free fat (%), particle size (mm) and vacuole volume (ml/100g) of the powders were measured. High fat powders ranging in free fat from 40 to 96%, in particle size from 30 to 64 mm and vacuole volume from 0.0 to 3.9 ml/100g powder were obtained at the same processing conditions, due to changes in the composition of the milk used.

Free fat (%)

The free fat (%) of the high fat powders varied from 40 to 96% and was affected linearly by the protein (%) and curvilinearly by the solid fat at 10°C (%), as shown in Fig 2a. At a constant solid fat value of 44.6%, the free fat increased from 57.9 to 91.2% as the protein increased from 3.18 to 3.81%. The effect of solid fat on the free fat was curvilinear. For example, at a constant protein value of 3.25%, the free fat decreased from 93.6% at the low (39.6%) solid fat to 55.6% free fat at 47.8% solid fat and increased again to 94.6% free fat at the high (56.0%) solid fat. (See Tables 1a and 1b).

Table 1a: Protein (%) and solid fat at 10°C (%) of Spring herd milks and free fat (%) and particle size (mm) of high fat powders.

Month of lactation	Protein (%)	Solid fat at 10°C (%)	Free fat (%)	Particle size (mm)
January				
February	3.18	44.1	40.5	57.5

	3.20	43.8	60.8	71.6
March				
April	3.37	43.8	81.6	44.6
May	3.28	39.0	95.8	38.8
	3.18	40.3	91.3	32.9
June				
July	3.45	43.2	82.8	31.8
	3.56	42.9	92.4	31.2
August				
September				
October	3.60	40.9	91.9	30.5
November	3.63	47.2	90.4	45.7
December	3.26	55.9	94.0	44.9

Table 1b: Protein (%) and solid fat at 10°C (%) of Autumn herd milks and free fat (%) and particle size (mm) of high fat powders.

Month of lactation	Protein (%)	Solid fat at 10°C (%)	Free fat (%)	Particle size (mm)

January				
February	3.15	47.0	53.1	45.9
	3.19	49.2	54.4	65.2
March				
April	3.07	40.5	74.6	44.6
May	3.43	41.6	90.3	39.5
June				
July	3.81	44.6	92.7	30.3
August				
September				
October	3.46	40.5	91.5	36.2
	3.47	40.5	94.8	30.4
November	3.57	42.5	51.1	66.2
December	3.23	47.0	52.2	70.7
	3.21	49.6	48.1	57.2

Particle size (mm)

The high fat powder particle size D(v, 0.5) value ranged from 30.0 to 64.6 mm, which was much smaller than roller dried powder. The particle size was affected curvilinearly by the solid fat at 10°C (%), as shown in Fig 2b. At a constant protein value of 3.25%, the D(v, 0.5) value increased by 20.6 mm from 38.4 mm at the low (39.6%) solid fat to a maximum of 59.0 mm at 47.8% solid fat and decreased again to 44.3 mm at the high (55.9%) solid fat. The effect of solid fat on the particle size was opposite to that of free fat. In fact, an inverse relationship was found between free fat and particle size (r = - 0.70).

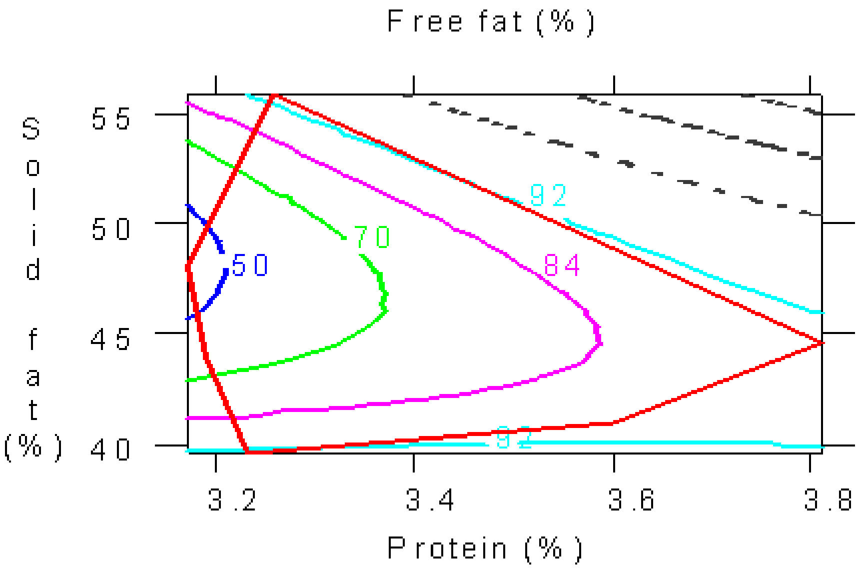

Figure 2a: Effect of protein (%) and solid fat at 10°C (%) on the free fat (%) of high fat milk powders.

