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Evalution of innovative technological approaches to replace palmoil with physically modified Swiss rapeseed oil in bakery products

Running title: Technological approaches to replace palmoil

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Tag for Graphical abstract

Graphical abstract: Microscope images of palm fat and palm fat replacers and photographs of baked shortbread biscuits.

Abstract

Palm fat is often used in baked goods because of its relatively low cost, and its positive impact on texture and shelf life. Demand for alternatives has risen in recent years due to concerns about the ecological and social sustainability. This is a challenge for the bakery industry since palm oil possesses unique properties.

In this study, unhydrogenated rapeseed oil was processed using novel physical technologies, such as wax crystallisation, stabilized foaming and Pickering emulsions, in order to simulate palm oil properties.

Analysis showed that while the initial viscosity of the fat substitute products was low compared to palm fat, the fat replacement products behaved very similarly to palm fat in the baking experiments. The resulting biscuits baked with emulsified rapeseed oil and rapeseed oil complemented with wax crystals were judged to be suitable replacements for palm fat in terms of processability, as well as analytical and sensory assessment.

Abbreviations

MCC emulsion : Pickering emulsion stabilised with microcrystalline cellulose

RPC emulsion : Pickering emulsion stabilised with rapeseed press cake

MC wax crystals : Rapeseed oil thickened with microcrystalline wax

MCC foam : Particle stabilised foam containing microcrystalline cellulose

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1. Introduction

Fats and oils influence the processability of biscuit dough with respect to rolling, laminating and shaping as well as the quality of the resultant baked goods in terms of texture, shelf life and sensory properties (Colla et al. 2018). Furthermore, gas holding capacity is also dependent on the type of fat, with semihard fats delivering a particularly even gas bubble distribution (Mamat and Hill, 2014). Palm fat is extracted from the fruit of the oil palm and is valued for its unique properties: it melts between 33 and 45 °C, solidifies between 35 and 42 °C and has a viscosity of 0.045 – 0.049 Ns/m^2. As a result, its texture is semihard at room temperature. Typical food applications include baking, frying, ice cream and pasta production processes (Ogan et al., 2015).

The characteristics of rapeseed oil differ greatly from palm fat since solidification occurs at 18.2°C, meaning rapeseed oil is liquid at room temperature. Traditional methods for increasing viscosity and melting point of rapeseed oil include hydrogenation, fractionation and transesterification. However, these chemical-physical processing technologies do not fulfil all the necessary conditions for organic certification (Bio Suisse, 2017).

In this project, three novel physical approaches were tested: Pickering water-in-oil emulsification of rapeseed oil using two different types of particles, Pickering foaming of rapeseed oil and the addition of waxes to induce crystallisation.

The first two approaches, Pickering emulsification and Pickering foaming, are subcategories of dispersion technologies and involve similar formation mechanisms. Traditional low molecular weight emulsifiers decrease interfacial tension and provide stability through steric hindrance resulting in fast stabilisation of foams and emulsions (Rayner et al., 2014). While Pickering stabilisation using particles with partial dual wettability is slower, the adsorption of particles at the interface is considered to be extremely stable (Stocco et al., 2009) or even irreversible (Dickinson, 2012; Gonzenbach et al., 2006). Various authors have highlighted the importance of surface wettability (contact angle), particle concentration, shape and size (Dickinson, 2012; Calabrese et al., 2018; Murray, 2007; Murray and Ettelaie, 2004). Contact angle can be adjusted by adsorption of surfactants or through chemical modification (Binks et al., 2007) but is limited in food applications as most of the substances used are not food grade. For water-in-oil emulsions, contact angles larger than 90°, representing a higher affinity to oil, are necessary to form stable emulsions (Köhler and Schuchmann, 2012). Particle size also needs to be below 25 μm to avoid any gritty mouthfeel (Engelen et al., 2005) and, as a rule, needs to be one order of magnitude smaller than the bubbles or droplets that are to be stabilised (Dickinson, 2012). The stability of Pickering emulsions is further influenced by particle concentration, shape and type of emulsification (Alison, 2018;

Schröder et al., 2018).

