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Protein and Energy Enriched Muffins Designed for Nutritional Needs of Older Adults

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Abstract

Disease related malnutrition is a common problem among older adults which results in human suffering and high health care costs. One way to counteract this condition is to offer appetizing and nutritious food products adapted to the needs of older adults. However, macronutrient enrichment of food products is not straight forward as it affects flavour and texture properties. In this study, muffins were fortified with rape seed oil and whey powder to reach increased fat and/or protein content and the nutritional value, sensory properties and physical parameters were investigated. The results showed that ingredients could be added to significantly increase the energy and protein density, but enrichment affected on appearance and other sensory properties. Extra fat made the muffins flat and moist with a smooth and fatty mouth feel, while whey powder addition resulted in high/pointy muffins with shiny appearance, hard texture and altered flavours. For co-addition of fat and protein the effects of added protein dominated. The specific role of muffin/cake batter compounds, and their transformation during the baking process, needs to be further investigated. Hence, more research is needed in order to offer older adult appealing foods with high energy and nutrient density.

Keywords: Malnutrition; Older adults; Sensory properties; Nutritional value; Whey protein

Introduction

Due to improved living conditions such as healthcare, nutrition and hygiene the population of older adults is growing worldwide [1]. However, increased nutritional needs regarding protein intake [2,3] together with increased risk of disease and disability make older adults vulnerable for disease related malnutrition (DRM). This is a serious conditions which elevates the risk of weakened immune system, bone and muscle loss, mortality and poor quality of life [4-6], accompanied with a high load on health care costs [7,8]. Reasons for DRM are complex including acute and chronic disease leading to inflammation that in turn causes loss of appetite and muscle wasting. Also, mastication problems and social changes [5] could be involved, as well as impaired appetite due to dry mouth and throat and olfactory dysfunction [9,10]. A poor appetite is strongly associated with poor nutritional intake [11-13].

In order to counteract DRM appetizing and nutritious food products adapted to the nutritional needs of older adults are needed, meaning high energy and nutrient density in small portions. It has been suggested that snacks rich in energy and protein between meals may be a good way to increase overall energy intake [13-15]. Protein-enrichment of regular food products can significantly increase the daily protein intake [16], and it is recommended that protein-enrichment is based on carriers that are already commonly consumed by older adults [17]. However, enrichment levels should not exceed the limit when the characteristics of the food product are altered to a degree which is not accepted by the consumer. In Sweden, coffee time is normally a much appreciated part of the day and muffins is the most popular choice among older adults to complement their cup of coffee (personal communication, Christina Karlsson,

nutritional manager, ICA, Sweden, 2014). Hence, designing muffins to suit the nutritional needs of older adults could contribute to decreased DRM.

Muffins and cakes are common bakery products. However, the transformation of the different ingredients during baking is not completely understood. In the oven, the cake sets into a solid foam structure as gas bubbles in the batter expand and coalesce along with starch gelatinization and protein denaturation and aggregation. The foaming properties of the proteins and the degree of starch gelatinization influence the overall rigidity of the foam network. Whey proteins have functional properties such as foaming, gelling and water binding capacity, and have been used to improve bread dough properties [18] and as egg-replacers in muffins and cakes [19-23]. Also, whey protein has a high nutritional value due to its amino acid composition [24,25], and is suggested to have a beneficial effect on muscle protein synthesis in older adults [25]. However, macro nutrient enrichment of food products is not straight forward as the addition of proteins and fat affects flavour as well as texture properties. The aim of this study was to investigate added nutritional value and impact on sensory properties and physical parameters of increased fat and/or protein content in muffins, based on rape seed oil and whey powder addition.

Materials and Methods

Muffin formulation

Four muffin formulations were developed; one standard reference muffin formulation prepared according to the guidelines of the muffin mix producer and three muffin formulations with added nutritional value (extra fat; extra

protein; extra fat and protein) (Figure 1, Table 1). The amounts of fat and protein addition were decided by adding as much as possible without exceeding the limit when the characteristics of the resulting muffins were altered too much to be regarded as muffins. In order to regulate the consistency of the batter and keep it similar between muffin formulations, different amounts of water was added (Table 1). The muffins were produced in a pilot scale bakery at RISE Agrifood and Bioscience, Sweden, and the baking procedure was kept as simple as possible to keep the procedure constant. The ingredients were stirred for 3 min and thereafter 20 g batter was added to baking forms. The muffins were baked in a preheated convection oven at 175 °C for 11 min, and thereafter left to cool for 15 min before weight check in triplicate. The muffins were freeze stored (-40 °C) until analysis.

