MARKET ANALYSIS AND MEAL READY-TO-EAT MAIN COURSE DEVELOPMENT IN THE CONTEXT OF MILITARY USE

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A one-day ration can be supplied to a soldier in the form of one ration pack for 24 hours or three packs of meal ready-to-eat, which equals one 24-hour ration. Based on the physical activity level and consequently energy requirements, there are two categories of military operations: a) normal operations, comparable to urban police work or firefighting, and b) combat operations which represent missions involving light-infantry. The aim of this study was: a) to analyse the EU market on the subject of a main course (MC) product in flexible packaging (n = 184), in the context of military use, and b) to develop thermostabilised MC aligning with modern health and nutrition recommendations for military use, i.e. protein, carbohydrate, fat, total energy intake, and essential amino acid composition. The greatest amount of ready-to-eat meals with shelf-life over one year are produced in the United Kingdom (n = 48) and most of the MC meals are preserved using freeze-drying (n = 135). While 90% of analysed products meet fat criteria for a physically active consumer (i.e. soldier), 39% meet carbohydrate criteria, 21% meet energy intake criteria, only 1% of the products are able to fulfill protein requirements. In this study, nine MC meals with shelf-life of three years were developed, which provide the necessary protein amount for a highly physically active consumer and cover its daily essential amino acid requirements.

Keywords: nutritional value, protein content, amino acid, retort pouch, sterilisation.

INTRODUCTION

In accordance with the guidelines for supply from Requirements of Individual Operations for Military Use, a one-day ration can be supplied to the soldier in a form of one ration pack for 24 hours, or in a way of three meal bags that are equal to one 24-hour ration (NATO, 2013). The aim of the meal ready-to-eat (MRE) is to provide military with adequate nutrition to maintain good health, performance, mental function and morale in the field environment (NATO, 2010).

Based on physical activity level and consequently energy requirements (Table 1), military operations could be divided into two categories: “normal” operations, which are comparable to urban police work or firefighting, and “combat” operations, which represent missions involving light-infantry. The necessary energy amount for a soldier during normal operations has been determined as ~3600 kcal/day (15.1

MJ/day) and ~4900 kcal/day (20.5 MJ/day) during the combat operations (NATO, 2010).

Table 1. Nutrition requirements summary

Requirements	Energy value, kcal	Protein, g	Carbohydrates, g	Fat, g
Man, 75 kg, active or moderately active lifestyle ¹	3300	103	536	83
Man, 75 kg, vigorous or vigorously active lifestyle ¹	3800	119	618	95
Woman, 60 kg, active or moderately active lifestyle ¹	2550	80	414	64
Woman, 60 kg, vigorous or vigorously active lifestyle ¹	2950	92	479	74
Combat operations ²	4900	158–185	550–800	110–190
Normal operations ^{2,3}	3600	118–185	404–584	54–140

¹ FAO/WHO/UNU, 2001; ² NATO, 2010; ³ NATO, 2013

Nutrition guidelines for military use (NATO, 2013) are based mainly on Australian and New Zealand (2006) national recommendations (NHMRC, 2006), where energy requirements are estimated based on body mass index (BMI) and physical activity level (PAL). Fundamentally, protein requirements are based on extrapolation of nitrogen losses in the human body in conditions of insufficient protein consumption on a regular basis (FAO/WHO/UNU, 2007). The desired minimal amount recommended for athletes is 1.5 g/kg body weight per day (Rodriguez, 2009). Carbohydrates and fat consumption requirements are based on recommended nutrient ration intake, where carbohydrates should provide 45–65% of total dietary energy intake, and fat should provide < 35% of total energy amount. Dietary fibre recommended daily intake is 30 g/day. Regarding sodium consumption, the recommended amount is 2.3–12 g, with a specific remark that main course (MC) should provide at least the minimal amount, and the rest should be achievable individually in an optional way, i.e. seasoning, salt. Such a huge range is justified by the fact that NATO includes countries with different cultures and diverse eating patterns, as well as salt consumption habits (NATO, 2013).

