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REVIEW OPEN ACCESS

Effects of Pea Protein on Satiety, Postprandial Glucose Response and Appetite Hormones: A Literature Review

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Abstract

Introduction: Type 2 Diabetes (T2D) is one of the leading causes of mortality with obesity being one of the greatest risk factors. Increased protein intake has been found to increase satiety, that could potentially aid in weight control. However, much of the research is elusive on the specifics of the effects of plant-based protein, specifically pea protein on satiety and responses linked to appetite. The purpose of this review was to investigate the effects of pea protein on satiety, postprandial glucose response and appetite.

Methods: Studies of the existing literature were found, filtered, and analyzed from scientific databases Cochrane Library, PubMed, ScienceDirect, and Web of Science entering a combination of the keywords "pea protein", "satiety", and "postprandial response". A total of 11 articles were analyzed to determine the relationship between pea protein consumption and postprandial response of satiety and appetite.

Results: Pea protein consumption as a preload increased satiety and lowered food intake between 30 and 120 minutes after ingestion. Postprandial blood glucose was lowered and various appetite hormones increased at different time lapses.

Discussion: Although the oral consumption of pea protein alone was seen to effectively induce satiety, other factors such as the addition of fibre, the method of administration, or rates of gastric emptying could significantly affect food intake.

Conclusion: This literature review establishes a link between plant proteins and its benefits of feelings of satiety and appetite to promote incorporating more plant proteins in the diet. Future research should further investigate the link between postprandial responses and appetite hormones to identify benefits of pea protein for use in the food industry and increase public consumption of pea protein.

Keywords: pea protein; satiety; postprandial response; appetite hormone

Introduction

Type 2 diabetes (T2D) is one of the leading causes of all-cause mortality [1,2]. Risk factors for developing T2D include obesity, aging, ethnicity, diet, lifestyle, and environment [3]. Diet has been found to be a factor to the development of T2D; therefore, multiple diets that limit animal intake have been explored to manage T2D [4,5]. One as such is the growing interest and demand for plant proteins. Since T2D has been shown to increase proportionally to the amount of animal protein consumed, there is rationale to increase protein sources from plants [6]. Plant proteins have been demonstrated to contribute to higher intakes of fibre, lower saturated fat [7], and increase satiety that directly contributes to lowering calorie intake [8]. Thus, plant proteins have been found to be beneficial to achieve and maintain a healthy weight [9], promote environmental sustainability, and reduce the risk of diabetes and other comorbidities [10].

Proteins are essential to maintain physiological functions. Proteins are vital in building muscles, synthesizing antibodies, and enzymes [11,12]. Since not all proteins could be synthesized in the body, proteins are required to be consumed in the diet [13]. There are concerns about plant foods not providing all 20 dietary amino acids [14]; however, the research suggest that the combination of plant proteins could achieve the desired amino acid profile [15]. The demand and shift in plant proteins intake has increased over the last few years [16] and this is expected to continuously rise following the increased interest in plant-based diets that consist of high-quality and accessible forms of plant protein [17].

Increasing the awareness of the benefits of plant proteins could encourage consumers seeking to incorporate healthier forms of protein into their diets [18]. Peas (Pisum sativum L.), also referred to as the common pea is one of the oldest domesticated crops that accounts for 36% of the

total pulse production in the world [19-20]. Peas are gaining more popularity for its high protein content, abundance, low cost, nutritional value and health benefits [18-19,21-22]. However, recent studies lack the mention of pea protein and its correlation to high levels of satiety and appetite hormones. Studies within the last 15 years individually explored pea protein's role on satiety, appetite hormone release, and benefits. Despite this, much of the research is elusive on the specifics of the effects of pea protein, on satiety and responses linked to appetite.

