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## A comprehensive review of plant-based meal replacements as a low-calorie solution for weight management

Nurizzati Y<sup>1</sup>, Aida FMNA<sup>1\*</sup>, Nur Shahirah N<sup>1</sup>, Raseetha S<sup>1</sup>, Ahmad Zahin Ilman O<sup>2</sup>, Nor Ashikin Z<sup>2</sup>, A. Abzar<sup>2,3</sup>, and Rasyiqah Nabihah Binti Roslli<sup>2</sup>

<sup>1</sup> Food Science and Technology Department, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

<sup>2</sup> Superfood Biotech Sdn Bhd, No 26, Jalan Astana 4A/ KU2, Bandar Bukit Raja, 41050 Klang Selangor, Malaysia

<sup>3</sup> Department of Crop Science, Faculty of Agriculture, University Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

### Abstract

Meal replacement can be the preferred option over the regular meal during breakfast, lunch, and dinner. The convenience of meal replacement products contributes to the popularity not only for working adults, but meal replacement also appeals to individuals with hectic schedules and those juggling household responsibilities. Meal replacement products often contain a combination of important nutrients focused on providing a balanced and convenient alternative to traditional and regular meals. These products typically include a combination of protein, carbohydrates, healthy fats, vitamins and minerals, as well as dietary fibres to meet the nutritional requirements of the body. There are also a number of meal replacement products with distinct ingredients to fit the preferences of the individuals. Despite its popularity, there are still different perceptions of individuals towards meal replacement products. In this review, the types of meal replacement products as well as the ingredients and benefits of the meal replacements and traditional meal has been compared. Furthermore, the effectiveness of meal replacement intake on satiety has also been studied. Satiety is defined as the period between meals that reduces appetite and discourages overeating. Besides that, the effectiveness of meal replacement products on weight loss and metabolic health has been explored. Finally, the benefits and drawbacks of meal replacement products has been discussed in detail.

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## 1. Introduction

Meal replacements (MRs) are increasingly recognized as an effective dietary strategy for portion control and weight management, particularly among individuals with demanding lifestyles. They provide controlled energy intake and balanced macronutrients, offering a practical alternative to traditional meals for breakfast, lunch, or dinner (1,2). These products, available as shakes, bars, soups, or powders, are designed to substitute one or more daily meals and have been shown to promote short-term weight loss when used as part of calorie-restricted diets (3,4). Their convenience and nutritional balance make them popular among working adults seeking time-efficient options for maintaining a healthy diet (5,6).

Historically, most commercial MRs were developed using animal-derived proteins, particularly whey and casein, due to their high biological value and complete amino-acid

\* Correspondence : Aida FMNA

aidafirdaus@uitm.edu.my

profiles (7). However, a global shift has emerged toward plant-based meal replacement (PBMR) formulations, driven by sustainability, ethical, and health considerations.

First, from an environmental perspective, the life-cycle assessment of dairy production reveals substantially higher greenhouse gas emissions, land, and water usage compared to plant protein sources such as soy, pea, and rice (8). Second, ethical and allergenic factors—including lactose intolerance, milk-protein allergies, and vegan dietary preferences—have increased demand for dairy-free alternatives (9). Third, functional differences make plant proteins nutritionally appealing: they are rich in dietary fiber, have slower digestion rates, and promote enhanced satiety and glycemic stability compared to rapidly absorbed animal proteins (10). Collectively, these factors position PBMRs as a more sustainable, inclusive, and physiologically advantageous approach to weight management.

Nevertheless, plant proteins exhibit substantial variation in composition and quality. Sources such as soy, pea, rice, hemp, and potato differ in their amino-acid balance, digestibility, and anti-nutritional compounds (11). For example, soy protein contains isoflavones and provides a complete amino-acid profile, whereas pea and rice proteins are hypoallergenic and gluten-free but may present challenges in lysine or sulphur amino-acid content (10). These compositional differences also influence product texture and sensory quality—pea and hemp proteins can cause chalkiness or earthy flavours, requiring formulation optimization through blending or hydrolysis (12). A comparative summary of plant protein quality, including Digestible Indispensable Amino Acid Score (DIAAS), anti-nutritional factors, and sensory impacts, is discussed later in this review.

In addition to protein, dietary fiber plays a central role in the functionality of PBMRs. Soluble fibers—such as inulin, oat  $\beta$ -glucan, and konjac glucomannan—enhance viscosity, delay gastric emptying, and improve postprandial glycaemic control (13). Insoluble fibers such as psyllium husk, barley bran, and quinoa residues promote bowel regularity and support gut microbiota modulation, improving long-term adherence to MR diets (14). These fibers not only contribute to satiety and metabolic regulation but also influence textural stability and mouthfeel in PBMR formulations.

Despite these benefits, sensory and palatability challenges remain a major limitation for plant-based products. Issues such as beany flavour, grittiness, or poor solubility can reduce consumer acceptance (12). To overcome these barriers, technological innovations—such as enzymatic hydrolysis, microencapsulation, flavour-masking agents, and the use of emulsifiers—have been explored to improve texture, taste, and stability (13). These developments are vital for enhancing the consumer appeal and nutritional performance of PBMRs.

From a regulatory standpoint, international frameworks define nutritional standards and labelling requirements for MR products. For example, the European Food Safety Authority (EFSA) requires MRs to provide 200–400 kcal per serving, with 25–50 % of energy from protein and at least 30 % of daily vitamin and mineral reference intakes, while the U.S. FDA and Codex Alimentarius enforce similar macronutrient and labelling guidelines (15). The Malaysian Recommended Nutrient Intakes (RNI 2017) also specify that MR products must deliver one-third of daily micronutrient needs per meal. These standards ensure safety, efficacy, and consistency across commercial formulations.

Finally, although MRs have been studied across various populations—including athletes, diabetic patients, and the elderly—this review focuses specifically on general adult consumers seeking weight management and metabolic balance through plant-based meal

replacement products. It does not include specialized clinical formulations or disease-specific applications, ensuring a focused evaluation of PBMRs as part of healthy lifestyle interventions.

