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Vendula Pachlová, Richard Adámek, Karla Bezděková, František Buňka

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Richardos Nikolaos Salek*, Eva Lorencová, Zuzana Míšková, Zuzana Lazárková, Vendula Pachlová, Richard Adámek, Karla Bezděková, František Buňka

Department of Food Technology, Faculty of Technology, Tomas Bata University in Zlín,
T.G. Masaryka 5555, 760 01, Zlín, Czech Republic

* Corresponding author. Tel.: +42 576 038 087

E-mail address: rsalek@utb.cz (R. N. Salek)

ABSTRACT

The scope of the study was the evaluation of Chios mastic gum (CMG) addition (0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45 and 0.50%, w/w) on the rheological, textural and meltability properties of spread-type processed cheese (PC; with 40%, w/w, dry matter and 50%, w/w, fat in dry matter) during a 60-day storage period (at 6 ± 2 °C). The hardness of the evaluated PC samples was affected by the amount of CMG applied and by the storage period. Hence, from a concentration 0.05% (w/w) of CMG up to 0.20% (w/w) the hardness of the samples decreased, followed by an increase (up to 0.40%, w/w) and a rapid decrease in hardness was again recorded. With the prolonging of the storage period the hardness of all samples increased. Furthermore, the results obtained by the rheological analysis and meltability were analogous to those of hardness analysis.

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1. Introduction

Processed cheese (PC) is a well-established dairy product produced by heating (natural) cheese in the presence of appropriate emulsifying salts (sodium phosphate, polyphosphates, citrates and/or their combinations), usually under vacuum with constant stirring, over a temperature range of 90 to 100 °C, until a smooth and homogenous compact cheese-matrix with desired properties is formed (Buňka et al., 2013; Černíková et al., 2010; Guinee, Carić, & Kaláb, 2004). Addition of emulsifying salts (ES) greatly contributes to the PC-matrix formation. Additionally, their main role lies on improving the emulsifying capacity of the proteins already present in the natural cheese (or blend of natural cheeses) by sequestering calcium from the casein matrix. This results in the enhancement of the casein proteins to act as the “real” emulsifiers, by replacing the calcium from the insoluble calcium-paracaseinate (present in the natural cheese) with sodium (Buňka et al., 2014; Chen & Liu, 2012; Dimitreli & Thomareis, 2009). Furthermore, PC could also be characterised as a complex, multicomponent dairy-system, described as a stable oil-in-water emulsion (Chen & Liu, 2012; Hosseini-Parvar, Matia-Merino, & Golding, 2015). In addition, the complexity of the developed processed cheese-matrix is based on the fact this product can contain various interacting ingredients; of dairy (e.g., anhydrous butterfat, butter, cream, milk powder, whey, buttermilk, caseinates, coprecipitates) or non-dairy origin (e.g. stabilisers, preservatives, flavoring agents, hydrocolloids) which can be optionally added to the blend. In general, their application is focused on content modification (dry-matter, fat, protein contents) or functional property (hardness, meltability, spreadability, etc.) improvement (Guinee et al., 2004; Lee & Klostermeyer, 2001; Lee, Anema, & Klostermeyer, 2004).

Mastic gum is the resinous exudate derived from the stem of the *Pistacia lentiscu*s L. var. *chia* (belonging to the *Anacardiaceae* family) tree which is native to coastal regions of the European Mediterranean, and is cultivated mainly in southern Chios, a Greek island. Cuttings made in the trunk of the tree cause a resinous liquid substance to be exuded. This exuded material remains under the tree for many days and thus, is coagulated by local environmental conditions. Thereafter, the coagulated product is collected and called mastic gum (Burešová, Salek, Varga, Masaříková, & Bureš, 2017; Paraskevopoulou, Tsoukala, & Kiosseoglou, 2009).

Chemically, mastic gum can be described as a complex natural product consisting of 3 categories of substances: (i) the polymer (cis-1,4-poly-β-myrcene) fraction, (ii) a volatile fraction (essential oil; consisted of monoterpene hydrocarbons, oxygenated monoterpenes, sesquiterpenes) and (iii) triterpenic content. Chios mastic gum (CMG) has been used for centuries as a food ingredient, herbal remedy or dietary supplement. Today, CMG is used as a chewing gum base, flavour additive in water, dairy products, confectionery and liqueurs, and as a texture modifier in bakery products (Burešová et al., 2017; Schoina et al., 2015; Terpou, Nigam, Bosnea, & Kanellaki, 2018). Additionally, mastic gum might provide protection against bacterial infections and could exhibit antacid effects in the gastrointestinal system. Results from previously performed scientific research have presented hepatoprotective, cardioprotective, cytoprotective, anti-inflammatory, antileukaemic and antiatherogenic properties and anti-tumour activity of mastic gum against human colorectal cancer (Dimas, Pantazis, & Ramanujam, 2012; Giaginis & Theocharis, 2011; Magiatis, Melliou, Skaltsounis, Chinou, & Mitaku, 1999). Finally, mastic gum has proven to be safe and well tolerated by humans and has been monographed in the European Pharmacopeia (01/2008:1876). The proposed dosage of mastic gum to achieve a therapeutic effect lies within the range of 1 to 5 g person^{-1} day^{-1} (Terpou et al., 2018; Triantafyllou, Chaviaras, Sergentanis, Protopapa, & Tsaknis, 2007; Xynos, Termentzi, Fokiakis, Skaltsounis, & Aligiannis, 2018).

Moreover, the concept of functional foods refers to food products that apart from being a valuable source of nutritional components can also provide other benefits to consumers (Leidi et al., 2018). Application of natural food additives has been proposed in many studies to target safe foodstuffs to prolong shelf-life (Angiolillo, Conte, & Del Nobile, 2014). One very promising natural food additive could be CMG (Daifas et al., 2004). In general, enrichment of PC with CMG could allow its labelling as a dairy product, providing a plethora of beneficial properties to consumers.

However, the scientific literature is missing a study characterising addition of CMG to PC or similar products. Thus, the aim of the current study was the investigation of another potential use of mastic gum, by exploring its impact on the viscoelastic and textural properties of spreadable PC (with 40%, w/w, dry matter and 50%, w/w, fat in dry matter) over a 60-day storage period (at 6 ± 2 °C).