Recently, Tavernier et al. (Tavernier et al., 2016) provided an overview of food-grade particles that have potential to serve as Pickering particles. These encompass, among others, materials of biological origin, such as fat crystals, wax crystals, protein-polysaccharide complexes, flavanoids and protein particles (Rayner et al., 2014). Cellulose in the form of microfibrillated cellulose, cellulose nanocrystals and nanocrystalline cellulose have been demonstrated to result in superior emulsion stability (Kalashnikova et al., 2011, Winuprasith and Suphantharika, 2013).

Crystallisation through the addition of waxes is an alternative technological approach: Wax's characteristics, such as a relatively high melting point of more than 40°C and kneadability at room temperature, indicate its potential for use in tailoring the properties of rapeseed oil. The final crystal size in the fat can be further adjusted through shear and cooling rates, as has been well-established from research into cocoa fat processing (Zhang et al., 2014; Svanberg et al., 2011). Therefore, the combination of wax-fat systems with induced crystallisation was tested in this project.

2. Material & Methods

Three technological approaches to increase the viscosity of rapeseed oil were tested and the resulting potential palm fat replacers were characterised. Baking tests were subsequently performed to assess the effectiveness of the different approaches.

2.1 Preparation and analysis of palm fat substitutes

All of the palm fat substitutes were produced in triplicate. After production, all emulsions and foams were stored at 3°C and characterized on days 0, 1 and 5.

2.1.1 Crystallisation of waxes in rapeseed oil

4 g microcrystalline wax (6095 Microwax, KahlWax, Trittau, Germany) was dissolved in 96 g of rapeseed oil (Holl Rapsöl, Florin AG, Muttenz, Switzerland) at 90°C and cooled to 20 °C.

2.1.2 Particle stabilised emulsions with microcrystalline cellulose

3 g microcrystalline cellulose (Microcrystalline Cellulose, JRS Pharma, Rosenberg, Germany) was added to 87 g tap water to form the aqueous phase of the emulsion. Emulsification took place in a rotating membrane device (Kinematica AG, Littau, Switzerland,

type Megatron MT-MM 1-52) applying a gap size of 2 mm, a sinter membranewith pore size 10 µm and a rotational speed of2000 rpm. The oil-water ratio was set at 20:80.

2.1.3 Particle stabilised emulsions with rapeseed press cake

Rapeseed press cake (Florin AG) was milled in a Retsch mill (Retsch ZM200, Retsch GmbH, Haan, Germany) at 8000 rpm using a 0.2 mm sieve (Retsch DR100neu, trapeze sieve 0.2 mm, Retsch GmbH). 5 g of milled rapeseed press cake were then mixed with 85 g rapeseed oil and emulsified in a rotating membrane device (Kinematica AG, Megatron MT-MM 1-52, gap size 2 mm, sinter membrane, pore size 10 µm, 2000 rpm) at a water-oil ratio of 41:59 to form a uniform water-in-oil emulsion.

2.1.4 Particle stabilised foams

3 g of microcrystalline cellulose, 5 g of powdered milk protein concentrate (Ledor MO 80 T SG, Hochdorf AG, Hochdorf, Switzerland) and 1 g guar kernel flour (Pacovis, Stetten, Switzerland) were dissolved in 91 g tap water at 40 °C and cooled to 20 °C. The resulting mixture was foamed in a Kinematica rotating membrane device (gap size 3 mm sinter membrane with pore size 2 µm, 10000 rpm rotational speed). Air was then added to achieve a gas volume fraction of 0.63.

2.2 Analysis of palm fat substitutes

Viscosity analysis of the crystallised and emulsified samples was performed in duplicate on days 0, 1 and 5. For the foamed and the reference samples (rapeseed oil and palm fat), viscosity was measured six times on day one. Microstructural assessment was performed directly after production. The statistics software R, including R-studio, was used to analyse the results by applying a Kruskal Wallis test followed by a post-hoc Wilconson test. The significance level was set at *P < 0.05 and the significance of the results was indicated by the letters a to f, where different letters imply significantly different results.

2.2.1 Rheometry

Rheometric measurements were performed using a Discovery HR-2 Hybrid rheometer (Software Trios, TA Instruments, New Castle, USA) using couette geometry (rotor : Roto Conical / DIN H/A-AL Smart-Swap, diameter 27.97 mm, cup : aluminium cup single gap H/A-AL Assy, diameter 30.33 mm, TA Instruments). The sample cups were filled and left to rest for 5 minutes at 10 °C. The sample viscosity was measured for 5 minutes at a shear rate of 1 $s^{-}1$, followed by 3 minutes at 1000 s^{-1} and a rest period of 5 min, before a final

measurement for 5 min. at 1 s^{-1} to simulate dough kneading. The temperature was set at 10 °C.

