"Trans Fatty Acids"

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The subject of oils and fats amongst bakers is perhaps more widely a discussion taken by plant bakers, and recently the subject of trans fatty acids has become "hot topic." (IFST, 2004) What does reduction in trans fats actually mean for the industrial baker? It is thought useful to give scope and background as to why low trans shortenings are discussed specifically now.

Industrial margarines, shortenings, and other oils, labelled by media "killer fats" have attracted strong focus to move away from lipids containing *trans* acid isomers. *(trans* isomers are developed during hydrogenation process, they are not present in fully hydrogenated fats and oils *footnote).* The following discusses the subject of Low *trans* Shortenings.

Function of plastic fats is influenced by the ratio of liquids to solids **(Telloke,** G.W. **1983)** in the lipid phase, and the crystal packing arrangement developed during processing. Control of crystal form, size, and shape must be balanced with careful blend selection, and are critical for final application in bakery products.

Fats as a function in bakery application is well studied. While traditional baking methods have become modified, the fundamental functional properties of fats are still required. Paramount importance are creaming and emulsifying capacity; creaming because of volume, and emulsification because of moisture and liquid take-up. These latter, are critical in applications such as cake batter systems, and it is emulsifiers, which are finding increased influence to the demands to improve performance. **(Podmore J. 1995)**

Design of a margarine or shortening for a specific bakery application or product, now presents challenges. Presence of *trans* fats in certain stress applications offers desirable physical and functional aspects. Often a selected fat is expected to perform in a range of products, and meet varied demands in manufacture, whereby a fats specific plastic range might be expected to perform to tight tolerances. Removal of trans therefore, reduces available options. Recognising this aspect coupled with preference to reduce total saturates generates further complexity.

Removal of *trans* fatty acids in oils and fats creates difficulties for margarine and shortening producers, which while perhaps meeting demands of nutritional compliance do not always satisfy the demand to supply materials that are sufficiently acceptable in performance.

Work is now presented which puts emphasis on the role of shortenings and demonstrates the potential to produce shortening formulated with reduced *trans* acid content and which are able to give performance akin to types containing relatively high levels of *trans.*

Footnote:

* Dietary trans acids come mainly from three sources: as a result of partial hydrogenation of vegetable or fish oils, in dairy fats where they are formed by natural biohydrogenation in the rumen, and through exposure to high temperatures during refining. They are present in a small number of seed oils. They are higher melting than the cis isomers.

· **Ref.-** *Gunstone F D., Herslof B. G., electronic Lipid Glossary 2, pub. Oily Press, 2004*

Results are simply presented in two parts. **Part I** discusses plastic shortenings, statistical validity is presented to demonstrate consequences of baking performance, both with and without *trans* acids in shortening formulations, and highlights the use of emulsifier used to enhance creaming capacities in cake batter systems and

general creaming, where reformulated low or zero *trans* blends are required. **Part II** deals with Fluid shortenings. Fluid / liquid shortenings have been used in Europe for sometime, but these generally find use specifically as frying media. Uses have been found for these types of shortening as replacements for plastic shortening in general dough fats, and have found wider use as carriers of functional ingredients for other bakery applications. Details are discussed on the use of Beta prime stable fluid shortenings and emulsifiers used to enhance the same.

PART I - Low *trans* Plastic Shortening

The hydrogenation of oils adds hydrogen to a fatty acid double bond. During hydrogenation, trans fatty acids are formed. Selective hydrogenation involves hydrogenation of the most polyunsaturated fats first. (those with most double bonds) The trans fatty acids will then increase until they are hydrogenated. **(Fig 1)** shows that as we continue to hydrogenate, then unsaturated liquid oil becomes firmer, and iodine value becomes smaller. If reaction is continued to completion, saturates increase, and *trans* decrease. A fully hydrogenated fat/oil might also be referred to as fully saturated. Either way, these fats would contain insignificant *trans.*

Trans fatty acids can have a substantially higher melting point (Fig. 2) than the corresponding cis fatty acid - the difference can be in excess of 30℃.

Experiment & Methodology

Effects of using a range of Distilled monoglyerides to make a typical commercial plastic shortening are investigated using three fat blends, and three forms of Distilled Monoglyceride at six dose levels. Method is deigned using multivariate analysis, where objective is to discriminate between combinations and subsequently identify optimal combinations. **(Table 1)** This is done for two reasons: First, in order to include both the process-lab variation and the bakery-lab variation in the population of treatment, and allow for variation in test samples, which might be too narrow and highly influenced by outliers; second, to get the best possible result, which is determined by the size of experiment, and to identify best dosage-response.