It is crucial for MRE to provide a soldier with appropriate nutrition during the mission. Amino acids (AAs) play a major role in the growth and maintenance processes in a human body. AAs, which are not synthesised in the human body are called essential and must be consumed with food, i.e. by consuming proteins. Essential amino acids, and their required amounts, are summarised in Table 2. For necessary daily AAs amount calculations, a median weight for a male soldier was taken as 79 kg.

The aim of this study was: a) to analyse EU market on the subject of main course (MC) products in flexible packaging ($n = 184$), in the context of military use, and b) to develop thermostabilised MC aligning with modern health and nutrition recommendations for military use, i.e. protein, carbohydrate, fat, total energy intake and essential amino acid composition.

Table 2. Amino acid (AA) requirements based on body weight¹

AA	AA requirement, per bodyweight, per day	
	mg/kg	mg/79 kg
Lysine	30	2370
Leucine	39	3081
Isoleucine	20	1580
Valine	26	2054
Threonine	15	1185
Tyrosine	25	1975
Tryptophan	4	316
Methionine	10.1	798
	or	or
Cysteine	4.1	324
Histidine	10	790

¹ FAO/WHO/UNU, 2007

MATERIALS AND METHODS

Framework formulation. During the development of the MRE for “normal operations”, it was decided to choose a MC as the main protein source, which should cover the necessary protein amounts if consumed thrice a day, 370–400 g each time, i.e. in the morning, during the day and in the evening. Based on possible MRE variations, where each MRE consists of a MC, chocolate bar, nuts or raisins, wholegrain bread; MC nutrition requirements were formulated as stated below:

- Energy value, kcal: min 140 kcal·100 g⁻¹
- Protein, g: 10.0–14.3 g·100 g⁻¹;
- Carbohydrates, g: max 12.5 g·100 g⁻¹;
- Fat, g: 8.4 g·100 g⁻¹.

In this work, no strict threshold for dietary fibre and salt was defined, however, dietary fibre and salt content were analysed as optional nutrients. The recommended daily dietary fibre amount is 30 g. Salt consumption should not exceed 12 g/day (NATO, 2013). Other micro- and macronutrients are not discussed in this work.

Market research. Market analysis was performed through the perspective of a previously formulated framework, by studying Europe’s largest retail shop (such as Carrefour, Coop etc.) online stores during the period October 2019 – April 2020, on the subject of ready-to-eat meals with long shelf-life (i.e. > 2 years) at ambient temperature. During the analysis, a data base of 14 brands was created (Table 3) forming 184 samples, focusing on nutrient amount and the energy value of ready-to-eat products. Dried product data was acquired after adding water as described on the packaging. Further, market research data was analysed in terms of previously described requirements for product formulation.

MC development. Sufficient nutrient density is the main challenge during the development of functional products for physically active consumer. The Baltic region traditional cuisine consists of agricultural products with meat/fish as conventional protein sources in most dishes.

Therefore, it was decided to place at minimal threshold of meat/fish content in MC as 30%.

Such an amount (30% of meat) is able to provide 6 ± 1 g of protein per 100 g of the product, which leads to a conclusion that a side dish should provide at least 4 g of protein per 100 g of the product. On the production scale, technological conditions necessitate to pump the garnish in a form of a suspension, where the solid part is garnish, and the liquid part is water in the amount that garnish is able to soak during the sterilisation process. For dishes consisting of garnish that is not able to provide the necessary protein amount, protein concentrates were added. The most suitable way to add whey protein concentrate in our case was to add a sauce to the dish, for example, by substituting milk in a recipe of béchamel sauce with water and whey protein con-