2.2.2 Microscopy

A thin film was spread onto an object slide. No cover was added to avoid deformation of bubbles and droplets. The samples were assessed using an inverse light microscope (Echo Resolve, Echo, San Diego, USA) at magnifications of 4x, 10x and 20x.

2.3 Application tests

All baking tests were performed in triplicate, except for the sample including particle stabilised foam, which was only performed once as the resulting dough was barely processable and the sample was, thus, judged as less suitable to replace palm fat in either artisanal or industrial bakeries.

2.3.1 Production of shortbread biscuits

18.1 g of powdered sugar were mixed with 20.3 g palm fat (RSPO-SG, Florin AG), rapeseed oil or palm fat replacer and 11.4 g egg. Palm fat was replaced one to one by physically modified rapeseed oil and as a result, oil to water ratios changed between samples with different palm fat substitutes. This approach was chosen in order to detect changes in processability of the dough. The respective mixture was then kneaded (kneader, type GP20, Brunner Anliker, Kloten Switzerland) into a homogenous mass, before 44.1 g of white flour, 3.5 g of table salt and 2.6 g of crystallised sugar were also added. The dough was stored at 5 °C for 1.5 h and then stepwise rolled (Rondo Star, Rondo AG) to a thickness of 8 mm. Circular shaped pieces (5.5 cm diameter) were cut out and baked for 14 min. at 180 °C bottom heat and 190 °C top heat in a rack oven (Condo C-4-128, MIWE Condo, Arnegg, Switzerland). The shortbread biscuits were turned after having been baked for 7 min..

2.3.2 Evaluation of the quality of the baked goods

Sensory evaluation

The sensory evaluation protocol for the shortbread biscuits was based on a difference from control test, as described by Strobl (Strobl, 2013), with 14 untrained panellists. Grading of the reference sample with palm fat was fixed at ‘0’ for all of the evaluated attributes. For all of the other samples, the test panel judged attributes to be stronger (positive numbers) or weaker (negative numbers). In addition to the reference and the samples, a second, blind reference sample was added to test the panel’s tasting ability. The six attributes tested

were sweetness, saltiness, fattiness, sandiness, firmness and aftertaste. Panelists were in addition asked to comment on their observations.

Texture analysis

Both types of baked goods were analysed using the 'cookie' program of a texture analyser (TA.XT plus, two vertical plates and knife, TA Instruments) to assess firmness and elasticity. The baked goods were placed on two vertical plates to support the samples. A knife shaped device was then pushed downwards at a velocity of 2.00 mm/s to deform the baked goods until they fractured. The force necessary to fracture the baked goods was defined as the firmness, the path between the shear plate and baked goods upon fracture as the measure of elasticity.

Luminosity measurement

The baked goods were homogeneously pulverised, mixed and flattened on a white bench. The samples were then analysed using a L*a*b*-measuring device (Chroma Meter CR-400, Konica Minolta, Tokyo, Japan).

3 Results & Discussion

3.1 Characterisation of differently treated rapeseed oil samples

3.1.1 Microstructure

Assessment of the samples under light microscopy (Fig. 1) showed distinct differences in the structural composition of the samples. The enrichment of the rapeseed oil with microcrystalline wax resulted in the formation of evenly distributed crystals in the sample. While the general structure resembled the microstructure of the tested palm fat, the palm fat crystals were smaller in comparison and more densely packed.

Tag for Figure 1

Fig. 1: Overview and close up microscope images of palm fat and the tested alternatives, from left to right: palm fat (reference), MC wax crystals, MCC emulsion, RPC emulsion, MCC foam.

Emulsification upon addition of microcrystalline cellulose resulted in the formation of stable emulsions, with additional small droplets covering the surface of larger droplets. The addition of milled rapeseed press cake resulted in a stable emulsion interspersed with rapeseed press cake particles and droplets covered with small particles that were different in colour to the rapeseed fragments.

Foam stabilised with microcrystalline cellulose, complemented by milk protein and guar gum resulted in the formation of large bubbles covered by particles.