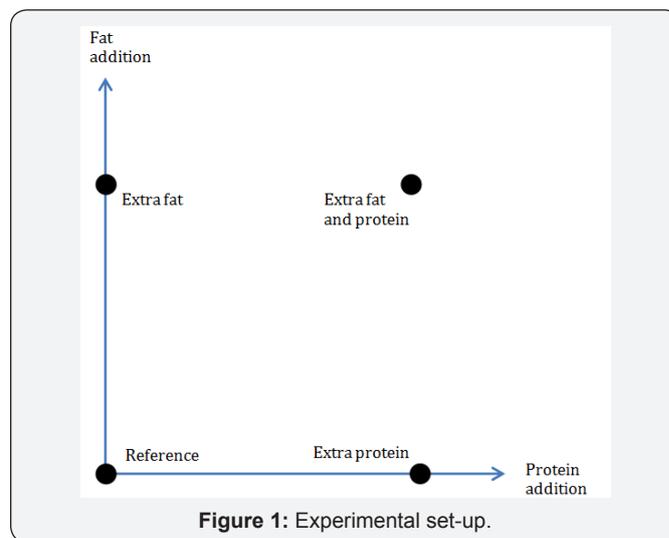


Figure 1: Experimental set-up.

Table 1: Characteristics of muffin formulations and physical parameters of baked muffins (mean ± standard deviation).

Muffin Type	Recipe	Content ^c (g/100 g muffin)		Weight Loss ^d (%)	Water Content ^e (%)	Water Activity	Width ^f (mm)	Height ^h (mm)
		Fat	Protein					
Reference	300g muffin mix ^a 120g rape seed oil 120g water	26.7	4.9	8.5 ± 0.1	24.7 ± 0.3	0.87 ±0.01	47.3 ± 0.9	29.5 ± 1.0
Extra fat	300g muffin mix ^a 252 g rape seed oil 120 g water	42.3	3.8	7.2 ± 0.2	19.8 ± 0.3	0.85 ±0.01	48.2 ± 0.9	24.7 ± 1.7
Extra protein	300g muffin mix ^a 120g rape seed oil 165g water 66g whey powder ^b	23.2	12.4	8.4 ± 0.0	27.0 ± 0.2	0.89 ±0.00	48.3 ± 1.1	31.4 ± 2.9
Extra fat and protein	300g muffin mix ^a 252g rape seed oil 165g water 66g whey powder ^b	37.4	10.2	7.5 ± 0.1	23.2 ± 0.4	0.89 ±0.00	48.0 ± 1.1	26.4 ± 0.4

^asugar, wheat flour, whole egg powder, potato starch, baking powder E450 an E500, aromas, NaCl, beta-carotene. Mix by B. Engelhardt & Co AB, Sweden.

^b76 g protein; 6 g carbohydrates; 10 g fat /100 g powder, B. Engelhardt & Co AB, Sweden.

^ccalculated based on recipe and water loss, ^dn=5, ^en=4, ^fn=2, ^gn=8, ^hn=4

Moisture content and water activity

Moisture content was measured gravimetrically in four replicates in a vacuum oven (Sanyo Gallenkamp, Loughborough, UK). Approximately 1.8 g of sample was weighed into an aluminum dish and dried at 80 °C until constant weight achievement. The water activity was measured in triplicates using an Aqua Lab 4TE (Decagon Devices, Pullman, Washington, USA). Mean values and maximum deviations are presented in (Table 1) Width and height were measured by a scale.