Table 3. Analysed brands

Country of origin	Brand name	Products analysed	Preservation technology
Czech republic	Adventure menu ¹	12	Vacuum drying
Estonia	Tactical foodpack ²	15	Freeze-drying
Finland	Bla Band ³	9	Freeze-drying
Germany	Trek'n'Eat ⁴	22	Freeze-drying
Netherlands	Adventure food ⁵	14	Vacuum drying
Norway	Real turmat ⁶	19	Freeze-drying
Norway	Real field meal ⁶	19	Freeze-drying
Poland	LYO FOOD ⁷	15	Freeze-drying
Sweden	gooh! ⁸	11	Pulsed electric field
United Kingdom	Expedition foods ⁹	16	Freeze-drying
United Kingdom	Firepot ¹⁰	10	Freeze-drying
United Kingdom	Summit to eat ¹¹	10	Freeze-drying
United Kingdom	Wayfarer ¹²	7	Retort sterilisation
United Kingdom	Ready to eat Wet meal ¹³	5	Retort sterilisation

¹ Adventure menu. <https://adventure-menu.com/> (here and further accessed 9 September 2021); ² Tactical foodpack, accessed 9 September 2021. <https://www.tacticalfoodpack.com/>; ³ Bla Band. <https://scandinavianoutdoor.com/bla-band/>; ⁴ Trek'n'Eat. <https://www.katadyngroup.com/>; ⁵ Adventure food. <https://adventurefood.com/>; ⁶ Drytech. <https://realoutdoorfood.com/>; ⁷ LYO FOOD. <https://lyofood.com/?language=selected>; ⁸ gooh! <https://www.gooh.se/>; ⁹ Expedition foods. <https://expeditionfoods.com/>; ¹⁰ Firepot. <https://www.firepotfood.com/>; ¹¹ Summit to eat. <https://www.summittoeat.com/>; ¹² Wayfarer. <https://wayfarer.nianticlabs.com/>; ¹³ MREmountain. <https://mremountain.eu>

centrate, or by substituting legumes with pea or bean protein.

The product development process was divided into three stages:

1) During the theoretical stage, the most interesting and promising dishes for a Latvian consumer were chosen as the target products. To calculate theoretical recipe nutritional value, a data-base with nutritional value and AA profile of each ingredient was created.

2) Each recipe was developed practically on the laboratory scale with consequent organoleptic evaluation process.

3) During the manufacturing-scale experiment stage, each MC was produced in the same environment as it was planned for the daily production. Each product was evaluated after each production experiment, and changes to the recipe were made if necessary. For successful product recipe samples, nutritional value was determined and changes to the recipe were performed if necessary.

In this study, no preservatives, colorants or flavour enhancers were added. The used ingredients are listed in Table 4.

For suspension stabilisation during the processing, different thermo-vulnerable gums were used, which break down under heat during the sterilisation process in a retort.

MC packaging. It is crucial for a MC to be convenient in usage and be safe for the consumer — it should not be fragile or harm the consumer in the case of a fall on the pocket that contains the MC. For our purposes, 5-layer laminated retort pouches (lacquer-polyester-aluminum-nylon-polypropylene) were used. For more convenient use, it was decided to choose pouches with a bottom — Doypack type

packaging, produced by C. L. P Industries Ltd. “Tadbik” (Kibbutz Negba, Israel).