2. Materials and methods

2.1. Materials

Materials such as: Edam cheese blocks (50%, w/w, dry matter content, 30%, w/w, fat in dry matter content, 7-week maturity; Kromilk, a.s., Kroměříž, Czech Republic), butter (82%, w/w, dry matter content, 84%, w/w, fat content; Sachsenmilch Leppersdorf, GmbH, Wachau, Germany), ES [sodium dihydrogen phosphate (NaH_2PO_4; MSP) and disodium hydrogenphosphate (Na_2HPO_4; DSP); Břeclav – Poštorna, Czech Republic] and CMG [Chios island Gum Mastic Growers' Association (CGMGA), Chios, Greece] were used in this study.

2.2. Processed cheese sample manufacture

Model PC sample production was designed to achieve end-products with 40% (w/w) dry matter content and 50% (w/w) fat in dry matter content as the optimal target values (Table 1). The ES were a binary mixture consisting of MSP and DSP in a 3:7 ratio and a total concentration of 3%, w/w (calculated based on the total weight of the melt). CMG concentrations were (%, w/w) 0.05, 0.10, 0.15, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45 and 0.50 (the amount of CMG was calculated on total weight of the melt). A control sample was prepared without CMG.

To manufacture the PC samples a Vorkwerk Thermomix TM 31-1, blender cooker (Vorkwerk & Co., GmbH, Wuppertal, Germany) with indirect heating was used. The same apparatus was used by Buňka et al. (2013), Černíková et al. (2010), Lee and Klostermeyer (2001) and Weiserová et al. (2011). Cheese and butter were cut into pieces (20 × 20 × 20 mm), placed in the process and minced for 60 s (at approximately 5000 rpm). The mixture of ES, water and CMG was then added into the blend. The blend was heated to 90 °C and maintained for 1 min (total melting time was approximately 12 min.). The hot molten mass was then poured into cylindrical polypropylene pots (52 mm in diameter; 50 mm high; Greiner Packaging Slušovice s.r.o, Slušovice Czech Republic) and wrapped with aluminium lids. The dry-matter and fat in dry-matter contents of the samples were maintained constant (40% dry matter content and 50% fat in dry matter) by modification of butter and water addition. Packed samples were cooled and stored under refrigeration conditions (6 ± 2 °C) until analyses were performed. Analyses were performed on the 2nd, 9th, 30th and 60th day of storage (at 6 ± 2 °C, 1st day was the production day), with exception of rheological analysis, which was conducted on the 30th day of storage.

2.3. Dry matter content and pH measurement of processed cheese

Dry matter content was gravimetrically determined according to ISO 5534 (ISO, 2004) by drying the PC samples at 102 ± 2 °C until constant mass. The pH was determined (at ambient temperature) by inserting a glass tip electrode of a calibrated pH-meter (pH Spear, Eutech Instruments, Oakton, Malaysia) directly into the samples at three randomly chosen locations. Analyses were performed in triplicate.

2.4. Determination of processed cheese hardness

Texture profile analysis is a well-established method and frequently referred as a standard method for texture characterisation (Bourne, 2002). The principle of the method is penetration event of a test-sample, using mechanical testing equipment (in imitation of the chewing process). The hardness of PC spreads was determined using a TA.XT plus texture analyser (Stable Micro Systems Ltd., Goldaming, Surrey, UK). The definition of hardness is defined by Civille and Szczesniak, (1973), Fiszman and Damásio, (2000), and Weiserová et al. (2011). Penetration parameters were: depth 10 mm, probe speed 2 mm s^{-1}, trigger force 5 g and strain of deformation 25%. A stainless steel cylindrical probe (P20) with 20 mm diameter directly penetrated into the cylindrical cup (after removing the aluminium foil). Results were recorded as force-displacement/time curves describing the force (N) needed to deform the sample proportionally with time (s). Buňka et al. (2013), Cunha and Viotto (2010) and Piška and Štětina (2004) have previously applied a corresponding penetration method for PC textural properties measurement. Measurements were performed after 2, 9, 30 and 60 days of cold storage (at 6 ± 2 °C). On each day of analysis, each sample treatment was measured six times (n = 6).

2.5. *Rheological analysis of processed cheese*

A dynamic oscillatory shear rheometer (Rheostress 1, Haake, Bremen, Germany) equipped with a plate-plate geometry (35 mm diameter, 1 mm gap) was used for the determination of the PC viscoelastic properties. All PC samples were measured in the control shear stress mode over a frequency range from 0.01 to 100.00 Hz (at 20.0 ± 0.1 °C). The amplitude of shear stress (20 Pa) was selected in the linear viscoelasticity region. Also, the complex viscosity, storage (*G'*) and loss (*G"*) moduli were determined as a function of frequency f. Rheological analysis of the model PC samples was performed on the 30th day of storage and reported values were the mean of at least 6 replicates (n = 6).

2.6. *Meltability determination of processed cheese by computer vision system*

PC samples (5 mm thick, 40 mm in diameter) were placed on Petri dishes and heated in a microwave oven (type 29Z018, Zelmer, Warsaw, Poland) at 300 W for 60 s, after which they were removed and cooled for 15 min at ambient temperature (20 ± 2 °C) on a horizontal surface. Due to the noncircular spread of the samples observed during heating, measurement of the area of spread rather than diameter of spread was recorded. The area of the melted PC sample was measured using a computer vision system. The computer vision system used included a digital camera (Coolpix P6000, Nikon, Tokyo, Japan) supported by a copy stand, monitor and computer. Image processing and area measurement were performed using ImageJ software. ImageJ is a Java-based open source image processing software package freely downloadable from the US National Institute of Health website. Meltability of PC determined by the computer vision method was presented as the ratio of PC area after and before heat treatment according to the following equation (1):

$$M = A_2/A_1 \times 100 \qquad (1)$$

where M is the meltability of PC determined with the computer vision approach and A_2 and A_1 are the area (mm^2) of PC after and before heat treatment, respectively. On each day of analysis, each sample was measured 6 times (n = 6). Furthermore, similar methods for PC meltability determination were previously applied by Sołowiej, Cheung, and Li-Chan, (2014) and Wang and Sun (2002).