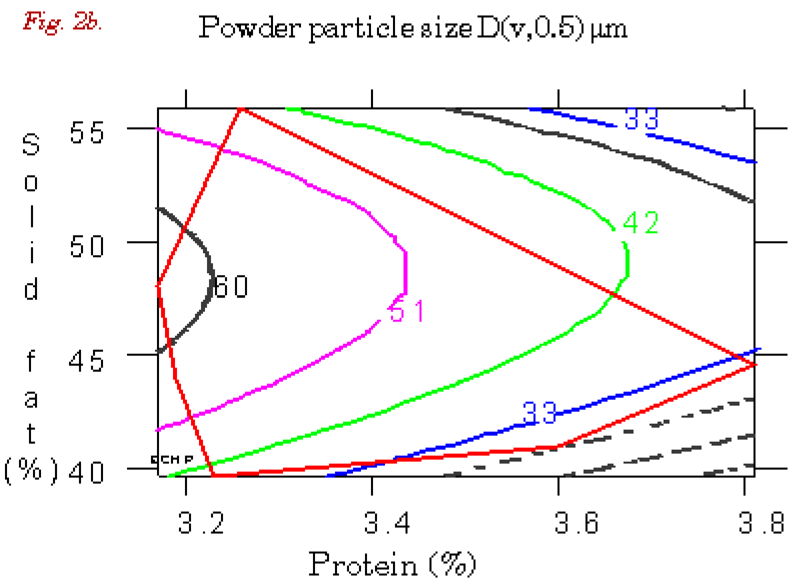

Figure 2b: Effect of protein (%) and solid at 10°C (%) on the powder particle size D(v, 0.5) mm.

Vacuole volume (mls/100g powder)

The vacuole volume of the powder particles was low, ranging from 0.0 to 3.0 mls/100g powder. This was undoubtedly due to the high free fat levels in the powders, which in turn suppressed foaming and air entrapment. Neither of the composition variables affected the vacuum volume levels significantly. This is to be expected for such a narrow range of results.

Skim milk powders

The influence of the milk protein (%), solid fat at 10°C (%) and herd type on the skim milk powder vacuole volume (mls/100g powder), interstitial air (mls/100g powder) and particle size (mm) was also quantified. There were no significant effects on the results measured. However, the particle size and vacuole volume of these powders were reduced when a smaller dryer nozzle size was used, but the interstitial air was increased, as would be expected. There was a low positive correlation of 0.45 between particle size and vacuole volume, indicating that of the order of 20% of the particle size in this case was due to the occluded air.

Making chocolates from the MTL high free fat powders

16 trial chocolates were made to determine the influence of powder composition and particle structure on the chocolate properties. The input variables were free fat (%), solid fat at 10°C (%), powder mean particle size (mm) and vacuole volume (ml/100g powder). The viscosity (Pa s) and yield value (Pa) at 40°C of the chocolate at conching were measured. The viscosity of the chocolates varied from 1.14 to 2.56 Pa s. The viscosity was significantly reduced by the free fat and mean particle size of the powders. The viscosity was not significantly affected by the solid fat at 10°C and the vacuole volume of the powder particles. The yield value varied from 11.5 to 25.9 Pa. Yield value was significantly reduced by the solid fat at 10°C and increased by the vacuole volume. The yield value was not significantly affected by the free fat and particle size of the powders. The results are shown in Table 2.

Table 2: Main effects of the powder properties on the viscosity and yield value of the conched chocolate.

Term	Viscosity (Pa s)	Significance	Yield value (Pa)	Significance
Constant	1.88		19.8	
Free fat (%)	-1.09	**	-4.9	Not significant
Solid fat at 10°C (%)	-0.66	Not significant	-12.2	**
D(v,0.5) mm	-1.02	*	-0.5	Not significant

Vacuole volume	-0.16	Not significant	10.1	*

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