Therefore, this review aims to (i) highlight the scientific rationale for shifting from animal-based to plant-based MR formulations, (ii) compare key plant protein and fiber sources relevant to MR development, (iii) evaluate their effects on satiety, weight loss, and metabolic health, and (iv) discuss the technological and regulatory considerations that guide PBMR innovation and market translation.

## **2. Current Trend of Meal Replacement Products**

In recent years, the popularity of meal replacement has significantly increased. According to Eastlake (2024), (5) meal replacement products appeal to people looking for an easy way to satisfy their nutritional needs because they are readily available and designed to provide a balanced combination of essential elements. These products cater to individuals who wish to effectively meet their nutritional needs, particularly those aiming to gain weight, and they have become a popular alternative to traditional meals. These products include meal replacement bars, shakes, soups, and any other pre-packaged products. Furthermore, options for meal replacement products like shakes, bars and powders are convenient for people with busy schedules because they can be consumed on the go. Due to their small packaging, individuals can easily carry them in their bags and still have access to nutrients whether they are at work, on the road or running errands.

Meal replacement products provide a time-saving alternative by removing the need for grocery shopping, cooking, cleaning, and meal preparation. According to Eastlake (2024) (5), many individuals in today's fast-paced culture frequently find it difficult to prepare and consume traditional meals that meet their nutritional needs. The need for nutritionally adequate meals has become a growing concern, particularly in the context of modern lifestyles characterized by longer working hours and changing dietary patterns. Consequently, the frequency of consuming traditional meals is decreasing. Therefore, the demand for meal replacement products is increasing, as they offer a convenient way to obtain essential nutrients while reducing meal preparation time (16). Ready-to-eat foods are also famous among people with busy lifestyles. Ready-to-eat foods are plant or animal-based products that have been frozen, cooked, and processed, so they can be eaten directly or with minimal preparation, like boiling or reheating (17). However, most individuals prefer meal replacement products over ready-to-eat meals, possibly because of their perceived benefits. Meal replacement products are believed to be able to provide a comprehensive balanced mix of essential nutrients, such as proteins, carbohydrates, fats, vitamins, and minerals and it usually comes in fixed portions, which helps in managing calorie intake and preventing overeating. Ready-to-eat foods, on the other hand, may be available in varied or larger servings, which can make it more difficult to regulate calorie consumption.

In addition, meal replacement products offer a convenient option to manage calorie intake. These products are specifically formulated to provide a controlled amount of calories per serving, making them suitable for individuals to monitor and limit their daily calorie intake more efficiently. However, the individual should refer to their doctors or nutritionist for advice and the recommended amount needed daily. Furthermore, meal replacement products also provide a better portion size (1). With that, individuals are able to take these products without worrying about the calorie intake or the nutrients. These products are

practically designed with an excellent amount of nutrients, thereby, these products have the ability to support individuals' daily nutritional requirements. By displaying the calorie per serving as well as the portion size recommended, it helps to promote mindful eating habits that still fulfil balanced diet and health goals.

### **3. Perception of Individuals Towards Meal Replacement Products**

Although meal replacement products are becoming increasingly popular, individual perceptions vary widely. There are some individuals who are doubtful about meal replacement products and whether they are able to provide the same level of nutrients and health advantages as whole foods. Commonly, they are worried about not getting enough essential vitamins, minerals, fibres, and phytonutrients that whole food provides. Phytonutrients are compounds that are found in plants that are believed to support good health in terms of antioxidant, anti-inflammatory, and anticancer properties (17). These nutrients play a vital role in supporting diverse aspects of health, including digestion, immune function, and disease function. The processing involved in manufacturing meal replacement products may lead to the loss of nutrients or decrease their bioavailability. For example, certain minerals can be lost during refining processes that remove parts of whole foods. Moreover, processed foods like meal replacement products often lack nutrients that are found in whole foods. The individuals should not be relying solely on meal replacement for nutrition, which may result in dietary monotony. Instead, we have traditional meals and whole foods too, like fruits and vegetable, to ensure optimal nutrient intake.

Besides that, many individuals prefer whole and unprocessed foods, such as fruits, vegetables, and whole grains, in their diets, as they are more satisfying and enjoyable to consume rather than processed foods. According to Njike et al. (2016), (18) the sensory experience of consuming whole foods, such as the crispness of vegetables or the sweetness of fresh fruits, can enhance the eating experience. The act of chewing and the variety of textures in whole foods often provide a greater satisfaction compared of processed foods. The natural composition of nutrients in whole foods is thought to be more beneficial for health as it does not require a lot of preparation that could diminish the nutrients. Moreover, these individuals believe that whole foods and traditional meals are more trustworthy. There is less concerned about additives, preservatives, and artificial ingredients in whole foods that are commonly found in processed foods. As for traditional meals, the amount of these components can be restricted during cooking, thus, these individuals prefer to make their own meals rather than have meal replacement products.

The packaging of meal replacement products and the health claims that are displayed on it can influence an individual's opinion. The health claims such as "without added sugars", "lowers cholesterol" and "fat-free" are able to perceive the individuals about the effectiveness and the value of the products. The claims are being the featured influence the individuals to believe in the ability of the products to work on their promises. By displaying these information and claims, it strengthens the perception, builds trust and enhances individuals' confidence in purchasing and consuming the product (19).

### **4. Different Types of Meal Replacement Products**

Meal replacement products are usually contained with a blend of essential nutrients and components aimed at offering a balanced and convenient substitute for traditional and regular meals. These products generally have a mix of protein, carbohydrates, healthy fats,

vitamins, and minerals as well as dietary fibres to fulfil the nutritional needs of the body. The types of meal replacement products help individuals choose and pick their meal according to their own preferences and comply with their specific nutrition needs. The different types of meal replacement products to be discussed are high-dietary fibre meal replacement, high-protein meal replacement, low-calories meal replacement, and gluten-free meal replacement. A thorough discussion about the different types of a meal replacements and the ingredients that are usually added to the product has been discussed below.