2.7. Statistical analysis

The obtained results were analysed by analysis of variance (one-way ANOVA) followed by posttest (Tukey test), with 95 % reliability. The data obtained were expressed as mean ± standard deviation. The significance level used in the tests was 0.05. The statistical analyses were realised using Minitab®16 software (Minitab, Ltd., Coventry, UK).

3. Results and discussion

3.1. Dry matter content and pH measurement of processed cheese

The dry-matter levels of all developed PC samples were within the range of 40.09 to 41.23% (w/w), depicting the “stability” of the dry-matter content of the examined samples, allowing their comparison (Marchesseau, Gastaldi, Lagaude, & Cuq, 1997). The pH of the molten mass is another factor that can influence the properties of PC. Fig. 1 depicts the development of pH values of the model PC samples (stored for 2, 9, 30 and 60 days at 6 ± 2 °C) on the concentration of CMG. From the results obtained it can be assumed that the addition of CMG did not significantly affected the pH values of the manufactured PC samples

($P > 0.05$). In particular, the pH of the PC samples ranged from 5.64 to 5.97, which can be characterised as acceptable for spreadable PC. Moreover, the fact that the production of the PC model samples was performed using “real” raw materials (Dutch-type cheese, butter, CMG) and the buffering capacity of the applied ES, could serve as possible explanations for the “narrow” variability observed in the pH values (Dimitreli & Thomareis, 2009; Lee & Klostermeyer, 2001; Lu, Shirashoji, & Lucey, 2008). In all cases (regardless of the applied amount of CMG) the pH of the examined samples slightly decreased with the prolonging of the storage period ($P < 0.05$). Furthermore, the majority of the samples showed a decrease of pH values between 0.1 and 0.3 pH units. The results obtained are in accordance with those of Shalaby, Mohamed, and Bayoumi, (2017) and Salek et al. (2015).

3.2. Determination of processed cheese hardness

The results of hardness development of the examined PC samples as a function of the storage period and amount of CMG are shown in Fig. 2. In general, the addition of CMG significantly influenced the hardness of the samples ($P < 0.05$). From the obtained results it could be reported that with the increasing storage period the hardness of all samples (regardless of the applied level of CMG) increased. Moreover, similar results and their explanation were previously reported in the studies of Awad, Abdel-Hamid, El-Shabrawy, and Singh (2002), Shirashoji, Jaeggi, and Lucey (2006), Salek et al. (2017) and Weiserová et al. (2011). Furthermore, the increasing amount of CMG resulted in significant changes in the hardness of the examined PC samples ($P < 0.05$). In particular, the rising concentration of CMG resulted in a significant decrease in the values of hardness of the PC samples ($P < 0.05$). Hence, the highest values of hardness were observed in the control sample. Additionally, from a concentration 0.05% (w/w) of CMG up to 0.20% the hardness of the samples decreased, followed by an increase (up to 0.40% w/w) and therefore, a rapid decreased in hardness was again reported.

On the whole, this trend in the hardness values development could be characterised as “untypical”. From the available results in the scientific literature there are very few reported hydrocolloids that could decrease the hardness of PC. Hence, it could be stated that the application of CMG has a unique effect on the mechanical properties of PC, leading to the statement that the changes in PC properties might be directly affected by the presence of CMG particles. The current phenomenon could be explained by the active role of CMG in the interactions between substances (proteins, fat) which are responsible for the formation of PC matrix. Moreover, PC is a gel-like dairy product, produced as a mixture of ingredients in dispersion which solidify due to processing, resulting in a network with mechanical properties (Fu & Nakamura, 2018) According to Burešová et al. (2017) and Mavrakis and Kiosseoglou (2008) CMG particles could affect the creation of a formed protein network.

Additionally, it could be hypothesised that the development of aggregates of large macromolecules in PC could occur due to the interaction between the protein network and CMG. The concentration-dependent effect of CMG might be closely related to the amount of CMG particles present in the PC matrix and involved in the occurring interactions, leading to the hypothesis that a certain concentration is necessary to obtain a “noteworthy” impact on PC properties (Burešová et al., 2017). Moreover, the incorporation of CMG particles might lead to the interruption of the formed gel structure, resulting in decreased values of hardness. However, this could be attributed to the complete lack of particle-network structure interaction and to accumulation of CMG particle aggregates in isolated regions within the formed network leading to a decrease in the mechanical properties of PC (Mavrakis & Kiosseoglou, 2008).

By the same token, the PC structure was probably interrupted by the presence of CMG particles, leading to the hypothesis that CMG might serve as a "barrier" during the formation of the PC three-dimensional network. Moreover, Mavrakis and Kiosseoglou (2008) stated that in some cases CMG particles tend to accumulate at the protein network regions, where they can assemble and produce a thread-like structure. The formation of the latter structure could "strengthen" the developed gel through interactions between the network substances and CMG particles. This could be a possible explanation for the increasing values of hardness, when CMG was applied in a "critical" concentration range from 0.30 to 0.40% (w/w).

Furthermore, another possible explanation for the observed hardness values development could be the thermodynamic incompatibility phenomenon between the applied CMG and present proteins within the PC matrix. In particular, thermodynamic incompatibility might be one of the mechanisms leading to phase separation in milk protein/polysaccharide systems. In general, pH, ionic strength and temperature are among the factors that can influence the thermodynamic incompatibility phenomenon. Moreover, thermodynamic incompatibility of proteins and polysaccharides can be observed at pH range above the isoelectric point of the protein and/or at a sufficient high ionic strength (Ercelebi & Ibanoğlu, 2007; Hemar, Tamehana, Munro, & Singh, 2001; Tobin, Fitzsimons, Chaurin, Kelly, & Fenelon, 2012).

3.3. Rheological analysis of processed cheese

Small amplitude oscillatory shear tests [measuring the storage (G') and loss (G'') moduli] are commonly applied for PC viscoelastic properties characterisation. (Macků, Buňka, Voldánová, & Pavlínek 2009; Piska & Štětina, 2004). The dynamic rheological measurements were performed at the linear viscoelastic region of the model PC Samples. The frequency sweep of the samples showed the difference in their viscoelastic properties. The results of rheological analysis are shown in Figs. 3–5. In general, from the obtained results it could be summarised that PC samples with divergent viscoelastic properties were produced by means of the use of various concentrations of CMG ($P < 0.05$). Viscosity is key-parameter describing the ability of a PC sample to spread and/or flow (Kapoor & Metzger, 2008). Moreover, the complex viscosity of the tested samples was significantly affected by the applied amount of CMG (Fig. 3; $P < 0.05$).

