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Texture and other changes during storage in model high-protein nutrition bars formulated with modified milk protein concentrates

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ABSTRACT

Extruded or toasted milk protein concentrate with approximately 80 g protein per 100 g were incorporated into model high-protein nutrition bars formulated at 30 g protein per 100 g. The model high-protein nutrition bars also contained other constituents, including glycerol, palm kernel stearin, sugar alcohol syrup, and high-fructose corn syrup, to mimic commercial high-protein nutrition bars. The bars were stored at room temperature (~22 °C), 32 °C, or 42 °C for up to 42 days. Texture, water activity, and color were measured periodically over the storage period. High-protein nutrition bars formulated with unmodified milk protein concentrate served as the control and maintained similar texture to those high-protein bars formulated with toasted milk protein concentrate. High-protein nutrition bars prepared with milk protein concentrate extruded at 65 °C were significantly softer than the control. Significant differences in hardness and fracturability between high-protein nutrition bars formulated with milk protein concentrate extruded at 120 °C and the control were intermittent over the storage period. Water activity of the high-protein nutrition bars increased slightly during storage, but remained less than 0.65, which assured shelf stability. Surface color change was minimal at 22 °C storage, but increased at 32 °C and 42 °C.

1. Introduction

Milk protein concentrates (MPCs) are multifunctional ingredients used in processed cheese to improve overall yield, specialty nutrition products to fortify with protein, and dairy foods such as yogurt to improve texture (Mistry, 2002; Mistry & Hassan, 1992). MPCs are produced from skim milk via membrane filtration, diafiltration, evaporation, and spray drying to a food powder that maintains the proportion of casein (80 g per 100 g protein) to whey (20 g per 100 g protein) (Singh, 2007). The total protein content in MPC is dependent on processing and ranges from 40 g (i.e., MPC40) to 85 g (i.e., MPC85) protein per 100 g of dry product. In food applications, MPCs provide heat and emulsion stability, opacity, and flavor (Baldwin & Pearce, 2005).

High-protein nutrition (HPN) bars, intermediate-moisture foods containing 20 g to 50 g protein per 100 g, are one application where MPCsare underutilized (Baldwin & Pearce, 2005; Imtiaz, Kuhn-Sherlock, & Campbell, 2012). Instead, blends of whey proteins, caseinates, and soy proteins are used in HPN bars, but the nutritional value and flavor of MPCs make them suitable for these applications too (Imtiaz et al., 2012). Prices of whey protein, a co-product of cheese production, have risen with the development of their functionalized forms that improve performance in protein fortified foods (Smithers, 2008). Whey and soy protein are nutritionally comparable with each other, but the casein protein in MPCis digested slowly, allowing for greater nitrogen retention and muscle growth post exercise (Tang, Moore, Kujbida, Tarnopolsky, & Phillips, 2009).

Despite its advantages, MPCs perform poorlyin HPN bars. The minimum shelf-life for commercial HPN bars is 6 months, but product stability for greater than 12 months is often desired and not possible when MPCs are included (Imtiaz et al., 2012; McMahon, Adams, & McManus, 2009). Model protein bars prepared at 20 g MPC80 per 100 g bar hardened substantially after 50 d storage at room temperature, well short of the desired 6 months (Loveday, Hindmarsh, Creamer, & Singh, 2009). HPN bars formulated with milk protein isolate (MPI) had crumbly texture and lacked cohesion, another important, but rarely reported aspect of HPN bar quality (Imtiaz et al., 2012; Li, Szlachetka, Chen, Lin, & Ruan, 2008).

The exact mechanism of instability in MPC-formulated HPN bars has not been elucidated. However, it is most likely due to moisture migration, limited free water, macronutrient phase separation, and internal disulfide bond formation with subsequent protein

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aggregation that lead to quality deterioration in other HPN bars (Loveday et al., 2009; McMahon et al., 2009; Zhou, Liu, & Labuza, 2008a).Macronutrient phase separation can occur with preferential exclusion of the solvent (e.g., water) and co-solvent (e.g., sugar alcohol, sugar syrup) from the local protein domain (McMahon et al., 2009). Without solvent/co-solvent protein interactions, water can migrate away from the protein to lower molecular weight constituents allowing for local protein interactions via disulfide bond formations, subsequent aggregations, and more complete network formations, which have all been previously linked to HPN bar hardening (Loveday et al., 2009; Loveday, Hindmarsh, Creamer, & Singh, 2010; Zhou, Liu, & Labuza, 2008b). However, excessive interaction between the protein and some co-solvents such as propylene glycol can lead to rapid aggregations and subsequent hardening (Liu, Zhou, Tran, & Labuza, 2009).

Two of Fonterra's (Auckland, New Zealand) protein bar specificMPCs (i.e., PowerProtein™ 4857 and PowerProtein™ 4861) and one WPC (i.e., PowerProtein™ 515) were evaluated instrumentally and texturally by a trained sensory panel in model HPN bars formulated at 30 g protein per 100 g (Imtiaz et al., 2012). The bar specific WPC imparted softening and improved cohesion without being enzymatically hydrolyzed (Imtiaz et al., 2012). HPN bars formulated entirely with PowerProtein™ 4861 maintained firmness, but had increased crumbliness during storage (Imtiaz et al., 2012). HPN bars formulated with PowerProtein™ 4857 hardened during storage, but had less influence on cohesiveness (Imtiaz et al., 2012). No protein modification details were provided in the study, but it was shown that MPC functionalization prior to use in HPN bars can improve its feasibility in these applications.