#### 4.1. High-dietary Fibre Meal Replacement

Dietary fibres are non-digestible carbohydrate oligomers and polymers derived from plant-based foods. They are neither digested nor absorbed in the small intestine but are partially or completely fermented in the colon (10,19). High-fibre diets are usually low in fat and calories, aiding in the maintaining of a healthy body weight (20). The low content of fat helps individuals feel full, thus reducing overall caloric intake. Dietary also fibres enhance the texture, stability, and shelf life of foods. All of it is due to the water-holding, swelling, oil-holding, gelling, and emulsifying properties (10). Li mentioned that dietary fibres intake helps lower blood sugar and blood lipids, as well as reducing the risk of coronary heart disease and stroke. The fibre fermentation and its utilization pathways are described in Figure 1. The Recommended Nutrient Intakes (RNI) for Malaysian highlighted that consuming of fibre-rich foods over 25 gram per day offer health benefit such as lowering the risk of coronary heart disease and type 2 diabetes, as well as maintaining healthy weight in adults (RNI, 2017) (21). Diets high in fibre can help with long-term weight management by reducing the amount of digestible calories. Due to its special properties in the stomach and small intestine, the soluble fibre and its gel-like texture reduce blood sugar levels after meals and increase feelings of fullness by affecting the release of specific gut hormones (22). The high-dietary fibre ingredients to be discussed are konjac glucomannan, psyllium husk, and barley.

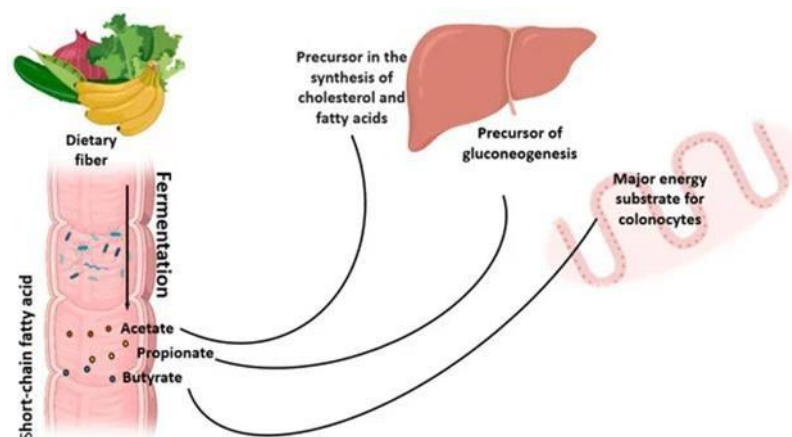


Figure 1. Fibre fermentation and its utilization pathways.

Source: Ioniță-Mîndrican et al. (20).

##### 4.1.1. Konjac Glucomannan

Konjac glucomannan (KGM) is a highly viscous dietary fibre sourced from the root of konjac plant. It resists hydrolysis by human digestive enzymes and passes directly to the colon, where it is utilized by intestinal microorganisms. Long-term consumption of KGM can lower calorie intake, balance body salt levels, and help manage obesity as well as diabetes, thereby

enhancing overall health (23). KGM is made up of 45% to 78% glucomannan on a dry weight. Diets that are rich in KGM have been considered healthier dietary options, where the purified KGM has been commonly used as a food additive and supplement. The addition of KGM to a low-fibre diet helps improve bowel movements and increases stool volume in healthy individuals (18). KGM is composed of  $\beta$ -1,4-linked D-glycosyl units of molar ratio with a 1.6:1.0, with branching points at the C-3 positions of both D-glucosyl and D-manosyl residues, as well as some at the C-6 positions of glucosyl units (24). Figure 2 shows the structure of konjac glucomannan. Furthermore, KGM is beneficial to Type 2 diabetes mellitus (T2DM) patients, a metabolic disorder marked by reduced insulin sensitivity and inadequate insulin secretion, as sticky dietary fibre can enhance the feeling of fullness and decrease appetite. KGM is a soluble fibre that produces a gel-like substance where it can slow down the gastric emptying when mixed with water in stomach. Due to the slow rate of KGM to enter intestine from stomach, it delays the gastric emptying, thus promoting the feelings of satiety and help the individuals to feel full for a longer period (23). Glucomannan is the main active compound in konjac where it forms a barrier around the food in order to reduce the absorption of cholesterol and bile acids. A protective layer on the intestinal wall is formed, thus, increases the time food remains in the stomach (25).

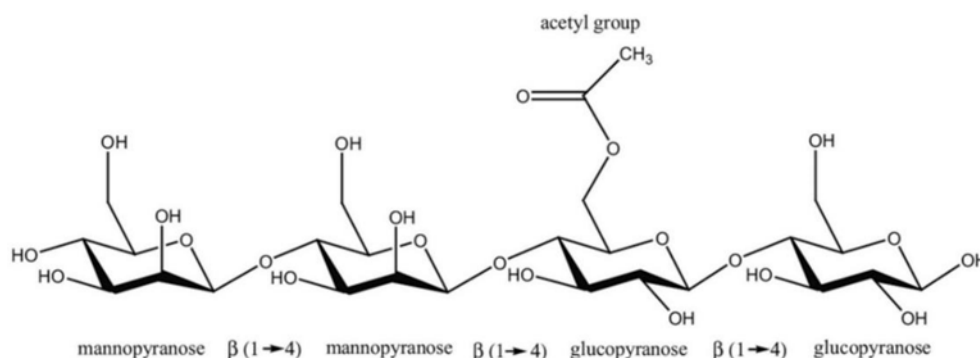


Figure 2. Structure of konjac glucomannan.