Table 4. Main course ingredient list

No	Main course	Ingredients
1	Cabbage stew with ham	Thermally processed ham, fresh potatoes, sauerkraut, water, fresh onions, fresh carrots, sugar, tomato paste, canola oil, rice protein, fresh garlic, salt, seasonings
2	Beef goulash with buckwheat	Water, thermally processed beef, buckwheat, fresh champignons, rapeseed oil, tomato paste, fresh onions, flax seeds, whey protein, stabilisers, flour, sugar, salt, seasonings
3	Pea porridge with smoked pork	Water, thermally processed bacon, dried yellow peas, smoked ham, onions, fresh carrots, canola oil, pea protein, starch, salt
4	Pasta Bolognese	Water, minced ham, pasta, tomato paste, fresh carrots, fresh onions, starch, fresh garlic, salt, seasonings
5	Lentils with chicken and vegetables	Water, thermally processed chicken fillet, lentils, fresh champignons, frozen green peas, canola oil, starch, stabilisers, salt
6	Mashed potatoes with meatballs	Water, minced ham, fresh potatoes, whey protein, stabilisers, starch, salt seasonings
7	Chili con carne	Water, thermally processed ham, red beans, tomato paste, fresh carrots, canned corn, fresh onions, lentils, bean protein, canola oil, fresh garlic, salt, seasonings
8	Rice with smoked salmon	Water, thermally processed salmon fillet, rice, fresh carrots, green peas, canned corn, fresh onions, rapeseed oil, rice protein, fresh garlic, stabilisers, salt, seasonings
9	Vegetable stew with chicken	Thermally processed chicken fillet, water, fresh potatoes, green peas, green beans, fresh carrots, canola oil, fresh paprika, pearl barley, cream, fresh garlic, sugar, salt, seasonings, stabilisers

MC retort sterilisation. The sterilisation process (Kirse-Ozolina *et al.*, 2019) was performed in a PANINI SN4280 steam-air retort (Panini Ltd., Italy) at Kronis Ltd. production facilities. The calculated F_0 value for all samples was 20 ± 5 minutes. Throughout the experiment, the following retort programme setpoints were set:

- 1) preliminary step: steam inlet and outlet are open until the references resistance-type thermocouple (Pt100), which controls the process, indicates 80 °C;
- 2) come-up (CUT) phase: 20 min to 118 °C;
- 3) holding phase: 70 min at 118 °C, overpressure 1.7 bar;
- 4) cooling phase: 60 min, or until the references packaging (with thermocouple inside) achieves 20 °C.

Chemical analysis. Chemical analyses were performed at the laboratories of J. S. Hamilton Baltic Ltd. and the used methods are summarised in Table 5. Salt content was calculated by multiplying the measured sodium with a factor of 2.5.

Table 5. Methods of chemical analysis

Parameter	Method
Protein (N*6.25)	PB-116 ed. II of 30.06.2014
Energy value	Calculated according to Regulation (EU) No 1169/2011
Fat	PN-A-82100:1985
Total carbohydrates	Calculated by difference
Dietary fibre	AOAC 991.43:1994
Salt (Na*2.5)	Flame atomic absorption spectroscopy method (FAAS), PB-318/FAAS, ed. I of 27.07.2015
Proteinogenic AA	High-performance liquid chromatography method with spectrophotometric detection (HPLC-UV/Vis) and diode array detection (HPLC-DAD), PB-53/HPLC ed. II of 30.12.2008
Tryptophan	High-performance liquid chromatography method with fluorescence detection (HPLC-FLD), PB-136/HPLC ed. I of 06.02.2012

Data processing. Data processing was performed with MS Office Excel v16 software. Results were given as mean values. A p -value less than 0.05 was considered as statistically significant.

RESULTS

Market analysis. Market analysis showed (Table 3) that the greatest variety of ready-to-eat meals with a long shelf-life (i.e. > 2 years) is produced in the United Kingdom ($n = 48$) and most of the MC meals are preserved using freeze-drying ($n = 135$), which contributes to 73% of analysed samples.

Complete sample analysis showed (Fig. 1), that 41% of MC were based on red meat, 30% were vegetarian, 24% contained white meat, and 5% of the products were seafood based.

Fig. 1. Analysed samples main ingredient type

Fig. 2. Analysed foods that meet certain criteria, %

Data showed (Fig. 2), that among the 184 products on the EU market, 165 products met the criteria of not more than 8.4 g fat per 100 g of the product, 71 products did not exceed 12.5 g carbohydrates per 100 g of the product, 39 products provided at least 140 kcal/100 g, and only two products contained 10.0–14.3 g protein per 100 g of product.