Benefits of high satiety levels after consumption of pea protein to benefit weight control and weight loss should be highlighted. Satiety is the combination of cognitive, sensory, and physiological signals that the brain receives to interpret how much one's appetite is inhibited after consumption of nutrients [23]. Knowledge about pea protein consumption and high levels of satiety and its link to weight control and weight loss could change how many manage their diet. With greater levels of satiety, less calorie intake is shown [23]. Despite this, studies suggest barriers to high pea protein consumption [24] and research related to the topic are attributed to lack of palatability and flavour [24]. This gap in literature is amplified by the challenges the food industry faces to incorporate more pea protein in foods and beverages [25]. The purpose of this review was to investigate the effects of pea protein isolates on postprandial responses of satiety and appetite and its benefits, with appetite hormones examined as secondary outcomes.

Methods

Study Inclusion Criteria

Articles investigating the relationship between pea protein and responses of satiety and appetite in humans from 2008-2021 were chosen and reviewed. Included in the studies were ones of pea protein isolate, hydrolysate, or powder that influenced satiety, food intake, postprandial suppression, and appetite. There were no restrictions on sex or weight. The review focused on analysing existing data on the influence of satiety as a result of protein consumption, participants without T2D were examined in this review. This exclusion was made to help organize known data which in turn could allow increased public knowledge of the topic at hand.

Search Results with PRISMA Model

To conduct this review, studies were chosen following PRISMA guidelines for systematic literature reviews published in the following databases in the English language: Cochrane Library, PubMed, ScienceDirect, and Web of Science databases were searched within the 2007–2022-time range. Keywords: pea protein, pea protein satiety, and pea protein postprandial response were used, that identified 502 records. Using the citation management software EndNote, duplicates were removed, 195 records remained. Out of the remaining studies records without keywords, "pea protein" and "satiety" in their title, abstract, or keywords listed by authors were excluded. This led to a list of 99 records with relevant studies focused on pea protein as well as examining satiety, appetite, and fullness. Out of these records, clinical trials with no publicly available data, studies that did not provide clear distinction of pea protein isolate/hydrolysate mixed with another source of protein or macronutrient, and studies that investigated animal studies were also excluded. Following the PRISMA model, 9 studies are included in the review. A manual search of the databases was conducted, and an additional 2 studies were identified and eligible to be included in the review. Therefore, a total of 11 studies were chosen to be included in the review based on scientific relevancy and inclusion criteria, (Figure 1). Among the chosen studies, the outcome variables were measured by subjective appetite scales between 30 minutes and 2 hours for studies conducted in a controlled lab setting with supervision of lab members. This timeline for each trial led to outcomes indicating either higher satiety level after consumption or similar levels of hunger before and after consumption.

Results

Pea protein consumption was shown to increase satiety or maintain similar levels compared to other proteins. Appetite hormones were also seen to change depending on time lapse and the type of hormones examined (Table 1).

Satiety Levels and Food Intake

Pea protein has been demonstrated to affect food intake and levels of satiety. This was observed to occur as early as 30 minutes after pea protein intake [24] and its effects could last up to two hours after ingestion [24,26]. Findings indicate 15 g of pea protein hydrolysate (PPH) exhibited the greatest satiety and fullness along with suppressed hunger, desire to eat and thirst [26]. In another study, 30 g of pea protein added to a vegetable soup was found to be the optimal dosage to increase satiety levels [27]. This is supported by the longer time lapse (90 minutes) for food intake. Increased feelings of fullness and decreased food intake was found to be further sustained if pea protein was administered intraduodenally whereas oral administration of pea protein decreased hunger only up to 120 minutes [28]. In addition to time lapse affecting levels of satiety, other qualitative factors also affected participants' satiety and appetite levels.