Source: Fang et al. (22)

#### 4.1.2. Psyllium husk

Psyllium husk, found in the seed coat of *Plantago ovata* plants, contains substantial, which is soluble and insoluble fibres. It is a viscous, predominantly water-soluble fibre proven effective for controlling blood cholesterol and glucose levels (26,27). It is a rich source of soluble dietary fibre and known for its hepatoprotective properties and high antioxidant content (28). Besides that, Abdullah mentions that it helps in maintaining regular bowel movements and relieving constipation by absorbing water and forming a gel-like substance that softens stools. When psyllium husk interacts with water, a thick and highly viscous gel known as psyllium gel is formed (29). One of the function of psyllium husk is that it can be applied as hydrocolloid in food production where it helps in improving the texture and enhancing the quality of the product (30). Furthermore, its soluble fibres content contributes to managing blood sugar levels and reducing cholesterol, making it beneficial for cardiovascular wellness. Psyllium, a type of dietary soluble viscous fibres, also can slow down gastric emptying and reduce the absorption rate of fat and glucose and it increases the exposure of lower sections of the small intestine to the nutrients. The changes in gastric emptying affects to a delayed feeling of hunger. The satiety effect observed after consuming psyllium suggests that it could be a beneficial dietary plan to increase satiety (31). Psyllium

husk supports weight loss and weight management by expanding in the stomach and promoting a feeling of fullness (31).

#### 4.1.3. Barley

Barley (*Hordeum vulgare*) stands out as a sustainable source of dietary fibres with diverse health benefits. It also contains a high amount of starch, proteins, lipids and phytochemicals. These fibres are primarily categorized into two main groups, which are soluble and insoluble fibres. Insoluble fibres of barley, such as cellulose and hemicellulose, contribute to enhancing digestive health, weight management, and regulation of blood sugar levels. Barley is recognized as for its high levels of soluble fibres, especially beta-glucan and antioxidants, the beta-glucan in barley is able to enhance the quality by improving glycemic and insulin response (32).

Besides that, soluble fibres in barley like glucan and arabinoxylan are recognized for their ability to lower cholesterol, regulate blood sugar levels, and promote gut health (33). The hull-less barley is more nutritious than hulled barley because it offers higher levels of proteins, lipids and soluble fibres (34). The processing of hulled barley can be challenging and time-consuming, while hull-less barley offers the benefit if requiring much less processing (32). The high fibre content in barley may help in relieving constipation and encouraging regular bowel. Additionally, the antioxidants in barley are valued to enhance immune function and protect against free radical damage by reducing the risk of various cancers, including colon cancer. Therefore, barley has become one of the ideal options for weight management due to its high fibre content, low calories, and fat that help in promoting a longer-lasting feeling of fullness (34).

#### 4.2. High Protein Meal Replacement

Proteins are a macronutrients and complex molecules that play various roles within organisms. This macronutrient is essential as it has major roles in cells and also plays vital roles in growth, development, and tissue repair in the body, such as blood clotting, fluid balance, and immune response. Proteins are made up of the union of diverse types of amino acids (35,36). These amino acids are divided into two categories, non-essential amino acids, which are produced by themselves in the body, and essential amino acids which have to be gotten by consuming meals that have them in it. Proteins serve as the fundamental building blocks in the body that constitute bones, cartilage, muscles, blood, skin, enzymes, hormones, and vitamins (36). A high-protein meal replacement typically includes 15 to 25 grams of protein per serving. However, it can reach over 30 grams depending on the formulation, such as supporting muscle building and weight management (37). The protein intake of Malaysian has increased since 2003, with an average intake of 56.7 grams per day, contributing to 16% of total energy intake (TEI; RNI, 201). The excessive consumption of protein can raise the demand of insulin in the pancreas that may lead to beta- cell dysfunction (38). Some examples of protein being used in meal replacement products are discussed below in detail.

##### 4.2.1. Barley

Whey protein, an essential part of milk proteins that can be quickly absorbed, causes a rapid increase in amino acids after ingestion. Ingestion affects the metabolism of skeletal muscle. This “fast” digestive milk-soluble protein helps in stimulating muscle protein synthesis and enhancing muscle function. The “fast” means that after consumption, the rise

in amino acids, and leucine levels in the blood increases quickly (38,39). Consequently, due to the rapid digestion and absorption of whey protein, they deliver essential amino acids to the muscles more quickly, thereby boosting muscle repair and growth, particularly after exercise. Moreover, the rapid rise in amino acid and leucine levels enhances protein synthesis and promotes more efficient muscle recovery. Besides that, this component contributes to its popularity due to its muscle branding and weight management. Whey-derived products are a rich source of vitamins and minerals and contain a high amount of digestible proteins and essential amino acids. The amino acid profile of whey protein is almost the same as the amino acid profile of human skeletal muscle, resulting in it being absorbed more quickly than other protein sources (40). In addition, it is also a very good source of Sulphur-containing amino acids, which provide the energy needed for numerous metabolic functions in the body (41). Due to the high content of digestible proteins, whey protein is a key component in meal replacement products aimed at promoting weight loss, muscle maintenance, and general wellness. It is also popular among athletes, bodybuilders, and individuals that aim to increase their overall protein intake.

#### 4.2.2. Soy Protein

Soybeans are a significant type of legume that has long been used as a protein source in Asian countries (42). Consuming soy protein offers several health benefits, including antioxidant and antihypertensive effects (43). Consequently, consuming soy protein lowers cholesterol and body fat, prevents osteoporosis, and reduces the risk of stomach, colorectal, and breast cancer. Soy proteins have a wide range of functional physicochemical properties that are useful in food applications, such as emulsification, foaming, gelation, water absorption and fat absorption (12). Soy proteins assist in fat absorption in meal replacement products by acting as emulsifiers, which creates a colloidal mixture where fat is evenly dispersed in water or another liquid (44). The nutrient content of soy protein includes carbohydrates, nitrogen compounds, and minerals, which promote microbial growth and lead to high biological and chemical oxygen demand (42). Furthermore, soy protein is a great alternative to animal-based protein, making it popular among vegetarians, vegans, and people with lactose intolerance and dairy allergies. Despite its benefits, there is also a drawback of consuming soy protein. According to Ahsan (2018) (45), soy protein is one of the eight most common food allergens where it typically begins in infants and young children under three years old. Soy allergies can be triggered by either inhaling or consuming soy products. Additionally, soy protein and its isoflavones may affect thyroid function, especially in people who already have thyroid problems. Isoflavones have the ability to inhibit thyroid peroxidase (TPO), an enzyme essential for the production of thyroid hormones. This could result in increased levels of thyroid-stimulating hormone (TSH) and lead to hypothyroidism in individuals who are at risk (46).