Sensory evaluation

Sensory evaluation and training were carried out over a period of 10 days by a trained external panel (RISE Agrifood and Bioscience). The panel comprised eight assessors who were selected and trained according to guidelines: ISO 3972, ISO8586-1 and ISO 8586-2. The sensory analysis was made using Quantitative Descriptive Analysis (QDA) [26]. In the test

the trained panel developed objective descriptions of perceived sensory attributes products [26]. In two 3-h training sessions, the judges generated set of attributes (Table 2) and developed consensus regarding the evaluation of each attribute. The judges evaluated the perceived intensities on a continuous 100-mm line scale, labeled “low intensity” at 10mm and “high intensity” at 90mm (Visual Analogue Scale). In two sessions (60 min each), the judges rated triplicates of each product. The intensity ratings were recorded into numbers by a computerized system (FIZZ 2.47 B, Biosystemes, France). The samples were coded with three-digit numbers and presented in randomized order according to a Latin square design. Two muffins were served at the time, together with tap water and neutral wafers. Muffins from the same batch were used for all analyses. The data was statistically analyzed by two-way Analysis of Variance (ANOVA) with samples and assessors as fixed effects. Significance ($p \leq 0.05$) between samples was calculated by Tukey’s pair wise comparison test (FIZZ 2.47 B, Biosystemes, France).

Table 2: Sensory Attributes.

Category	Attribute	Description
Appearance: whole muffin	Moist surface	Opposite to dry. Scale running from dry to moist
	Pointy	Intensity of peakiness, high intensity equals to vulcano-like appearance
	Shiny surface	Intensity of glossiness
Texture: evaluated by hand	Moist feeling	Opposite to dry. Scale running from dry to moist
	Hard texture	Intensity of hardness while pressing from above
Appearance: sliced muffin	Air bubbles in crumb	The size of the holes in the muffins
	Moist crumb	Opposite to dry. Scale running from dry to juicy
	Texture: evaluated by mouth – sliced muffin	Smooth mouth feel
Taste and Flavour	Fatty mouth feel	Greasy feeling of fat and oil
	Total flavour	Total impression of the full taste and flavor perception, independent of which taste/ flavour
	Sweetness	Intensity of sweet taste
	Vanilla	Intensity of vanilla flavour
	Fatty taste	Intensity of greasy perception
	Off-flavor	Intensity of flavours not belonging to a muffin

Results

Four muffin recipes were developed; one standard reference muffin recipe and three muffin recipes with added amounts of fat and/or protein; the recipe with added fat resulted in a 60% increase of final muffin fat content; the recipe with added protein resulted in a 153% increase of final muffin protein content; and the recipe with added fat and protein resulted in a 40% increase of final muffin fat content and a 108% increase of final muffin protein content compared to the reference muffin (Table 1). Images of the muffins are presented in Figure 2. Weight loss during baking was expected to be due to loss of water in form of steam. The muffins with added fat had the lowest residual moisture content after baking, but also the lowest weight loss, which could be explained by the lower proportion of water in the batter (Table 1).

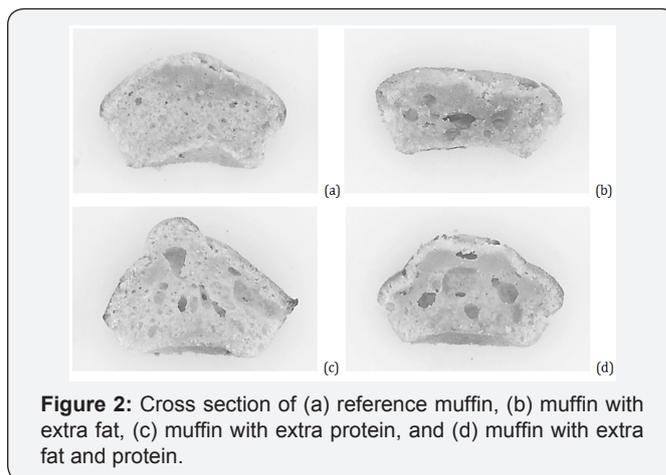


Figure 2: Cross section of (a) reference muffin, (b) muffin with extra fat, (c) muffin with extra protein, and (d) muffin with extra fat and protein.