According to Glibowski, Zarzycki, and Krzepkowska (2008) viscosity and hardness are correlated. The results of the PC samples complex viscosity presented an analogous trend as it was mentioned above for the results of hardness. In addition, the storage (G') and loss (G'') moduli can serve as valuable “tools” to express the intensity of elastic and viscous behavior of viscoelastic materials. Figs. 4 and 5 show the dependence of the storage (G') and loss (G'') moduli of the model PC samples (produced with various amounts of CMG after 30 days of storage at 6±2 °C) on the frequency (within the range of oscillation measured, i.e. 0.1 – 100.0). The curves of G' and G'' moduli also depict the same trend as it was previously identified. When $G' > G''$ the developed PC presents a more elastic behaviour, indicating a weakening of the developed cheese structure. In most of the examined cases, the manufactured PC samples showed a more elastic behaviour (since $G' > G''$), indicating that solid-type structures were present and both parameters increased with frequency. However, the increasing amount of CMG led to a less elastic structure (compared with the control sample), which could be attributed to the action of CMG particles, probably interrupting the formation of the protein network. Furthermore, a relationship among PC hardness and storage modulus (G') probably occurs (Salek et al., 2019).

On the whole, the results of rheological analysis were in excellent accordance to those obtained for hardness analysis. Thus, we could once again hypothesise that the changes in the PC viscoelastic properties might be directly affected by the presence of CMG particles present in the PC matrix and involved in the occurring interactions (e.g., hydrogen bonds, interactions between caseins or caseins and fat, calcium-mediated electrostatic bonds among the caseins). The latter statement could lead to the hypothesis that a certain concentration of CMG is needed to obtain a “barrier” effect on PC viscoelastic properties (Burešová et al., 2017; Macků et al., 2009).

3.4. Meltability determination of processed cheese by computer vision

Meltability of PC is one of its most important functional properties (Hennelly, Dunne, O’Sullivan, & O’Riordan, 2005; Sołowiej et al., 2014). Fig. 6 shows the effects of CMG addition on the meltability of PC during a 60-day storage period at 6 ± 2 °C. The meltability of the tested samples increased with the rising of the storage period ($P < 0.05$). Furthermore, the addition of CMG resulted in end-products with various values of meltability. Additionally, from a concentration 0.05% (w/w) of CMG up to 0.20% the meltability of the samples decreased, followed by an increase (up to 0.40% w/w) and a rapid decrease in the values of meltability was observed. This specific trend was also identified for the values of complex viscosity.

During the meltability test the protein-matrix adsorbs energy, which influences the interactions (unfolding of proteins may occur) maintaining the protein-network structure. Hydrophobic interactions under entropic control are strengthened while those (i.e., electrostatic and van der Waals’ interactions and hydrogen bonds) under enthalpic control are weakened. Furthermore, when hydrophobic sites are exposed due to protein unfolding, hydrophobic interactions are promoted resulting in the aggregation of the protein molecules leading to a decrease in PC meltability (Kuo, Wang, Gunasekaran, & Olson, 2001). According to Dimitreli and Thomareis (2004) the measurement of PC viscosity could help to characterise its meltability. Furthermore, viscosity and hardness are correlated, since a relationship among materials hardness and dynamic rheological moduli might occur (Salek et al., 2019). Hence, the latter statement could lead to the conclusion that meltability and hardness are also correlated. In general, it was evident from the above-mentioned results that the results from the meltability test are in excellent agreement with the textural and rheological analyses of the investigated PC samples.

4. Conclusions

The aim of the work was to investigate the viscoelastic properties of model PC spreads produced with various concentrations of CMG over 60 days of cold storage (at 6 ± 2 °C). It could be concluded that the hardness of the tested samples was affected by the amount of CMG applied and the storage period. Hence, from a concentration 0.05% (w/w) of CMG up to 0.20% the hardness of the samples decreased, followed by an increase (up to 0.40%, w/w) and a rapid decrease in hardness was again recorded. Moreover, the results obtained by the rheological analysis and meltability test were analogous to those of hardness analysis. Finally, it could be assumed that CMG is a promising substance in the manufacture of PC, leading to the development of end-products enriched with a valuable natural product with numerous beneficial effects for the consumer.

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References

Angiolillo, L., Conte, A., & Del Nobile, M. A. (2014). Food additives: Natural preservatives. In Y. Motarjemi (Ed.), *Encyclopedia of food safety* (pp. 474–476). Cambridge, MA, USA: Academic Press.

Awad, R. A., Abdel-Hamid, L. B., El-Shabrawy, S. A., & Singh, R. K. (2002). Texture and microstructure of block type processed cheese with formulated emulsifying salt mixtures. *LWT – Food Science and Technology, 35*, 54–61.

Bourne, M. C. (2002). Texture, viscosity, and food. In M. C. Bourne (Ed.), *Food texture and viscosity* (pp. 1–32). Amsterdam, The Netherlands: Elsevier Science Publishing Co Inc.

Buňka, F., Doudová, L., Weiserová, E., Černíková, M., Kuchař, D., Slavíková, Š., et al. (2014). The effect of concentration and composition of ternary emulsifying salts on the textural properties of processed cheese spreads. *LWT – Food Science and Technology, 58*, 247–255.

Buňka, F., Doudová, L., Weiserová, E., Kuchař, D., Ponížil, P., Začalová, D., et al. (2013). The effect of ternary emulsifying salt composition and cheese maturity on the textural properties of processed cheese. *International Dairy Journal*, *29*, 1–7.

Burešová, I., Salek, R. N., Varga, E., Masaříková, L., & Bureš, D. (2017). The effect of Chios mastic gum addition on the characteristics of rice dough and bread. *LWT – Food Science and Technology*, *81*, 299–305.

Černíková, M., Buňka, F., Pospiech, M., Tremlová, B., Hladká, K., Pavlínek, V., et al. (2010). Replacement of traditional emulsifying salts by selected hydrocolloids in processed cheese production. *International Dairy Journal, 20*, 336–343.

Chen, L., & Liu, H. (2012). Effect of emulsifying salts on the physicochemical properties of processed cheese made from Mozzarella. *Journal of Dairy Science*, *95*, 4823–4830.