#### 4.2.3. Pea Protein

Pea serves as a significant supplier of nutritional elements, being abundant in protein, starch, and fibre (47). It shares similar functional properties with soy protein, such as emulsification, but has another benefit of being non-allergenic (48). Pea protein is notable among legume proteins due to its high availability and low allergenicity. Moreover, it has a well-balanced amino acid composition, which includes a high content of lysine. The routine consumption of foods containing pea protein helps lower the chances of cardiovascular

diseases and diabetes. Besides that, pea protein gives protection against various cancers like breast cancer, renal cancer, and colon cancer (49). Shanthakumar et al. (2022) (47) also mentions that pea protein offers health advantages such as antioxidant, antihypertensive, and anti-inflammatory properties as well as regulating industrial bacteria activities and reducing cholesterol levels. Peas may help suppress appetite due to the high protein content. It can result in slowing down stomach emptying, reducing glucose absorption and concentration as well as increasing the release of hormones that regulate hunger (47). Figure 3 shows the simplified extraction steps of pea protein by alkali extraction precipitation. It is known as the most conventional technique for producing pea protein isolates (47).

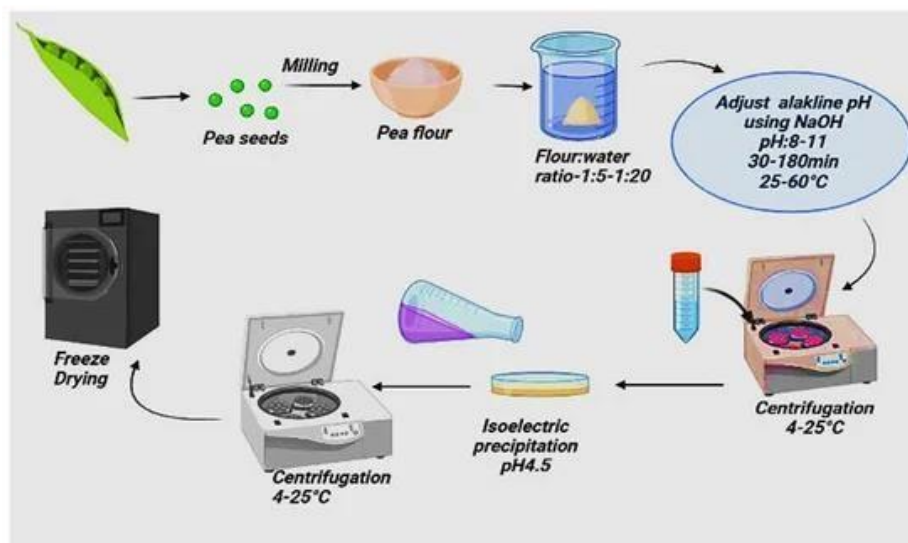


Figure 3. Extraction of pea protein by alkali precipitation.

Source: Shanthakumar et al. (47)

#### 4.3. Low-calories Meal Replacement

Low-calorie diets broadly limit fats or carbohydrates without one being proven more essential for weight loss as long as the calorie deficit is maintained. It is usually relied on specifically formulated nutritional meal replacement (50,51). Generally, this specification needs a content high amount of protein, vitamins and minerals to ensure complete nutrition. Other than that, it may also contain fibre to enhance satiety. Low-calorie foods were first developed to meet the dietary needs of people with diabetes and other specific medical conditions (51). These foods provide essential nutrients while reducing calorie intake, hence, able to maintain better dietary control. Additionally, a very low-calorie diet (VLCD) is a dietary plan that significantly cuts daily energy intake, typically below a person's resting metabolic rate (52). The normal caloric intake is between 800 and 1,200 kcal per day, but VLCD limits the energy intake, which is only 450 to 800 kcal per day (52,53). This diet is usually used to achieve rapid weight loss in individuals with metabolic problems, obesity, or those at risk for type II diabetes (52). However, it is not recommended for regular weight management and should only be used under specific conditions with medical supervision, as advised by obesity guidelines (51). The examples of low-calorie ingredients used in meal replacement products are unsweetened almond milk, oats, and quinoa which have been discussed in detail below.

#### 4.3.1. Unsweetened almond milk

Unsweetened almond milk is an alternative to plant-based milk, which is famous for being low in calories and carbohydrates (54). Almond milk contains a balanced composition of proteins, fats, fibre, vitamins and minerals and is free from lactose, thus it is an excellent option for lactose intolerance and vegans (54,55). The almond meal and other necessary ingredients are used to produce unsweetened almond milk (54).

Almond meal, which are made from ground almonds, are the primary component in almond milk. The other necessary ingredients include water, stabilizers and additional vitamins and minerals to boost its nutritional value. Figure 4 shows the simplified process flow of almond meal. The reason unsweetened almond milk is a low-calorie option is because it contains no added sugar, thus, it is suitable for individuals that want to manage sugar intake and ideal for individuals who are practicing low-carb and ketogenic-diets.