Evaluation was made on *Physical Parameters:* Whipping Test: 5, 10 and 15 minutes. Hardness: 1, 2, and 4 weeks Batter Density and Specific Volume.

Sensorial Parameters *AppearanceSurface, TextureCrumb Structure, Moistness, Eat Quality, Shortening Texture Sensorial parameters scored at discrete 0-10 scale.

Fat blends and nutritional aspects were considered (Table 2). Selected blends were considered typical commercial blends, used in northern hemisphere. Fat blend 1 (FB 1) contains hardened soybean, which is largely phased out in UK, but still applicable within USA.

Blends were designed for optimal working temperature and acceptable melting points, and SFC's were targeted to the working temperature. **(Fig. A)** Selected emulsifiers are Distilled Monoesters, and are used with the selected fat blends to assess performance. Distilled monoesters are of high, medium, and low saturation, shown by iodine valve. **(Table 3)**

A 3-tube Gertenberg pilot plant was used to process the shortenings, (Table 4) and process conditions selected. In general when processing reduced *trans / trans* free shortenings consideration should be given to crystal quality, and the selected process conditions must attempt to minimise post-crystal formation. (thereby avoiding sandy and brittle textures) The selected process was not necessarily optimal, because while each of the three fat blends share similar solid fat curves, they have quite different triglyceride arrangements. Optimisation of each fat blend to each emulsifier was not within scope of this investigation.

Shortening were held at 22oC from DOM +1 week and cakes prepared using "all-in-one" traditional form of mixing action, on standard Hobart Mixers. Sugar of flour batter method might have been more optimal, but design of test was to "stress" emulsifier and blend. Cakes were baked and stored lmonth on shelf-life test, and organoleptic evaluation made.

Crumb firmness was measured using Stable Micro Systems (TA.XT2) at 24 hours, two and four weeks. Cakes were MAP- packed in Nitrogen. Creaming tests were performed in Hobart Planetary mixer at 22℃. Density (g/ml) volume was measured after 5, 10 and 15 minutes. **Table 5** shows cake batter formulation.

RESULTS

In (Fig. 3) a plot of loadings is seen. A multivariate response of simultaneously physical and sensorial measurements is generated by a latent structure of two components, denoted factor 1 and factor 2. Plot of respective scores is shown in **(Fig. 4)** Multivariate plot of loadings **(Fig. 3)** shows the optimal area.

(Table 6 & 7) summarise results, and demonstrate optimal combinations between fat blends and emulsifiers.

Optimal combinations are marked by a positive plus `+', and non-optimal by a negative minus '-' When looking at **(Table** 7) it appears that **DIMODAN U/J** is NOT optimal for any fat blend. Fat blend 1 (26% *trans)* can use a lower dosage of emulsifier than fat blend 2 and 3. Clearly this demonstrates the theory that trans configuration contributes to quality of crystal packing arrange-ment, and generally increases performance. Fat blend 2 *(<1% trans)* utilizes an interesterified fat blend with good properties. (interesterified blends containing short chain C12 fatty acids are helpful in fat products, that require improved physical performance) Emulsifiers used within fat blend 3 (3% *trans)* must be dosed higher to have the same effect as fat blends I and 2.

Conclusion:

In summary - Lower emulsifier addition is possible in Fat-blend I using Emulsifier I & 2 compared to fat-blend 2 and fat-blend 3. Results within scope of these tests indicate need to increase saturated monoester to maintain performance when switching to reduced or trans free blends

PART II - Low *trans* **Fluid**

Shortenings - Strategies for use

in Cake Application

Background

Part 1 investigated plastic shortening. These types of fats are more "traditional", and Fluid shortenings are generally accepted more as frying media. Where boxed plastic fats are not used, then pumpable shortenings have also found good application because SFC's have tended to be closer to traditional boxed fats and pumpable shortenings are found

to have tolerance towards "all purpose" applications. The very point of adding fat/oil to cake was to confer moistness, extend MFSL, and achieve desirable crumb structure to the cake. Plastic shortenings can be creamed - whereas Fluid Shortenings cannot be creamed. Fluid shortenings in baking processes (particularly cake) rely on relatively high levels of emulsifiers, and historically, this has never been fully utilised in Europe. Emulsified fluid shortenings are more readily and widely accepted in North America. **(O'Brien, R.D. 1998)**

Established principle form of shortenings in Europe tends to be boxed / deboxed fats. There are now trends which challenge the use of plastic shortenings:

1. Nutritional requirements, and demands to restrict saturated fatty acids *and trans* fatty acids. The term "hydrogenated" used on pack declarations has now become targeted.