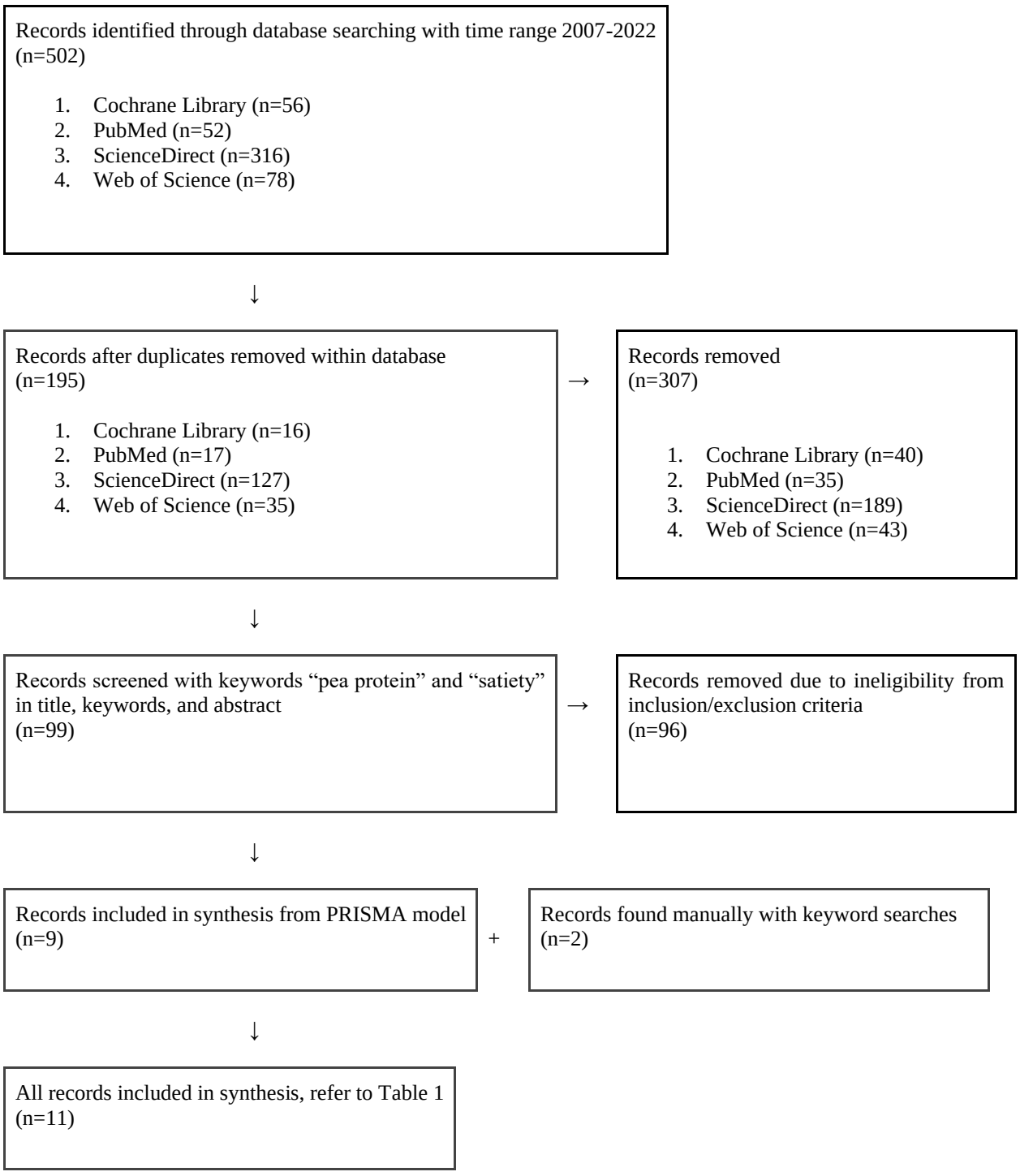

Figure 1. Flow chart of the selection of reviewed articles following PRISMA model (created with Microsoft Word). Redmond, WA: Microsoft; 2021.

Table 1. Summary of included studies (n=12) on pea protein postprandial responses of satiety and appetite