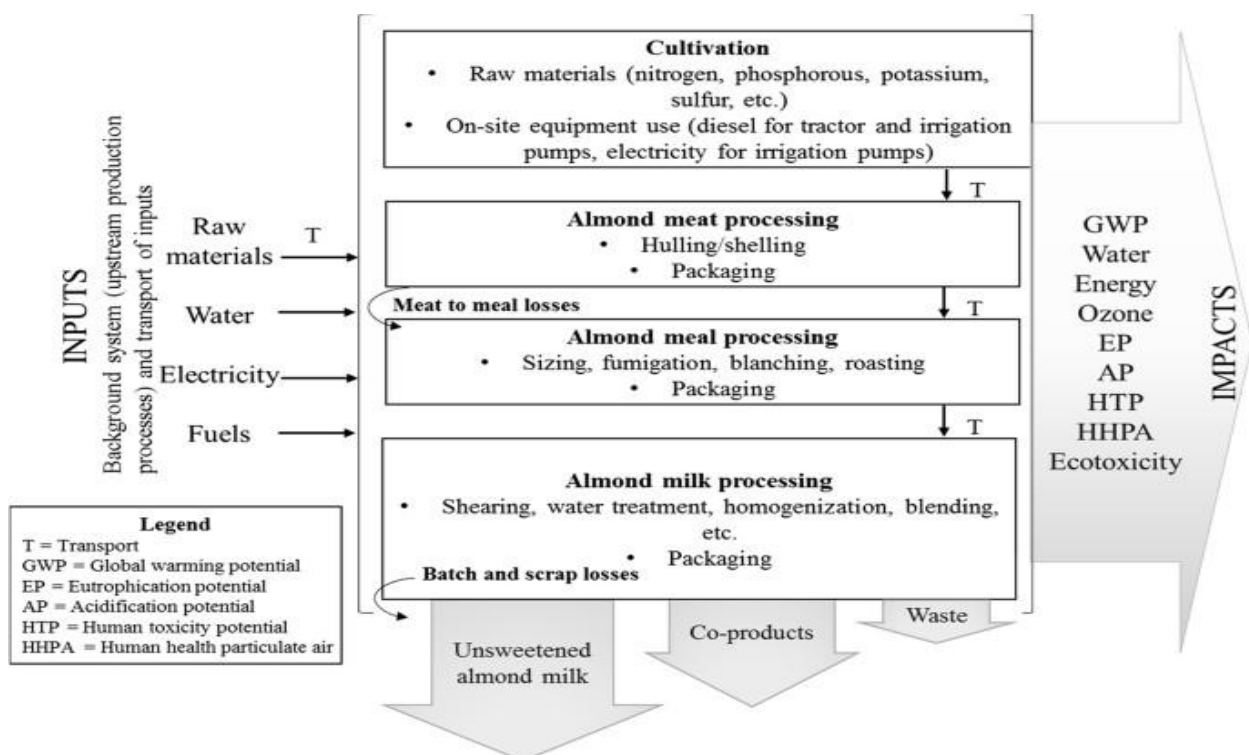


Figure 4. Simplified process flow of almond meal. Source: Winans et al. (54).

#### 4.3.2. Unsweetened almond milk

Oats are well-known for their high-nutritional flavors and unique flavor and they stand out among cereals for containing various types of nutrients beneficial for human food, animal feed, healthcare and cosmetics (56,57). The higher consumption of whole grains is strongly correlated with a lower incidence of chronic (57). Moreover, oats are rich in dietary fibre and contain distinctive proteins and vitamins. The oats consumption in the human diet has risen because of its health benefits, which are linked to the dietary fibres, such as beta-glucan, as well as the functional proteins, lipids, starches and phytochemicals present in the grain (58). As oats ripen, they produce numerous secondary metabolites, notably beta-glucan. This viscous and soluble fibre can be found in the endospermic cell wall of the oats (59). Due to the presence of beta-glucan, oats are considered as a low-calorie option. This is because beta-

glucan helps create a feeling of fullness, therefore, helps in controlling overall calorie consumption and weight management. Oats are one of diets that is high in beta-glucan where they can lower the blood lipid levels as well as reduce blood pressure by regulating insulin metabolism with mild hypercholesterolemia (56).

#### 4.3.3. Quinoa

Quinoa (*Chenopodium quinoa Willd*) is a nutrient-rich plant that has attracted significant scientific interest (60). Quinoa is generally high in protein, where it contains all essential amino acids but it has low levels of reducing sugars, carbohydrates and fats and they are easily digestible as they are gluten-free (61,62). It is recognized as a valuable functional and medicinal properties, with research indicating its benefits in treating obesity and associated endocrine disease, including type II diabetes (60). Besides that, quinoa also offers various health benefits, such as reducing cholesterol levels and aiding cardiovascular disease, constipation, and breast cancer. Additionally, quinoa is packed with immune-boosting phytochemicals, including saponins, phytosterols, and phytoecdysteroids (63).

#### 4.4. Gluten-free Meal Replacement

A gluten-free diet claims the total elimination of gluten, which is a protein complex found in foods. Some example of products that contain gluten are wheat, barley, rye, kamut, and their hybrid strains (64). The alternative of these foods or wheat-based foods can be legumes, fruits and vegetables, which are known as naturally gluten-free foods. Gluten-free products usually have high level of fat in order to enhance their appearance and palatability. They are generally higher carbohydrate and lipid but less protein (65). Celiac disease (CD) is a chronic autoimmune disorder that predominantly affects the small intestine in genetically susceptible individuals. It is caused by an abnormal immunological reaction to gluten, which is the primary protein found in wheat, rye and barley, which lead to progressive atrophy of the intestinal villi, poor absorption and malnutrition (65,66). Below are the common gluten-free ingredients being used in meal replacement products.

##### 4.4.1. Germinated brown rice flour

Brown rice, a whole grain food that contains dietary fibres, vitamins, minerals, and minor bioactive ingredients, making it more nutritious than refined white rice (30). Germinated brown rice (GBR) is produced by incubating hulled brown rice under specific temperature and humidity conditions to enhance its cooking quality (30,67). Germination is an effective technique for eliminating non-nutrients while increasing the content of protein, dietary fibre, beneficial nutritional compounds, and bioactive compounds (68). It is considered a healthier alternative to brown rice due to its improved nutrient bioavailability. The addition of germinated brown rice flour (GBRF) to wheat breads, steamed buns, and noodles modifies the gluten network structure through interactions with dietary fibres, starch granules, and reduce sugars in GBRF (30,67). Due to the gluten-free, it gives a low Glycemic Index (GI) which is good for blood sugar management. GBRF is high in dietary fibre, essential for digestive health. By germination, the fibre content increased from 5.27% to 6.13%, thus, the functional properties of the flour in gluten-free product improved (68).