Civille, G., & Szczesniak, A.S. (1973). Guidelines to training a texture profile panel. *Journal of Texture Studies*, *4*, 204–223.

Cunha, C. R., & Viotto, W. H. (2010). Casein peptidization, functional properties, and sensory acceptance of processed cheese spreads made with different emulsifying salts. *Journal of Food Science, 75,* C113–C120.

Daifas, D. P., Smith, J. P., Blanchfield, B., Sanders, G., Austin, J. W., & Koukoutisis, J. (2004). Effects of mastic resin and its essential oil on the growth of proteolytic *Clostridium botulinum*. *International Journal of Food Microbiology*, *94*, 313–322.

Dimas, K. S., Pantazis, P., & Ramanujam, R. (2012). Chios mastic gum: A plant-produced resin exhibiting numerous diverse pharmaceutical and biomedical properties. *In Vivo*, 26, 777–785.

Dimitreli, G., & Thomareis, A. S. (2009). Instrumental textural and viscoelastic properties of processed cheese as affected by emulsifying salts and in relation to its apparent viscosity. *International Journal of Food Properties*, *12*, 261–275.

Dimitreli, G., & Thomareis, A.S. (2004). Effect of temperature and chemical composition on processed cheese apparent viscosity. *Journal of Food Engineering*, *64*, 265–271.

Ercelebi, E. A., & Ibanoğlu, E. (2007). Influence of hydrocolloids on phase separation and emulsion properties of whey protein isolate. *Journal of Food Engineering*, *80*, 454–459.

Fiszman, S. M., & Damásio, M. H. (2000). Instrumental measurement of adhesiveness in solid and semi-solid foods. A survey. *Journal of Texture Studies*, *31*, 69–91.

Fu, W., & Nakamura, T. (2018). Effects of starches on the mechanical properties and microstructure of processed cheeses with different types of casein network structures. *Food Hydrocolloids, 79*, 587–595.

Giaginis, C., & Theocharis, S. (2011). Current evidence on the anticancer potential of Chios mastic gum. *Nutrition and Cancer*, *63*, 1174–1184.

Glibowski, P., Zarzycki, P., & Krzepkowska, M. (2008). The rheological and instrumental textural properties of selected table fats. *International Journal of Food Properties, 11*, 678–686.

Guinee, T. P., Carić, M., & Kaláb, M. (2004). Pasteurized processed cheese and substitute/imitation cheese products. In P. F. Fox, P. L. H. McSweeney, T. M. Cogan, & T. P. Guinee (Eds.), *Cheese: Chemistry, physics and microbiology. Vol. 2. Major cheese groups* (pp. 349–394). Amsterdam, The Netherlands: Elsevier.

Hemar, Y., Tamehana, M., Munro, P. A., & Singh, H. (2001). Viscosity, microstructure and phase behavior of aqueous mixtures of commercial milk protein products and xanthan gum. *Food Hydrocolloids, 15*, 565–574.

Hennelly, P. J., Dunne, P. G., O’Sullivan, M., & O’Riordan, D. (2005). Increasing the moisture content of imitation cheese: effects on texture, rheology and microstructure. *European Food Research and Technology, 220*, 415–420.

Hosseini-Parvar, S. H., Matia-Merino, L., & Golding, M. (2015). Effect of basil seed gum (BSG) on textural, rheological and microstructural properties of model processed cheese. *Food Hydrocolloids, 43*, 557–567.

ISO. (2004). *Cheese and processed cheese–Determination of the total solids content (reference method). ISO Standard No. 5534*. Geneva, Switzerland: International Organization for Standardization.

Kapoor, R., & Metzger, L. E. (2008). Process cheese: Scientific and technological aspects – A review. *Comprehensive Reviews in Food Science and Food Safety*, *7*, 194–214.

Kuo, M. I., Wang, Y. C., Gunasekaran, S., & Olson, N. F. (2001). Effect of heat treatments on the meltability of cheeses. *Journal of Dairy Science*, *84*, 1937–1943.

Lee, S. K., & Klostermeyer, H. (2001). The effect of pH on the rheological properties of reduced-fat model processed cheese spreads. *LWT – Food Science and Technology*, *34*, 288–292.

Lee, S. K., Anema, S., & Klostermeyer, H. (2004). The influence of moisture content on the rheological properties of processed cheese spreads. *International Journal of Food Science and Technology*, *39*, 763–771.

Leidi, E. O., Altamirano, A. M., Mercado, G., Rodriguez, J. P., Ramos, A., Alandia, G., et al. (2018). Andean roots and tubers crops as sources of functional foods. *Journal of Functional Foods*, *51*, 86–93.

Lu, Y., Shirashoji, N., & Lucey, J. A. (2008). Effects of pH on the textural properties and meltability of pasteurized process cheese made with different types of emulsifying salts. *Journal of Food Science*, *73*, E363–E369.

Macků, I., Buňka, F., Voldánová, B., & Pavlínek, V. (2009). Effect of addition of selected solid cosolutes on viscoelastic properties of model processed cheese containing pectin. *Food Hydrocolloids*, *23*, 2078–2084.

Magiatis, P., Melliou, E., Skaltsounis, A. L., Chinou, I., & Mitaku, S. (1999). Chemical composition and antimicrobial activity of the essential oils of *Pistacia lentiscus* var. *chia*. *Planta Medica*, *65*, 749–752.

Marchesseau, S., Gastaldi, E., Lagaude, A., & Cuq, J. L. (1997). Influence of pH on protein interactions and microstructure of process cheese. *Journal of Dairy Science, 80*, 1483–1489.

Mavrakis, C., & Kiosseoglou, V. (2008). The structural characteristics and mechanical properties of biopolymer/mastic gum microsized particles composites. *Food Hydrocolloids*, *22*, 854–861.

Paraskevopoulou, A., Tsoukala, A., & Kiosseoglou, V. (2009). Monitoring air/liquid partition of mastic gum oil volatiles in model alcoholic beverage emulsions: Effect of emulsion composition and oil droplet size. *Food Hydrocolloids*, *23*, 1139–1148.

Piska, I., & Štětina, J. (2004). Influence of cheese ripening and rate of cooling of the processed cheese mixture on rheological properties of processed cheese. *Journal of Food Engineering*, *61*, 551–555.