Study & Year	Participants (n)	Study Type	Assessment	Control	Dose	Comparators	Duration	Significant Results
Smith et al., 2012 [32]	Exp 1 = 19 M Exp 2 = 20 M, 20-30 years	Single-blind, randomized	VAS for motivation to eat, thirst, physical comfort, energy, fatigue	Tomato soup	10 g (P10) or 20 g (P20) of yellow pea protein	10 g (F10) or 20 g (F20) of yellow pea fibre	1 treatment per week, 1 week apart	Food intake after 30 min of P20 was lowest. Post-meal blood glucose was suppressed after 20 g of protein compared to control
Abou-Samra et al., 2011 [24]	Exp 1 & 2 = 32 M, 20-35 years	2 single-blind, randomized, cross-over	VAS at 10 min intervals after preload	Water	20 g of pea protein	20 g of casein, whey, egg albumin or maltodextrin	1 day: 30 min before and after ad libitum meal for 2 hrs	Exp 1: food intake was lower, satiety higher Exp 2: similar results with higher intake after preload compared to control in all groups
Mollard et al., 2014 [30]	15 M, 18-35 years	Randomized crossover trial	VAS and capillary blood glucose monitor (Accu-Chek monitor)	Noodles and tomato sauce	10 g pea protein	7 g pea hull fibre, 7 g pea hull fibre + 10 g pea protein, 406 g yellow peas	1 treatment per week, 1 week apart	No effect compared to control, pea protein did not affect food intake or blood glucose between before 0-120 minutes or after 135-195 minutes an ad libitum meal served 2h later
Johnston et al., 2021 [33]	11 F & 15 M, 18-50 years	Double-blinded, randomized controlled trial	VAS for subjective appetite, palatability, energy, fatigue, physical comfort	Oat flour cereal	*Ad libitum*	Oat flour + pea starch (starch), oat flour + pea protein (protein), oat flour + pea starch + pea protein (starch+protein), oat flour + pea fibre + pea protein (fibre+protein), pea fibre + pea starch + pea protein (fibre+starch+protein)	1 treatment per week, at least 5 days between sessions, for total of 6 treatments = 6 weeks	No effects of treatment on food or water intake. After 30, 45, and 60 minutes the treatment, protein cereal exhibited a lower glycemic response compared with control cereal Lowest blood glucose response from fibre + starch + protein cereal

Study & Year	Participants (n)	Study Type	Assessment	Control	Dose	Comparators	Duration	Significant Results
Diepvens et al., 2008 [26]	20 F & 19 M, 18-60 years	Randomized, crossover with 2 parts	VAS for appetite profile and energy intake and blood sample for satiety hormones, glucose levels	Milk protein	15 g of pea protein hydrolysate	Whey protein, pea protein hydrolysate + whey protein	1 day: Experiment 1 = 4h, Experiment 2 = 7h + 180 min	Pea protein hydrolysate caused less hunger, less desire to eat, less thirst, greater satiety and fullness but did not support the levels of satiety hormones and ghrelin.
Baum et al., 2017 [29]	33 F & M, 18-40 years	Randomized, crossover with 2 groups (educational messaging, no messaging)	VAS at 0, 15, 30, 60, 90, 120 min after test breakfast	N/A	274 kcal of pea protein breakfast beverage	Whey protein-based breakfast beverage	1 day: 7 min for breakfast beverage, VAS at time intervals for 120 min, additional 60 min of snacks. Total = 180 min.	Educational messaging with breakfast decreases postprandial snacking and calorie intake but no difference between whey or pea protein breakfast
Geraedts et al., 2011 [28]	10 lean M, mean age of 25 years & 10 obese M, mean age of 41 years	Single-blind, randomized controlled crossover	Nasodudenal catheter, intravenous blood sampling catheter, blood samples, VAS	N/A	250 mg/kg body weight in 0.4 mL/kg body weight water)	Placebo of 0.4 mL/kg body weight of water	4 weeks: 1 experiment per week: 120 min of data collected at intervals + 10 minutes before ad libitum meal offered and eaten per session	Reduced food intake for both lean and obese subjects after intraduodenal protein administration vs placebo group. CCK levels increased at 10 and 20 minutes after intraduodenal administration in obese subjects.