#### 4.4.2. Flaxseed

Flaxseed (*Linum usitatissimum L.*) is recognized as a nutraceutical and functional food due to its high-quality proteins, minerals, and exceptionally high content in alpha-linolenic acid, omega-3 fatty acids, lignans, and dietary fibres. Thus, it leads to nourishment, support, fibre, mechanical support purposes, and a cluster of anti-cancer agents as well as other bioactive compounds (69,70). Besides that, this component comprises approximately 22% protein, featuring nutritionally balanced amino acid levels, making it useful to prevent protein deficiencies (70,71). Moreover, flaxseed is able to release bioactive peptides with physiological benefits upon digestion, however, it is still unrecognized as a protein source (71). Additionally, flaxseed provide both soluble and insoluble fibres where the soluble fibres are gums, pectin and beta-glucan. These soluble fibres help in reducing blood sugar levels and absorbing cholesterol and triglycerides, thus preventing diabetes and cardiovascular diseases (70). Flaxseed offers preventive and therapeutic benefits for a range of conditions, including cardiovascular diseases, diabetes, high blood sugar, obesity, breast and prostate cancer, osteoporosis and reproductive issues (70).

#### 4.4.3. Buckwheat

Despite its name, buckwheat is not a type of wheat but it comes from the seeds of a plant that is related to rhubarb. Buckwheat is considered a valuable functional grain in order to produce gluten-free breads due to its richness in vitamins, minerals, antioxidants, and bioactive components. Those components include proteins with a well-balanced amino acid profile, dietary fibre, flavonoids, fagopyrins, d-fagomine, and phenolic acid, all of which offer healing properties against chronic diseases (72,73). Sofi (2022) (72) states that buckwheat seeds provide a rich source of proteins with a balanced amount of amino acids, including albumins, globulins, prolamins, and glutelin. Moreover, these proteins are gluten-free, making them more suitable for individuals with celiac disease (72). Furthermore, buckwheat is naturally high in starch resistant, resulting in having a low of GI and are generally advantageous for most healthy adults (74). Buckwheat is also rich in unsaturated fatty acids, which provide health benefits, such as heart disease, cancer, inflammation and diabetes (72).

### 5. Different Types of Meal Replacement Products

Expected satiety refers to the amount of food anticipated to avoid feeling hungry (75). It can also be said as the measure of feeling satisfied that is expected to be felt after eating a particular food. In this case, the satiety of meal replacement is defined as the feeling of fullness and satisfaction after having any meal replacement products and the way in which meal replacements keep hunger away. Satiety is mainly regulated by the oral sensory and cognitive factors since the prior exposure to taste, texture, flavor, aroma and palatability which determines the need to eat. Additionally, the size of the meal taken affects the digestion process while the absorption of food after the meal is influenced by the nutritional status of the gut which regulates satiety as well (76).

The consumption of foods that offer fewer calories may help in lowering the overall food intake and the addition of more protein to meals can increase the feeling of fullness (75,77). Protein is recognized to provide the highest satiety among all macronutrient and assist in feeling fullness (77). The protein content in the diet should be 30 grams of protein, making up 30-40% of the total calories to be recognized as high-protein diets. High-protein diets increase hormones like glucagon-like peptide-1 (GLP-1), cholecystokinin (CCK), and

peptide tyrosine-tyrosine (PYY), which helps in reducing the appetite and increasing fullness (78). When protein reaches the digestive system, it triggers these hormones from cells in the gut to release, which enhance satiety and reduce hunger. Hence, it is able to reduce the desire to eat more and lower the anticipation of future food consumption.

Foods with low levels of glycemic index (GI), such as high-fibre ingredients like whole grains and legumes may help control appetite. Generally, high-fibre ingredients work by taking longer time to chew, which slows down eating, thus giving the body more time to feel full before overeating. The act of chewing itself helps to send signal to the brain to feel full. The physical properties of meal replacement products play a role in satiety. The thickness and texture of meal replacement products have an impact to the satiety (77). Foods with low GI add volume to meals and slow down the digestion (79). This is because low GI foods release glucose into the bloodstream more slowly because it contains complex carbohydrates that take longer to digest. Consequently, high levels of fibre in ingredients help the stomach, which results in enhancing satiety (77).

Furthermore, it is also important to see the frequency of meal replacement products taken by the individuals. Technically, the frequency of meals consumed depends on individuals, some people might have a meal replacement product just for one meal per day, while others might have two or three meals daily. It is mostly dependent on the individual's satiety, dietary goals, and nutritional needs. Low frequency of meals intake per day, such as 1- 2 meals can lead to lower body mass index (BMI). This eating pattern will regulate satiety hormones and boost metabolism, such as increasing leptin that helps control appetite and reducing the ghrelin that increases hunger (80). Additionally, the consumption of solid meal replacement products in fewer amount may result in greater feelings of fullness than consuming liquid meal replacement products. Chewing solid foods will release hormones like cholecystokinin (CCK), which signals the body of full feeling (81).

## **6. The Effectiveness of Meal Replacement for Weight Loss**

There are many meal replacements for individuals to choose according to their preferences and nutritional needs, including for individuals undergo weight management or those who are on a diet to lose their body weight or can be said as obesity. These products are designed to replace traditional meals whereas the products offer regulated amounts of calories and nutrients, making them more attractive to those looking to manage their weight. This is because calorie restriction is the most crucial for weight loss and followed by the macronutrient composition of the diet (50). Hence, the key role of meal replacement products specifically for weight management and weight loss is their ability to offer a precise number of calories per serving. Low-calorie meal replacement products are usually being picked by these individuals. Low-calorie diets usually limit either fats or carbohydrates, but the most important thing is that there should be a calorie deficit (50). The most crucial factor for weight loss is to maintain the calorie deficit, which by consuming fewer calories than the body uses. The lower consumption of calories results in the burning of stored fat for energy. Consequently, it leads to weight loss over time. According to Rondanelli et al. (2020) (82), the decrease in body weight that occurs with a low-calorie diet naturally includes a loss of both fat and fat-free mass (FFMs). Therefore, meal replacement products provide an efficient approach for losing weight while offering controlled portions that keep individuals feeling full and most importantly, help those individuals cut back calories and their weight management.