Salek, R. N., Černíková, M., Nagyová, G., Kuchař, D., Bačová, H., Minarčíková, L., et al. (2015). The effect of composition of ternary mixtures containing phosphate and citrate emulsifying salts on selected textural properties of spreadable processed cheese. *International Dairy Journal*, *44*, 37–43.

Salek, R. N., Černíková, M., Pachlová, V., Bubelová, Z., Konečná, V., & Buňka, F. (2017). Properties of spreadable processed Mozzarella cheese with divergent compositions of emulsifying salts in relation to the applied cheese storage period. *LWT – Food Science and Technology*, *77*, 30–38.

Salek, R. N., Vašina, M., Lapčík, L., Černíková, M., Lorencová, E., Li, P., & Buňka, F. (2019). Evaluation of various emulsifying salts addition on selected properties of processed cheese sauce with the use of mechanical vibration damping and rheological methods. *LWT – Food Science and Technology*, *107*, 178–184.

Schoina, V., Terpou, A., Angelika-Ioanna, G., Koutinas, A., Kanellaki, M., & Bosnea, L. (2015). Use of *Pistacia terebinthus* resin as immobilization support for *Lactobacillus casei* cells and application in selected dairy products. *Journal of Food Science and Technology*, *52*, 5700–5708.

Shalaby, S. M., Mohamed, A. G., & Bayoumi, H. M. (2017). Preparation of a novel processed cheese sauce flavored with essential oils. *International Journal of Dairy Science*, *12,* 161–169.

Shirashoji, N., Jaeggi, J. J., & Lucey, J. A. (2006). Effect of trisodium citrate concentration and cooking time on the physicochemical properties of pasteurized process cheese. *Journal of Dairy Science, 89*, 15–28.

Sołowiej, B., Cheung, I. W. Y., & Li-Chan, E. C. Y. (2014). Texture, rheology and meltability of processed cheese analogues prepared using rennet or acid casein with or without added whey proteins. *International Dairy Journal*, *37*, 87–94.

Terpou, A., Nigam, P. S., Bosnea, L., & Kanellaki, M. (2018). Evaluation of Chios mastic gum as antimicrobial agent and matrix forming material targeting probiotic cell encapsulation for functional fermented milk production. *LWT – Food Science and Technology*, *97*, 109–116.

Tobin, J. T., Fitzsimons, S. M., Chaurin, V., Kelly, A. L., & Fenelon, M. A. (2012). Thermodynamic incompatibility between denatured whey protein and konjac glucomannan. *Food Hydrocolloids, 27,* 201–207.

Triantafyllou, A., Chaviaras, N., Sergentanis, T. N., Protopapa, E., & Tsaknis, J. (2007). Chios mastic gum modulates serum biochemical parameters in a human population. *Journal of Ethnopharmacology, 111,* 43–49.

Wang, H. H., & Sun, D. W. (2002). Correlation between cheese meltability determined with a computer vision method and with Arnott and Schreiber tests. *Journal Of Food Science*, *67*, 745–749.

Weiserová, E., Doudová, L., Galiová, L., Žák, L., Michálek, J., Janiš, R., et al. (2011). The effect of combinations of sodium phosphates in binary mixtures on selected texture parameters of processed cheese spreads. *International Dairy Journal*, *21*, 979–986.

Xynos, N., Termentzi, A., Fokialakis, N., Skaltsounis, L. A., & Aligiannis, N. (2018). Supercritical CO2 extraction of mastic gum and chemical characterization of bioactive fractions using LC-HRMS/MS and GC–MS. *Journal of Supercritical Fluids*, *133*, 349–356.

Figure legends

Fig. 1. The development of processed cheese pH values on the concentration of Chios mastic gum (CS, control sample, 0% gum) during storage at 6 ± 2 °C and sampled after 2 (■), 9 (■), 30 (■) and 60 (■) days (results are means with bars representing standard deviations, n = 6).

Fig. 2. The development of processed cheese hardness (calculated as the maximum force during penetration, N) on the amount of Chios mastic gum (CS, control sample, 0% gum) during storage at 6 ± 2 °C and sampled after 2 (■), 9 (■), 30 (■) and 60 (■) days (results are means with bars representing standard deviations, n = 6).

Fig. 3. Dependence on the frequency (0.1–100.0) of the complex viscosity of the processed cheese samples (after 30 days of storage at 6 ± 2 °C) manufactured with different amounts of Chios mastic gum (%, w/w): ●, control; ▼, 0.05; ■, 0.10; ◆, 0.15; ▲, 0.20% ; ●, 0.25%; ●, 0.30% w/w; ▼, 0.35%; ■, 0.40; ◆, 0.45; ▲, 0.50.

Fig. 4. Dependence on the frequency (0.1–100.0) of the storage modulus (*G*') of the processed cheese samples (after 30 days of storage at 6 ± 2 °C) manufactured with different amounts of Chios mastic gum (%, w/w): ●, control; ▼, 0.05; ■, 0.10; ◆, 0.15; ▲, 0.20% ; ●, 0.25%; ●, 0.30% w/w; ▼, 0.35%; ■, 0.40; ◆, 0.45; ▲, 0.50.

Fig. 5. Dependence on the frequency (0.1–100.0)of the loss modulus (*G*'') of the processed cheese samples (after 30 days of storage at 6 ± 2 °C) manufactured with different amounts of

Chios mastic gum (%, w/w): ●, control; ▼, 0.05; ■, 0.10; ◆, 0.15; ▲, 0.20% ; ●, 0.25%; ●, 0.30% w/w; ▼, 0.35%; ■, 0.40; ◆, 0.45; ▲, 0.50.