While the samples with microcrystalline wax and the emulsion stabilised with microcrystalline cellulose were completely stable over five days of observation, a small amount of water separated from the emulsion stabilised with milled rapeseed oil press cake (see Fig. 1S). The foamed sample stabilised with microcrystalline cellulose exhibited significant separation and was unusable after storage of more than one day.

The similarity of the microstructures of palm fat and rapeseed oil with microcrystalline wax matched expectations since palm fat is a partially crystalline system (Zhang et al., 2014). Pickering emulsification using press cake particles resulted in stable emulsions, despite the large size of some of the particles which should in theory prevent good stabilisation of an emulsified system (Schröder et al., 2018). It is hypothesised that stabilisation was only partially as a result of the press cake particles, with the majority of the particle stabilisation being the result of residual waxes from the press cake. According to Rousseau (Rousseau et al., 2013) waxes are known to have the ability to stabilise Pickering emulsions.

In contrast to the good stabilisation effect of microcrystalline cellulose in rapeseed-water emulsions, the stability of the foams was limited. Three reasons might play a role here: (i) the relatively viscous base recipe may have hindered the particles' access to the bubble surface, (ii) energy density in the rotational membrane foaming device was set too low (Müller-Fischer et al., 2007) and (iii) the particle size of the microcrystalline cellulose may have been too large.

3.1.2 Viscosity and stability of palm fat substitutes

Viscosity measurements directly after production of the palm fat substitutes (Fig. 2) showed that the substitute samples differed significantly from each other with the exception of the emulsified samples. All physically modified samples had a significantly higher viscosity than pure rapeseed oil (0.024 Pas for rapeseed oil, viscosities between 1.053 Pas and 23.02 Pas for physically modified samples). Nevertheless, they all still differed greatly from palm fat (393.7 Pas).

During storage, the viscosity of the emulsified sample containing press cake increased by 19% from day 0 to day 5 while the viscosity of samples MCC and MC wax crystals decreased by 31 and 42%, respectively. In contrast to these changes, viscosities of rapeseed oil and palm fat remained unchanged over the observed storage time. Differences between the samples remained significant after both one and five days of storage with the exception of the two emulsified samples which differed significantly from all other samples but not from each other. The foamed samples were not measured after storage, since they were not sufficiently stable.

Tag for Figure 2

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*Fig. 2: Viscosity measurements at a shear rate of 1 s^{-1} for all palm oil replacements, measured on the day of production and after one and five days of storage. (n = 6, * P < 0.05).*

While the microstructure of palm fat resembled the microstructure of rapeseed oil complemented with microcrystalline wax (Fig. 1), the samples' initial viscosities differed significantly. The observed differences in initial viscosity might be attributable to details in fat crystal characteristics. Zhang et al. (Zhang et al., 2014) found a clear correlation between fat crystal size and crystal density in palm fat shortenings with different melting points. Shortenings with higher melting points contained smaller crystals but at higher densities. Hence, it would be advisable to test whether a defined shearing and cooling process during the production of the palm fat substitute with microcrystalline wax might make it possible to further increase the viscosity. Windhab (Windhab, 1999) described a mechanical activation mechanism during shearing of crystalline samples that enables targeted crystallisation of the fat crystal type. Recent publications for cocoa fat and palm fat support these findings (Svanberg et al., 2011; Latip et al., 2013). However, the effect on performance in dough processing and baking has not yet been investigated.

Tag for Figure 3

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*Fig. 3: Viscosity measurement of all palm oil replacement systems measured at a shear rate of 1 s^{-1} (left image), followed by measurement at a shear rate of 1000 s^{-1} to mimic kneading (centre image) and, after a rest phase of 5 minutes, measured at a shear rate of 1 s s^{-1} to determine structure recovery (n = 6, * P < 0.05).*