2. EU packaging waste directives.

3. Hygiene controls, and restricted presence of pallets into processing areas.

Purpose of this next part - was to investigate effects of utilizing known advantages of plastic shortenings, and selecting beta prime tending components, which could

remain liquid. Then enhancing with sufficient emulsifier concentration and types. It is interesting to discover the following:

1. Can fluid shortenings perform equal to plastic shortenings? 2. Are "high" levels of emulsifier required? 3. What is effect.of using 5' promoting hardstocks? 4. What is nutrition profile of plastic to fluid shortening?

Experiment & **Methodology**

Experiment was established to show range of fluid shortening types **(table 8)** including two controls. (one of these controls is a plastic shortening) In this example we have tested alpha tending Propylene Glycerol Ester **(GRINDSTED PGMS SPV)** with a distilled mono-ester **(GRINDSTED Dimodan HP)** It is well documented, that these emulsifier combinations have mainly found application in the Americas.

Control 1 is from previous example (Part 1). Control 2 is non-emulsified Low trans fluid Shortening. SFC's are presented, on oil blend only. (SFC's are NOT shown with the additional emulsifier) Viscosity of samples measured from 700cps to 4,500cps, using a Brookfield HBII viscometer. Viscosity was measured over a two month period, with very little or no change. It should be noted that removal of **GRINDSTED STS 30** from Control 2, or from samples containing significant palm oil addition, will result with rapid viscosity increase within one week, from DOM or sooner. Resultant material will come to have physical soft gel like characteristics like Vaseline, and will lose advantages of fluidity.

The selected emulsifiers are tested in liquid oil (rapeseed oil) and within fluid shortening systems.

Two emulsifier concentrations were tested, allowing formulated shortenings to coincide with selected cake batter formulation, and respecting guidelines set by EU food standards.

(Fig. **5)** shows typical methods to produce fluid shortening.
There are numerous options to produce these fluid
systems:

a) Standard scrape surface units can be used to initiate crystal
networks, then re-circulate back to blend tank, until material
reaches desired temp. (Important to establish cloud point, for
selected blend)

b) Alternatively cool to agitated vessel, and agitate until required holding
temperature is reached.

Optionally, a heat exchanger could also be added and looped to a final
holding tank to stabilize crystal networks.

Cake Formulation design

Cake batters are shown in **(Tables 9** & **10).** and are selected to use
12.5% and 6.25% shortening to meet EU regulation on limitations to use
of PGMS (E477). E 477 - Propane-1,2-diol esters of fatty acids may be
used in "fine bakery wares" at a max. of 5g/kg (finished product),
therefore designed "high dose" 12.5% & "low dose" 6.25% respectively.
Tested variants, with higher dose (8% PGMS) could meet EU
regulations if used at concentrations towards 6.25%

Experiments were also made on other emulsifier types, but these are
not currently published. Noteworthy, is the difference between cake
batter formulations. In Part I, up to 20% plastic shortening is used and
lower liquid content.

(table 9) However, in these investigations we are using fluid systems, and apart from previously mentioned legal considerations, these fluid systems are able to disperse throughout the batter very efficiently.

To "stress" cake batters further, apart from reduced shortening dose, more sugar and therefore more liquids are added. Egg tends to confer moistness to cake, but is reduced to minimize assistance with aeration. Adding additional water contributed to raising total increase in moisture.