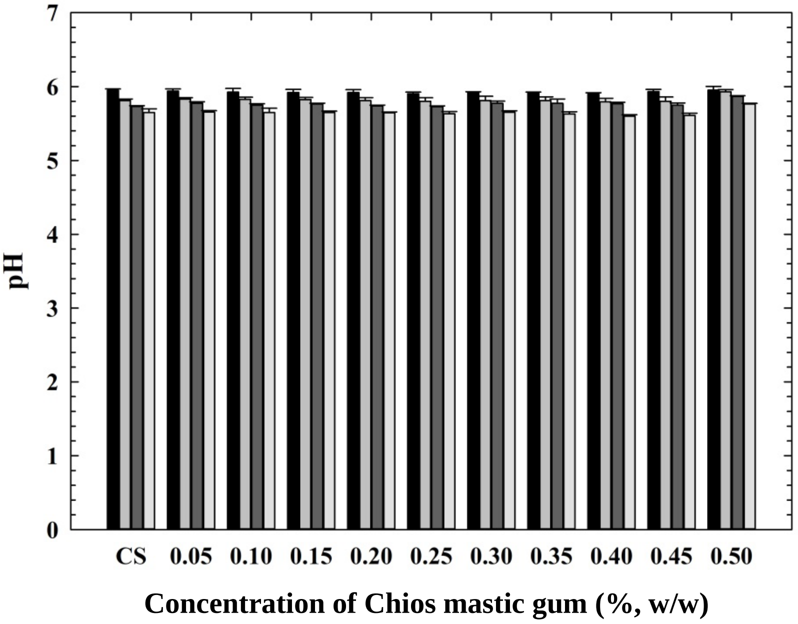
Fig. 6. The development of processed cheese meltability values (unitless) on the concentration of Chios mastic gum (CS, control sample, 0% gum) sampled after 2 (■), 9 (■), 30 (■) and 60 (■) days (results are means with bars representing standard deviations, n = 3).

Table 1

Formulation of the processed cheese preparations. [a]

Parameter	Control	MG_0.05	MG_0.10	MG_0.15	MG_0.20	MG_0.25	MG_0.30	MG_0.35	MG_0.40	MG_0.45	MG_0.50
Ingredient (%, w/w)											
Edam cheese	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00	48.00
Water	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00	33.00
Butter	16.00	15.95	15.90	15.85	15.80	15.75	15.70	15.65	15.60	15.55	15.50
Emulsifying salts	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Chios mastic gum	0.00	0.05	0.10	0.15	0.20	0.25	0.30	0.35	0.40	0.45	0.50
Processing conditions											
Stirring speed (rpm)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Temperature (° C)	90	90	90	90	90	90	90	90	90	90	90
Total melting time (min)	12	12	12	12	12	12	12	12	12	12	12

[a] The processed cheese samples were manufactured with various concentrations of Chios mastic gum; the emulsifying salts used were a binary mixture containing sodium dihydrogen phosphate and disodium hydrogenphosphate in a ratio 3:7.



pH
7
6
5
4
3
2
1
0
CS
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Concentration of Chios mastic gum (%, w/w)

Figure 1

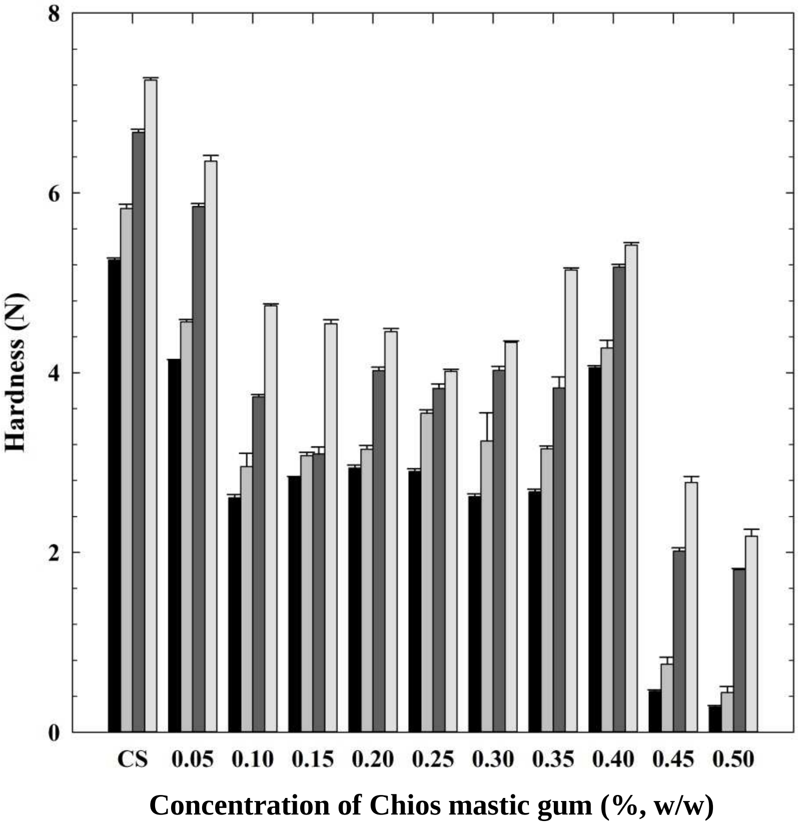

Hardness (N)
8
6
4
2
0
CS
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Concentration of Chios mastic gum (%, w/w)

Figure 2

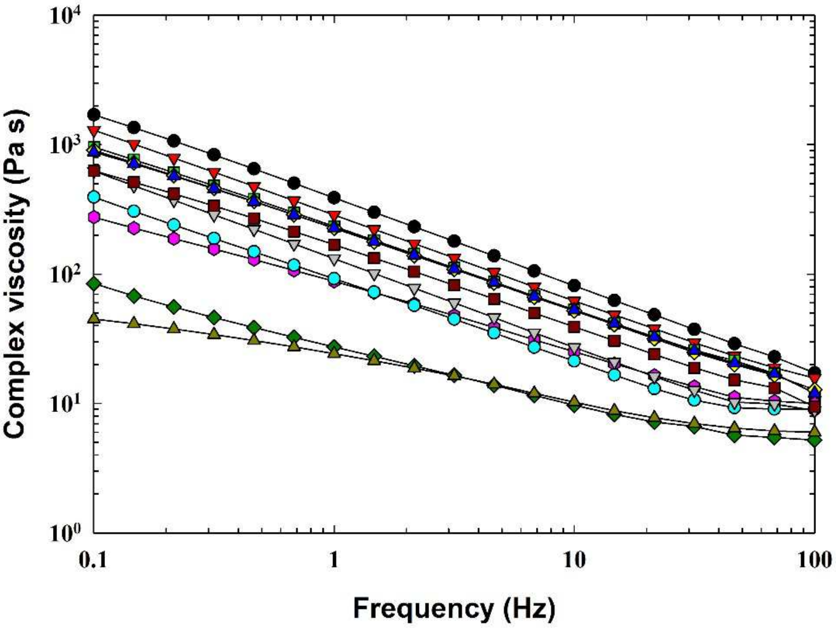

10^4
10^3
10^2
10^1
10^0
Complex viscosity (Pa s)
0.1
1
10
100
Frequency (Hz)