At a high shear rate of 1000 s-1 simulating conditions during dough mixing (Fig. 3), the viscosities of the two emulsion-based systems (MCC and RPC emulsion) did not differ significantly from each other but were significantly lower than samples made using foaming and crystallisation. Overall, the viscosities at 1000 s^{-1} were more than two orders of magnitude lower for palm fat (factor 1468) than those at 1 s^{-1}. For all the other samples, the reduction in viscosity was less pronounced (lowest reduction by factor 31.91 for emulsion with rapeseed press cake, highest reduction by factor205.5 for rapeseed oil with microcrystalline wax). Rapeseed oil was not considered in this comparison since it does not contain well-ordered structures, which could be destroyed by high shear. Following the measurement at high shear and a subsequent rest period, the recovery viscosity was analysed at a shear rate of 1 s^{-1}. The results (Fig. 3) show that differences in viscosity between palm fat and fat substitutes remain large but are smaller than in the untreated samples. Furthermore, the comparison of viscosity measurements at a shear rate of 1 s^{-1} before and after harsh shearing at 1000 s^{-1} demonstrates that recovery of starting viscosity is reproducibly the lowest for the sample with microcrystalline wax (16.67 fold reduction from first to second shearing at 1 s^{-1}), and highest for the foamed samples (1.260 fold), while recovery of the palm fat and the sample with microcrystalline cellulose was mediocre with a 6.423 and 2.871 fold reduction in average viscosity measured from first to second shearing at shear rate 1 s^{-1}, respectively. Observations of changes in viscosity for palm fat and the sample with microcrystalline wax exhibited similar trends with respect to strongest observed drops in viscosity upon high shear and lowest recovery of original viscosity upon rest. This is in line with the microstructure of the samples, which both contain elongated crystals. According to Doan et al. (Doan et al., 2018), both the crystal structure and bonds between such crystals are susceptible to shear, resulting in a considerable reduction in viscosity. In contrast, emulsified and foamed samples recovered their original viscosity to a large extent, suggesting good microstructure retention.

3.2 Performance of differently treated rapeseed oil samples in bakery applications

3.2.1 Processability

While, as observed during processing, both the emulsion-based palm fat replacements, MCC and RPC emulsions, resulted in relatively soft, buttery short bread biscuit dough texture, the samples with microcrystalline wax and pure rapeseed oil resulted in crumbly dough structures that were difficult to roll out. Shortbread biscuit dough made from foamed rapeseed oil was very sticky and, as a result, difficult to roll out. This was attributed to the higher overall water content of the dough mass, which was 13.36% water for the foamed rapeseed oil dough compared to 6.38% water for the palm fat based dough.

3.2.2 Texture of shortbread biscuits

Figure 4 shows that on day one, i.e. day of production, the firmness of the shortbread biscuits with palm fat and those with foamed rapeseed oil was significantly higher than the firmness of the sample with microcrystalline wax but were not significantly different from all other samples. Standard deviations are on the large side which can be attributed to small microfissures developed during baking which may influence local firmness. After two days of storage, no significant difference between the samples was observed.

Tag for Figure 4

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*Fig. 4: Firmness of shortbread biscuits measured as peak force upon breakage of the sample. Measurements were performed on days 0, 1 and 2 after baking (n = 6, * P < 0.05).*

The shortbread biscuits with MCC foam were the only samples with a significantly higher elasticity (Fig. 5). Some of the other samples differed significantly from others, but all were in a similar elastic range. No significant differences in elasticity remained after two days of storage as foam based replicate samples differed greatly from each other, leading to extremely large standard deviations.

According to Acker (Schultz, 1967), biscuits tend to absorb moisture if the surrounding air has a moisture content above 43%. It seems that shortbread biscuits absorb moisture during storage and, as a result, become more elastic and less firm.

Tag for Figure 5

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*Fig. 5: Elasticity of shortbread biscuits measured as the remaining distance between the sample after maximum bending and the base plate of the texture analyser. Measurements were performed on days 0, 1 and 2 after baking (n = 6, * P < 0.05).*

The increased elasticity of shortbread biscuits containing MCC foam may well be a consequence of the higher water content of the product when palm fat is exchanged for foamed rapeseed oil since the continuous phase of the foam consisted of more than 90% water, leading to an overall increase in moisture content of 109%. Similar, but less pronounced shifts, in firmness can be seen for shortbread biscuits containing emulsified rapeseed oil, where 20 and 40% of the fat was replaced by water in the MCC and RPC emulsion samples, respectively. This finding and the higher elasticity may be a result of a change in starch gelatinisation temperature, which decreases as the fat content decreases (Conde-Petit, 2001). Since the baking parameters were not adapted to the recipe, a higher degree of starch gelatinisation could be expected for the sample containing foamed rapeseed oil, thus resulting in a change in the texture of the end product. In addition, Tarancón et al. (Tarancón et al., 2013) found that the elasticity of the biscuits rose when oil-in-water cellulose emulsions were added and there was a corresponding increase in the total moisture content.