Cake batter were assembled by mixing to "all-in-slurry for 1minute, then transferring to pilot scale "Oakes" type mixer, which employes very different mixing action. **(Fig. 6)**

RESULTS

In **(table. 11)** results are shown. Moving LEFT to RIGHT along the table - high emulsifier dose on LEFT and nonemulsified fluid shortening on extreme RIGHT. We can see that where fluid shortening (we mean liquid oil plus additional hardstocks) is 12.5% dose, then we see INCREASE in SpVol over standard liquid oil carrier. But decreased shortening dose to 6,25% then we see opposite to be true, whereby best volume is seen with straight Liquid oil carrier at low dose. Why is this? It is known that availability of liquid oil to protein is able to induce destabilising effect. So weight for weight at the 12.5% dose within the cake batter, fluid shortening contributes less liquid oil. Therefore the fluid shortening system does not only function as just a carrier system, but also offers functionality, and contributes to aeration. If the same principle is applied weight for weight at 6.25%, then we see liquid oil giving more volume. The overall reduction of liquid oil carrier to the cake batter now minimises effects of destabilisation. CLSM (confocol laser scanning Microscopy) shows how pure rapeseed oil is dispersed at high and low dosage. **((Fig. 7** & **Fig. 8) Fat stained Nile Red, Protein/starch/gluten stained green (FITC), dark areas gas/air bubbles. Image size 375x375umFITC = Flourescein 5-isothiocyanat))** The fluid shortening at this particular concentration does not disperse as efficiently as the liquid oil. This collates well with results from the plastic fat, and non-emulsified fluid shortening, because these do not function as well at the 6.25% dose.

Effect of emulsifier concentration in liquid oil. **(Fig. 9 / 10)** is seen that with sufficient concentration of alpha tending emulsifiers (eg 8% PGMS) and addition of second surfactant, (eg. 2% distilled monoglyceride) a

solid film develops at oil droplet interface **(Fig. 9)**, to form stronger film than pure PGMS at same concentration, and thereby preventing inhibition of foam formation. A lower concentration of the emulsifier system (eg. 4% PGMS + 1% Mono) is not able to form discrete oil droplets, and coalescence occurs, and subsequently giving destabilising effect. The solid film at the oil-water interface effectively "encapsulates" oil **(Fig. 11)** during air incorporation, thus preventing contact with proteins from egg and flour, which contribute to foam formation. Destabilization is minimised or prevented. **(Stauffer. C. 1999)**

On examination of the plastic shortening **Fig. 12** (Control 1 + 1% mono) against non-emulsified fluid shortening (Control 2) **Fig. 13** both appear similar under CLSM, where crystallised fat is lipophillic at air-in-water interface. With sufficient level of Beta prime **(Fig. 14)** hardstocks within the fluid shortening - the dispersion of fat phase shows strong similarity to plastic shortening. Viewed under polarised light **(Fig. 15)** we are able to see the state of crystal-tocrystal flocculation, and see how London-Van de Waals maintains network structure.

Results show interesting CLSM slides when comparing same emulsifier concentration in liquid oil to fluid shortening **(Figs. 16 / 17) Additional solids within the shortening, (fig 17) shows the fluid shortening behaves like plastic shortening, forming fat film at air interface.** More interesting is the effect of emulsifier concentration in the fluid shortening, because CLSM shows these concentrations of 8% PGMS + 2% mono, and 4% PGMS + 2% mono to have the same behaviour within the cake batter system. **See fig. 18 and fig. 19**

Conclusion

Introduction of a' promoting hardstocks (palm oil) in liquid oil to form fluid shortening is beneficial to the increase of specific volume in our example when inclusion to formulation was dosed at 12.5%. The use of this type of fluid shortening system allowed for reduced emulsifier load in our examples. 4% PGMS + 1% distilled mono in fluid shortening system is found equally effective compared to 8% PGMS + 2% distilled mono, within the same fluid shortening. Also negative impact was not observed on crumb firmness.

Liquid oil used as a vehicle to carry emulsifier **(Hartnett, D.1 and Thalheimer, W.G.,** 1979) showed benefits to specific volume when dosed at 6.25%. However, there is marked and faster increase in cake firmness compared to 12.5% (data not shown) It is considered likely that while the higher concentration of emulsifier, would stabilise the oil droplets to remain discrete with the batter system - in fact it is egg/protein based aeration which takes over, and makes greatest contribution to aeration. Fluid shortening reviewed here have enough functionality to help decrease shortening contribution when using sufficient levels of solids - preferably beta prime tending, in commercial cake application. Examples tested here also demonstrated the possibility of reducing emulsifier concentration.

This review of fluid shortening systems also shows that it is possible to meet growing demand for nutritional requirements, lowering saturated fats by approximately 50% and at the same time securing reduction of *trans* fats.