Figure 3

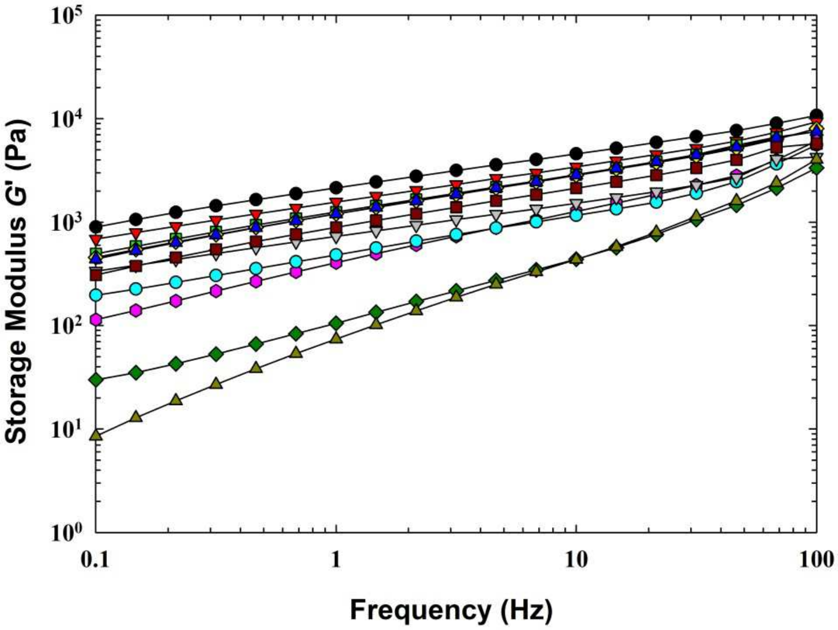

Storage Modulus G' (Pa)
Frequency (Hz)
10^5
10^4
10^3
10^2
10^1
10^0
0.1
1
10
100

Figure 4

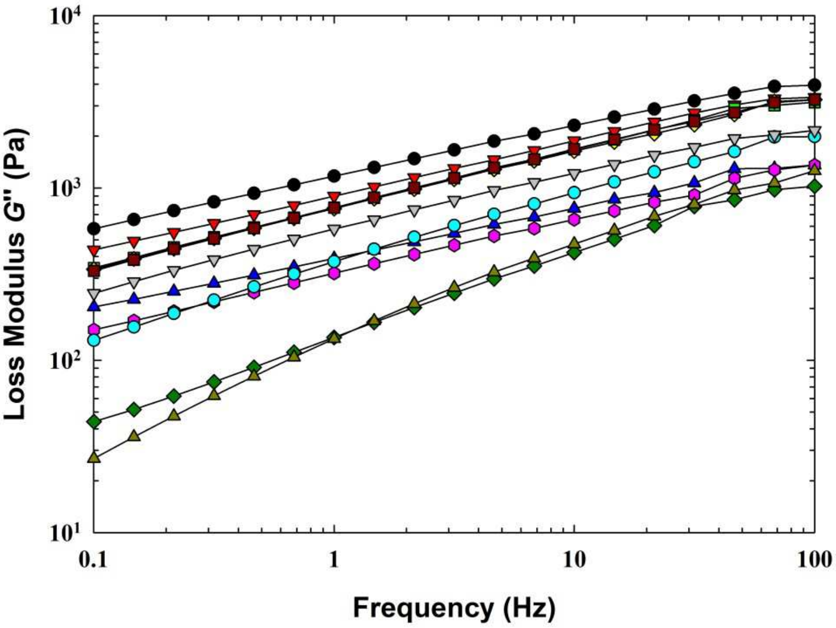


Figure 5

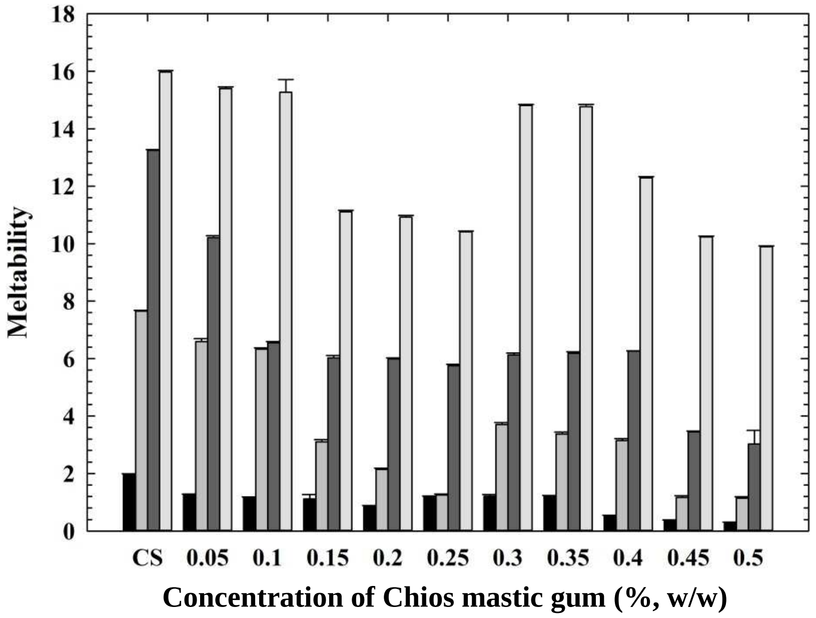

18
16
14
12
10
8
6
4
2
0
Meltability
CS
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
Concentration of Chios mastic gum (%, w/w)

Figure 6

Author contributions

RNS: conceptualisation, methodology, investigation, writing - review & editing, visualisation; investigation, supervision. EL, ZM, ZL: methodology; writing - review & editing. VP: methodology, writing - review & editing, project administration. RA: methodology, writing - original draft. KB: methodology. FB: supervision, writing - review & editing, visualisation.