Luminosity of the baked samples

Fig. 6 shows the luminosity of the baked samples using palm fat and palm fat replacements. While the samples with foamed rapeseed oil and palm fat were significantly lighter in colour than all of the other samples, the sample containing rapeseed press cake had a darker colour than the rest of the samples. This darkening of sample ‘RPC emulsion’ was significant compared to all other samples except sample ‘MC wax crystals’. And is interpreted as a direct consequence of the addition of dark greenish rapeseed press cake flour to the sample. The tendency towards more luminosity of the foamed sample might be attributable to typical scattering of light in a foam (Moin et al., 2001) or to the change in overall composition caused by the one to one replacement of fat with a fat-free foam in the recipe. The lighter color of the sample containing pure palm fat might be attributable to the higher fat content of the sample possibly resulting in reduced water activity and a lower availability of water for chemical reactions such as Maillard reaction (Purlis, 2010).

Tag for Figure 6

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*Fig. 6: L-values of shortbread biscuits on day one after baking (n = 6, * P < 0.05).*

Differences in luminosity are also evident in photographs of the baked samples (Fig. 7). Furthermore, shape retention of the shortbread biscuits with foamed palm fat replacer is visibly poor. This further emphasises processing difficulties attributed to the higher water content of the sample.

Tag for Figure 7

Fig. 7: Photographs of baked shortbread biscuits.

3.2.3 Sensory evaluation of baked samples

Fig. 8 shows the results of the sensory testing of both the shortbread biscuits and baked pastry cases. A blind sample of the palm fat reference sample was also added to the tasting session (shown as blind sample). The difference between the standard sample and the identical blind sample was very slight, indicating good panel quality.

Tag for Figure 8

Figure 8: Sensory test of shortbread biscuits (number of panelists: 14) using a difference from control procedure.

Compared to the reference shortbread biscuits made with palm fat, the samples with untreated rapeseed oil, MCC wax crystals, MCC emulsion and RPC emulsion were described as fattier (Fig. 8). Overall, the samples with palm fat replacements had a slightly firmer consistency and a weak aftertaste. The sample with foamed rapeseed oil was further

described as elastic and gummy in texture, but less fatty. The perceived difference in elasticity / gumminess confirms the differences shown by instrumental measurements (see Section 3.2.2). The underlying reason for the higher observed elasticity might be the higher water content that influences the degree of gelatinisation (Conde-Petit, 2001). The observed reduction in sandiness might be a consequence of a lower fat content, resulting in a change in cohesiveness of the sample (Mamat and Hill, 2014). The change in firmness of all the samples with higher moisture contents can be directly linked to water content (Tarancón et al., 2013). As elasticity is often defined as the force necessary to compress a sample (Majchrzak and Schlinter-Maltan, 2018), the higher perceived firmness might have triggered an increase in elasticity perception.

The overall deviations in sensory properties were small, with the exception of the samples containing foamed rapeseed oil. Therefore, the samples containing wax crystals or emulsified rapeseed oil are regarded as the most promising palm fat replacements for baked goods such as shortbread biscuits.

4 Conclusion

Overall, it can be concluded that replacing palm fat with physically modified rapeseed oil is possible. While the viscosity of the fat replacements is drastically lower than that of palm fat, these differences decrease during the production of shortbread biscuits. The one exception is baked goods in which palm fat was replaced by a foamed alternative. The negative effect on processability and end product properties of the tested microcellulose stabilised foams is primarily caused by the considerable increase in dough water content by a factor of 2. As no further water was added to the shortbread biscuit dough beyond the original moisture content of the flour, there was no possibility to adjust the total moisture content. Hence, water-based foams are judged to be unsuitable for replacing palm oil. In contrast, the emulsified samples stabilised with rapeseed press cake and microcrystalline cellulose, and the partially crystallised sample containing microcrystalline wax appear to have great potential as options to replace palm oil. Processability was good, textural assessment comparable and visual and sensory characteristics close to palm fat shortbread biscuits.

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Ethical guidelines

Ethics approval was not required for this research.

Data availability

Research data are not shared.

Declaration of interest

There is no conflict of interest.

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Supplementary Material

Tag for Figure 1S (Supplemental material)

Fig. 1S: Stability of samples of differently treated rapeseed oil after 5 days storage, from left to right: MC wax crystals, MCC emulsion, RPC emulsion, MCC foam.