Earlier, we reported on physical modification of MPC80 using extrusion and toasting and characteristics of resulting ingredients (Banach, Clark, & Lamsal, 2013). The altered functionality of the modified MPC80s, notably reduced protein solubility, altered water-holding capacity, and incidence of preformed disulfide bonds, was favorable for inclusion in HPN bars. In this study, we report texture and related changes in model HPN bars formulated with MPC80 processed at the same conditions.

2. Materials and methods

2.1. Materials and reagents

MPC80 was purchased from Idaho Milk Products (Jerome, ID). CornSweet® 55, a high-fructose corn syrup (HFCS), and palm kernel stearin were donated by Archer Daniels Midland (Decatur, IL). Lycasin® 80-55, a maltitol syrup, was donated by Roquette America (Keokuk, IA). All other reagents were analytical grade.

2.2. MPC80 extrusion and toasting modification

MPC80 was extruded or toasted as previously described in Banach et al. (2013). Briefly, the moisture content of MPC80 was adjusted to 380 g water per kg and extruded through a co-rotating twin-screw extruder (model# Micro 18, American Leistritz Extruder, Somerville, NJ) operating at 60 rpm with screws designed to impart low-shear. Two temperature profiles with 65 °C or 120 °C die temperature were used to manufacture two different extruded samples, E65 and E120, respectively. The extrudates were pelletized, dried for 72 h at 50 °C, and were finely ground with a centrifugal mill (model# ZM1, Retsch, Newtown, PA). MPC80 was also modified without shear by toasting at 75 °C (T75) or 110 °C (T110) for 4 h in a laboratory oven. All MPC80 ingredients were sieved through a 250 μm mesh prior to HPN bar manufacture. Each MPC80 modification was repeated twice.

2.3. Model high-protein nutrition bar manufacture

Model HPN bars were formulated to contain 30 g protein per 100 g (Table 1). The modified or unmodified MPC80 ingredient, glycerol, maltitol syrup, and water were combined with a wire whip attachment on 'stir' for 60 s followed by 2 min mixing on speed 4 using a stand mixer (model# K5SS, Kitchen Aid, St. Joseph, MI). Palm kernel stearin and HFCS were heated together until fatliquefaction and were cooled to 55 °C before being mixed into the protein/polyol mixture on speed 4 for 2 min. All mixing times were discontinuous as the mixers were paused every 30 s to scrape the side of the mixing bowl. Each model HPN bar listed in Table 1 are identified by their protein source (i.e., MPC, E65, E120, T75, and T110) and were prepared twice; once from each MPC80 ingredient preparation.

HPN bar dough was uniformly packed into cylindrical molds with 21 mm internal diameter and lengths of 13 mm or 107 mm. HPN bar dough in each mold was leveled with a spatula and the mold was sealed at both ends with parafilm. Water activity sample cups were filled halfway with HPN bar dough, covered with a lid, and were sealed with parafilm. Samples were sealed into separate zipper-seal plastic bags and were left at room temperature for 1 h prior to being randomly assigned to 42 °C, 32 °C, or room temperature (~22 °C) storage.

2.4. Instrumental texture evaluation of model high-protein nutrition bars

Compression, stress relaxation, and shear tests were performed on the HPN bar samples after storage for 1, 2, 4, 6, 13, 22, 32, and 42 d. Texture was also measured on the day of manufacture (i.e., day 0). Three measurements for each texture test were carried out for each HPN bar batch (i.e., MPC, E65, E120, T75, and T110) at three storage temperatures (i.e., 22 °C, 32 °C, and 42 °C) and eight storage times (i.e., 1, 2, 4, 6, 13, 22, 32, and 42 d). Prior to testing, HPN bar samples were allowed to equilibrate for at least 1 h at room temperature and were removed from their cylindrical molds. Reported values are the average of duplicate HPN bar preparations.

The short HPN bar samples were compressed at 2 mm $s^{-1}$with a flat plate (TA-30, Texture Technologies, Scarsdale, NY) to 60% strain with 0.05 N trigger force (model# TA-XT2i, Texture Technologies, Scarsdale, NY). Hardness was defined as the force attained at 60% strain and fracturability was the force where a significant break occurred during compression (Gunasekaran & Ak, 2003).

Separately, short cylindrical HPN bar samples were also used for stress-relaxation tests. Each specimen was compressed with the flat plate at 3.3 mm s^{-1} to 10% strain and held for 5 min while force versus time data was recorded. Force data were converted to stress (kPa) by dividing by the cross-sectional area of the HPN bar sample

Table 1
Model high-protein nutrition (hpn) bar formulations.

Ingredient (g per 100 g)	High-protein nutrition bar batch				
	MPC	E65	E120	T75	T110
MPC	37.39	–	–	–	–
E65	–	38.11	–	–	–
E120	–	–	37.41	–	–
T75	–	–	–	36.89	–
T110	–	–	–	–	36.30
Glycerol	21.50	21.48	21.50	21.50	21.50
Palm kernel stearin	18.46	18.43	18.45	18.45	18.45
Maltitol syrup	12.00	11.99	12.00	12.00	12.00
High-fructose corn syrup	10.00	9.99	10.00	10.00	10.00
Water	0.65	0.00	0.63	1.16	1.75

MPC, unmodified MPC80; E65 and E120, extruded MPC80s processed at die temperatures of 65 °C and 120 °C, respectively; *T75 and T110,* MPC80s toasted 4 h at 75 °C and 110 °C, respectively. Each HPN bar batch is identified by the protein ingredient it contains.