Developed product nutritional value and amino acid content. The nutritional analysis of developed MC with ingredients characteristic to the Baltic region showed (Table 6) that all samples were within the formulated requirements.

Table 6. Nutritional value of developed main course samples

MC ¹	Energy value, kca·100 g ⁻¹	Nutrient, g·100 g ⁻¹				
		Protein	Carbohydrates	Fat	Dietary fibre	Sodium
1	160.0	10.0	12.0	8.0	1.0	1.10
2	140.6	10.0	12.5	5.6	1.0	0.75
3	150.9	10.0	9.0	8.3	1.3	0.92
4	163.1	10.0	12.5	8.1	1.9	0.90
5	140.0	11.9	9.0	6.2	3.0	0.68
6	153.4	10.3	12.2	7.2	0.5	1.08
7	140.1	10.0	10.0	6.7	3.8	0.88
8	141.4	10.0	12.4	5.7	1.3	1.05
9	142.5	10.7	12.3	5.6	1.3	0.52
AM ²	136.0	11.0	15.0	3.5	N/A	1.2
LYO ³	116.2	10.2	13.4	1.8	2.7	1.1

¹ MC, main course; ² Adventurer menu (AM, Czech Republic) – Farmer ham with lentil ragout; ³ LYO FOOD Expedition (Poland) – Beef stroganoff

Adventurer menu (Czech Republic) and LYOFood (Poland) products did not meet all defined criteria in this work, but they still were analysed because they were the only two products that met minimum protein content. To meet optimum daily dietary fibre content, 100 g of product should contain at least 2.5 g dietary fibre, with the condition that three portions of MC is the only food consumed. Such criteria is met by two of the developed products and the LYOFood sample. Salt consumption of max 6 g/day will be exceeded if 100 g of the product contains 0.5 g sodium.

Amino acid composition of the developed products was expressed as a function of daily amino acid requirements (Table 2), where 100% indicated that the given AAs amount fulfils the necessary daily requirement. The data showed that all developed MCs were able to provide the consumer with recommended minimal amounts of essential AAs (Table 7), and even exceed it at by least twice.

DISCUSSION

It can be clearly seen that freeze-drying technology prevails among the MRE manufacturers. Use of such technology means that the consumer must be able to add pre-heated fresh water to the product or add cold water and heat the whole packaging, which is an alternative to thermostabilised ready-to-eat foods. Thermostabilised foods differ from lyophilised foods in that there is no risk factor such as lack of bottled or fresh water.

The lack of samples with enough protein on the EU market (Fig. 2) is mainly related with uncommonly high overall nutrient density, which should be achieved in a ready meal in terms of the framework (section "Framework formulation"). During the development of the products, it was concluded that, with addition of protein concentrates, it is possible to achieve certain criteria, but product acceptance dropped accordingly. Protein concentrates that were used in this study added off-flavours to the products and some had sandy mouthfeel, which was observed previously by others re-

searchers as well (Nogueira, and Steel, 2018). Added concentrates bound the available water, lowering the viscosity of the product, which led to difficulties in the pumping technological process. Besides that, it was found that products with meat with high fat content (i.e. > 16%) were accepted significantly better than products with lean meat ($p < 0.05$, data not shown). On the other hand, it was much more difficult to achieve protein requirements with fatty meat, without using protein concentrates. The use of lean meat consequently solves the protein requirement issue, but creates feeling of lack of flavour and moisture in the dish. Therefore, it was decided to use lean meats in products with added sauce (i.e. Beef goulash, Cabbage stew, Pasta Bolognese, Mashed potatoes, Chilli con carne), while fatty meats were used in dishes where sauce was not applicable (Pea porridge, Lentils with chicken, Rice with salmon, Vegetable stew with chicken).

It was concluded that if a MC contains 10 g of protein per 100 g, consumed thrice a day it will provide at least the minimum recommended amount of every essential amino acid. Nonetheless, there is evidence that amino acid oxidation rises during the physical activity, which leads to higher demand for amino acids (Tarnopolsky, 2004).