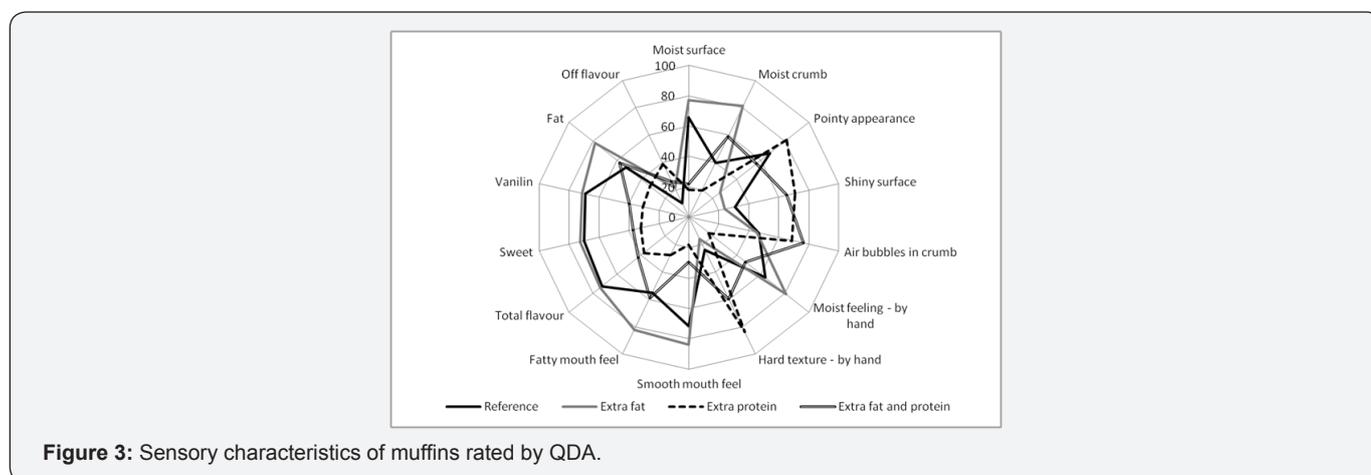


Figure 3: Sensory characteristics of muffins rated by QDA.

Table 3: Sensory characteristics of muffins rated by QDA. Mean values are given with standard deviations in brackets. Within each characteristic, values with the same letter are not significantly different (Tukey's test $p \leq 0.05$).

	Moist surface	Moist crumb	Pointy appearance	Shiny surface	Moist feeling - by hand	Hard texture - by hand	Air-bubbles in crumb	Smooth mouth feel	Fatty mouth feel	Total flavour	Sweetness	Vanillin flavour	Fatty taste	Off flavour
Reference	65.7b (11.7)	39.8c (13.1)	67.3b (7.1)	30.7c (9.4)	63.9b (9.0)	23.8c (8.0)	46.7a (22.6)	71.3b (9.0)	55.1b (15.7)	72.5a (7.6)	69.9a (8.1)	69.3a (7.5)	52.4a (14.6)	10.2c (15.4)
Extra fat	76.9a (9.3)	81.4a (6.4)	26.1d (15.9)	23.8d (13.0)	80.7a (7.9)	15.7d (7.1)	69.0b (11.3)	83.5a (7.0)	82.2a (8.5)	74.2a (9.8)	72.8a (10.4)	71.5a (11.2)	78.3a (9.9)	21.3b (21.5)
Extra protein	18.1c (7.9)	19.8d (8.6)	81.4a (10.0)	70.8a (9.5)	16.6d (6.7)	83.5a (6.1)	45.4a (12.9)	18.2d (8.1)	27.4c (8.5)	37.5c (11.6)	32.3c (10.1)	30.8c (8.1)	32.3c (9.8)	38.8a (21)
Extra fat + protein	21.8c (8.6)	58.8b (18.6)	56.4c (10.4)	65.4b (12.6)	47.2c (13.4)	59.6b (12.1)	76.4b (5.5)	29.4c (9.2)	58.7b (14.2)	42.3b (14.7)	37.3b (13.7)	40.0b (14.7)	57.7b (14.7)	26.3b (23.8)

The sensory evaluation generated data over the product properties appearance, texture and flavour (Figure 3, Table 3). Addition of extra fat resulted in flat muffins with a moist surface and crumb and increased fat flavour. Addition of protein, on the other hand, resulted in a pointy muffin which resembled a volcano with smooth batter pouring out from the centre of the muffin top, giving a shiny appearance.

Protein addition also indicated a decrease in total flavour as well as in sweet, vanillin and fat flavour, which may be due to dilution of flavour compounds as whey powder and water was added to the recipe. The panel could detect off flavours described as "eggy", "sharp", "baking soda", or "cottage cheese". These off flavours were perceived to largest extent in the muffins with extra protein and were derived to the whey powder. Both

sensory and physical measurement showed that the height increased, described by the panel as pointy. In the case of co-addition of protein and fat the muffins appearance was quite similar to the formulation with added protein, but without the volcano tip.