Additionally, a very low-calorie diet (VLCD) meal replacement works to help individuals with severe obesity. It is recommended for those who have not met their weight loss goals through other methods. VLCD contains less than or equal to 800 kcal where it limits the daily calorie intake, thus it helps with rapid weight loss (83). However, it is not suitable for regular weight management, instead it is intended only for specific cases and under medical supervision, as recommended by obesity guidelines (50). High-dietary fibre meal replacement products support weight management through several mechanisms. Firstly, high-dietary fibre foods help in reducing energy intake due to their physical properties and helping consumers feel satisfied by consuming small portions, thus reducing the chances of overeating. Certain types of fibre bind with fats and other nutrients in the digestive tract to prevent full absorption and reduce the energy absorption as well as the overall calories intake. Besides that, fibres help increasing the energy expenditure after meals where it enhances gastrointestinal motility and contributes to higher calorie burn, assisting in weight loss. Fibres also promote the excretion of bile acids and other compounds, which helps with fat loss. The excretion of bile acids signals the body to produce more, where the stored fats are used to support liver function and bile synthesis (84). Therefore, fibre in general, can be an effective option for weight loss.

## **7. The Effectiveness of Meal Replacement on Metabolic Health**

Recently, there has been growing interest in the potential of meal replacement products to enhance metabolic health. Metabolic health is evaluated based on the existence of metabolic risk factors associated with chronic non-communicable diseases. In instance, heart disease, stroke, cancer, chronic respiratory conditions and diabetes. These risk factors include high blood pressure, which stresses the cardiovascular system, elevated triglyceride levels, high fasting glucose, increased waist circumference and low levels of high-density lipoprotein cholesterol (HDL-C). Moreover, these individuals are considered unhealthy if they exhibit three or more risk factors (13). Meal replacement products offer strategies in enhancing metabolic health, where the individual could choose the product that would fit their nutritional requirements and dietary deficiencies. For example, individuals with diabetes are required to regulate their blood sugar levels, thus, gluten-free meal replacement products are claimed to be suitable for these individuals. This is because gluten-free meals offer low-glycemic index (GI) that are able to stabilize blood sugar levels by avoiding the rapid spikes and drops of the low-glycemic index (GI). With that, these products have their ability to provide steady energy levels and lower the risk of insulin resistance as well as type 2 diabetes. The GI measures how quickly carbohydrates in foods are digested and absorbed in the bloodstream. Hence, low-glycemic index products help digesting and absorbing carbohydrates more slowly, thereby causing less dramatic increases in blood sugar levels and insulin (85).

Cardiovascular disease, cancer, and diabetes are noncommunicable diseases that are recognized by obesity as the greatest risk factor (3). Gómez (2020) (3) also mentioned that weight loss reduces cardiovascular risk by improving the main components of metabolic syndrome, which include high blood pressure, abnormal lipid levels, and diabetes. As stated by the World Health Organization (WHO), cardiovascular diseases (CDVs) refer to various disorders of the heart and blood vessels. Heart attacks and strokes typically occur unexpectedly due to blockages that prevent blood flow to the heart or brain, which are frequently caused by fatty deposits in the blood arteries. In 2019, about 1.9 million people died from CDVs, making up 32% of all deaths worldwide. The majority of these deaths, which

is 85%, were due to heart attacks and strokes (86). The consumption of trans-fat, saturated fats, sodium, red meat, refined carbohydrates, and sugar-sweetened beverages should be limited and avoided. It is advisable to consume an abundance of non-starchy vegetables, fruits, whole grains, and legumes, along with a moderate amount of nuts, seafood, lean meats, low-fat dairy products, and vegetable oils (87). With that, there are so many options of meal replacement products that could fit with the individual's preferences. For example, high-protein meal replacement products and high-dietary fibres meal replacement products. However, individuals are advised to consult with their doctors or nutritionists beforehand to avoid any negative impacts.

Following that, strokes often happen due to the blockages that prevent blood flow to the heart or brain, like heart attack, that are commonly caused by fatty deposits in the arteries (86). Stroke ranked as the second prevalent cause of death globally and the third most frequent cause of disability, following heart diseases (88). In Malaysia, there were 47911 new cases, 19928 deaths, 443995 existing cases and 512726 disability-adjusted life years lost due to stroke (89). Lin (2021) (88) mentioned that reducing salt intake, plant-based diets rich in fruits, vegetables, whole grains, legumes, seeds, nuts and dairy, while limiting meats, sweets, and alcohols, have been proven to be beneficial in lowering stroke risk factors. Therefore, high-dietary fibres meal replacement products are suitable for stroke patients. Soluble fibre in meal replacement products assist in managing blood sugar level, which is crucial for stroke patients who are at risk of diabetes.

## **8. Conclusions**

From the current review we concluded that meal replacement provides a satisfactory and nutritionally balanced diet substantially to traditional meals which makes them a popular choice for individuals with busy lifestyle. These meal replacement products with the combination of protein, fats, carbohydrates, minerals, vitamins and dietary fiber. Even though meal replacement offers show beneficial effects such as weight loss, metabolic health and supporting satiety, the perception and preference still vary among individuals regarding their use. The limitations and advantages of meal replacement products have been highlighted in this review as compared to traditional meal, underscoring the need for further research to fully understand their long-term effects on health and well-being.

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## **Author Contributions**

N.Y, N.S.N: conceptualization, supervising, data analyzed, project leader, original draft preparation; A F.M.N.A, R.S: performed the experiments and analyzed the data, A.Z.I, A.A: supplies and materials, administration, draft editing; N.A.Z, R.N.B.R: method, performed the experiment, supplies and materials, draft editing; N.Y: contributed to experiment, questionnaire, and data preparation.

## Conflicts of Interest

The authors have no conflict of interest. All the figures included in this review have been cited in text as well as in the bibliography section. No animals or human studies are present in the review.

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