The developed products nutritional values fully align with modern recommendations for "normal" military operations, with the condition that the consumer will use the MC thrice a day with all other components of the MRE. However, if the MC would be consumed alone, it still would deliver the minimal daily amount of protein, i.e. 118 g/day.

CONCLUSIONS

In conclusion, it is clearly seen that the EU market lacks ready meals with high nutrition value, necessary for a consumer with huge physical activity level. However, it is possible to achieve the necessary nutrition with specifically developed products, which have higher nutrient density, as demonstrated in the presented paper.

Table 7. Amino acid composition balance¹, %

MC ²	Trp	Thr	Ile	Leu	Lys	Met	Cys	Tyr	Val	His
1	262	243	175	175	233	241	141	115	158	304
2	380	324	228	226	284	256	222	146	204	319
3	319	284	213	210	263	226	207	140	181	334
4	357	324	235	234	243	301	219	146	210	365
5	366	372	241	241	296	312	231	160	217	357
6	368	577	220	230	273	316	289	164	199	349
7	349	334	228	238	284	271	185	152	204	395
8	501	486	327	327	405	496	322	243	321	425
9	395	405	304	284	385	391	263	176	257	365
AM ³	406	415	319	312	385	301	230	188	280	441
LYO ⁴	274	242	184	184	208	219	210	101	163	286

¹ Amino acid (AA) composition of the developed products is expressed as a function of daily amino acid requirements (Table 2), where 100% indicates that the given AAs amount is fulfilling necessary daily requirement.

² MC, main course; ³ Adventurer menu (AM) Czech Republic – Farmer ham with lentil ragout; ⁴ LYOFood Expedition (Poland) – Beef stroganoff

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TIRGUS IZPĒTE UN ĒŠANAI GATAVAS MALTĪTES PAMATĒDIENA IZSTRĀDE MILITĀRĀS IZMANTOŠANAS KONTEKSTĀ

Vienas dienas uzturs karavīram var tikt nodrošināts ar 1 uzturdevas paku ēšanai gatavas maltītes uz 24 stundām vai 3 pakas ēšanai gatavas maltītes, kas atbilst 24 stundu uzturam. Pēc fiziskās aktivitātes līmeņa militārās operācijās var iedalīt divās kategorijās: normālās operācijas, kas salīdzināmas ar pilsētas policijas darbu un ugunsdzēsības darbiem, un kaujas operācijas, ko raksturo kājnieku misijas. Pētījuma mērķi bija: a) analizēt ES tirgū esošos pamatēdienus mīkstā iepakojumā (n = 184), militārās izmantošanas kontekstā, un b) izstrādāt termostabilizētus pamatēdienus, kas atbilst mūsdienu veselības un uztura rekomendācijām militārām vajadzībām, t.i., olbaltumvielu, ogļhidrātu, tauku, kopējās enerģijas un neaizstājamo aminoskābju sastāvam. Lielākais pamatēdienu daudzums ar derīguma termiņu ilgāk par vienu gadu tiek ražots Lielbritānijā (n = 48), un vairums no pamatēdieniem ir konservēti žāvēšanas procesā ar sublimācijas metodi (n = 135). 90% analizēto paraugu ir nepieciešamais tauku daudzums fiziski aktīvam patērētājam (t.i., karavīram), 39% ir nepieciešamais ogļhidrātu daudzums, 21% atbilst enerģētiskajām prasībām, bet tikai 1% no produktiem spēj sasniegt olbaltumvielu daudzuma prasības. Šajā pētījumā tika izstrādāti deviņi pamatēdieni ar derīguma termiņu trīs gadi, kas spēj nodrošināt fiziski aktīvu patērētāju ar nepieciešamo olbaltumvielu daudzumu, apmierinot aminoskābju un enerģijas nepieciešamības prasības.