Discussions

The effects of the added protein appeared to dominate those of fat addition, both regarding appearance and flavour. Addition of fat and/or protein affected the textural properties of the muffins. The panel evaluated the muffins both by pressing with their fingers and by textural feeling in the mouth. Fat addition resulted in a moist feeling when touched by hand, and a smooth and fatty mouth feel. Protein addition, on the other hand, gave a less moist and smooth muffin with hard texture. The addition of both fat and protein resulted in muffins with textural properties in between that with fat or protein addition, but a bit harder and less smooth than the reference muffin. Hence, whey protein addition made the muffins harder and tougher to chew. This is in line with Paraskevopoulou & Donsouzi [21] who concluded that substitution of egg with whey protein in pound cake resulted in increased hardness and chewiness due to decreased batter aeration and denser crumb structure strengthened by the whey protein particles. The muffins with added whey protein also contained large air bubbles similar to the findings of Yang & Foegeding [27] who reported large air bubbles in angel food cake prepared with whey protein, due to disproportion and/or coalescence of air bubbles before setting of the foam structure. Native whey protein is compactly folded and soluble in water. Denaturation, on the other hand, results in an unfolded structure with decreased solubility. Hence, the baking properties of whey protein may be improved by pre-treatments that alter the foaming, emulsifying and stabilization properties [28,29]. For example has partial denaturation of whey protein by ultrasound been reported to improve the aerated structure of cake, resulting in higher volume, lower density, and reduced hardness and chewiness [22].

It is important for this study to point out that the recipes with added fat and/or protein were not adjusted for optimized flavour or baking properties. In a commercial application, these factors need to be carefully considered in order to achieve a product accepted by the market. In this study, addition of extra ingredients implied depletion of components in the base recipe such as sugar, flavouring agents and baking powder. The depletion effect was most evident for muffins with protein addition where several flavours were decreased, accompanied by an increase in off flavour. Also, sugar and moisture levels in the batter are important for the starch gelatinization process which affects the resulting volume of cakes [23]. Addition of proteins and fat changed the conditions of starch gelatinization as the proportions of starch, sugar and water is changed which affected muffin volume and texture. In the present study one mixing time and speed was selected for all muffin preparations.

However, during development of batter formulations, it was noted that batter mixing time had large impact on the resulting muffin volume. This relationship seemed to be most important for the batter with added whey powder. A long mixing time resulted in a very flat muffin after cooling, due to arching of the muffin bottom. A short mixing time resulted in a very pointy muffin where a large part of the batter poured out from the top and formed a hard and shiny layer. This behaviour was probably connected to the foaming properties of the whey protein, as was also noted by Okkels et al [30]. Evidently, processing conditions are highly important in case of protein addition in order to achieve bakery products of high quality. Whey powder addition involved extra water addition to enable batter mixing and portioning. Even though extra water was added, and the resulting muffin type had the highest moisture content and water activity, these muffins were perceived as dry and tough. Similar results were reached by Andersson [31]. The sensorial properties of muffins are affected both by the proportions of macronutrients, but also by parameters such as starch gelatinisation and protein conformation, which in turn depend on processing time and temperature, batter pH, moisture content, water activity, sugar content and more. The specific role of the muffin batter compounds, and their transformation during the baking process, need to be further investigated.

Conclusion

In the present study we have studied the effect of fortifying muffins with energy and proteins. Sufficient amounts of rape seed oil and/or whey powder were added to a muffin batter in order to significantly increase the fat and/or protein content. Offering fortified muffins with nutritional value adapted to the needs of older adults could be one way to counteract DRM. However, the appearance and other sensory properties were affected by the macronutrient addition. Addition of fat made the muffins flat and moist with a smooth and fatty mouth feel. Whey powder addition, on the other hand, resulted in a high and pointy muffin with a shiny appearance, hard texture and low flavour intensity. For co-addition of fat and protein the effect of added protein appeared to dominate the effects of fat addition. The specific role of the muffin batter compounds, and their transformation during the baking process, is not yet fully known, and more research is needed to offer older adult appealing foods with high energy and nutrient density.

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Conflict of Interest

No conflict of interest exists.

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