Study & Year	Participants (n)	Study Type	Assessment	Control	Dose	Comparators	Duration	Significant Results
Lefranc-Millot et al., 2015 [27]	22 F & 11 M, 18-65 years	Double blind, randomized, placebo controlled, crossover	VAS, blood samples	Soup	15 g and 30 g of pea protein isolate (NUTRALYS ®)	30 g whey protein	4 weeks: 1 visit per week, 7.25 hrs per visit from 7:45 am to 3:00 pm	15 and 30 g of pea protein reduced caloric intake. 30 g of pea protein led to an increase in perceived levels of satiety
Sirtori et al., 2012 [34]	93 F & 82 M, no age criteria	Double blind, randomized, parallel group	Blood samples, attending physician examination, body weight, blood pressure	Casein (control protein), cellulose (control fibre)	2 bars/day (34.6 g/day) of pea protein isolate + cellulose/oat fibre/pectin	Casein + cellulose, casein + oat fibre, casein + pectin	4 weeks separated into 7 treatment groups, consuming 2 bars/day throughout	Glucose and insulin decreased after pea protein and oat fibre consumption compared to baseline. Plant-based protein with fibre successfully decreased cholesterol levels
Claessens et al., 2009 [35]	8 M, mean age of 32 years	Single blind, Latin square randomization	Blood samples	0.2 g/kg maltodextrin beverage	0.2 g/kg pea protein hydrolysate (~250mL)	Rice, soy, gluten, whey, egg protein hydrolysate drinks	7 trials with testing days separated by at least 2 days: 2h test duration after test drink	All protein hydrolysates induced more insulin secretion compared to the control drink with no significant difference between the comparators except for lower glucagon response in gluten hydrolysate
Hawley et al., 2020 [31]	15 young M, 18-29 years & 15 older M, 60-85 years	Single-blind, crossover, randomized, controlled	VAS, REE, SO, blood sample	N/A	40 g of pea protein isolate drink and 263.8 kcal	40 g of whey protein isolate drink and 265.8 kcal	2 test days separated by 1-2 weeks: 1 test day = 4-hr test day, 24-hr food log following test day to record food intake	High-protein breakfast with either pea or whey protein isolate had no significant effect on food intake or energy expenditure, but age group is what led to effect of appetite levels

Abbreviations used: M: Male participants, F: Female participants, VAS: Visual Analogue Scales DIT: Diet-induced thermogenesis; REE: Resting energy expenditure; and SO: Shifts in substrate oxidation

When presented with educational messaging at the time of pea protein preload, higher satiety and decreased appetite levels were observed [29]. Baum *et al.* found that the group exposed to educational messaging consumed less snacks (mean of 2.5 ± 0.3) up to two hours after pea protein preload compared to the non-messaging group (mean of 3.6 ± 0.5) [29]. It was also found that the non-messaging group chose twice as many unhealthy snacks [29]. However, not all studies found benefits to the consumption of pea protein compared to other protein sources.

Benefits of pea protein in increasing satiety and reducing appetite were not consistent in all studies. Mollard *et al.* found that pea protein alone or the combination of pea protein and hull fibre did not have any effect in increasing satiety since it did not affect food intake of an ad libitum meal [30]. Additionally, Hawley *et al.* demonstrated that the source of protein whether it was from whey or pea, had no significant effect on appetite, food intake, and energy expenditure [31]. Even with reported increased or similar levels of satiety to the control, physiological components were not consistent with satiety hormone levels glucagon-like peptide-1 (GLP-1), cholecystokinin (CCK), and ghrelin [26].

Postprandial Glucose Response and Appetite Hormones

While some studies show inconsistencies in blood glucose and appetite hormone levels, studies by Smith *et al.* and Johnston *et al.* show its strong correlation. Smith *et al.* found lower postprandial blood glucose after 20 g of pea protein consumption [32]. Similar findings were found by Johnston *et al.* that found postprandial blood glucose to be lower in the cereal containing 7.3–8.5 g of pea protein with 13.9-20.2 g of available carbohydrate compared to the control cereal with 3.13 g of protein and 28 g of available carbohydrate [33].

When both insulin and blood glucose levels were measured, it was found that the consumption of two daily bars containing 34.6 g of pea protein isolate and cellulose/oat fibre/pectin per day for four weeks to be the most beneficial in reducing blood glucose and insulin levels. This led to a 57% insulin reduction and 4% glucose reduction [34]. The time frame for this study was much longer than most, thus, when these levels were evaluated at a shorter interval of time, Claessens *et al.* found PPH to lower glucose levels at 30 minutes after its consumption compared to the control drink ($P<0.025$), soy, gluten, and whey drinks [35]. Although insulin levels were observed to spike at 30 minutes after consumption for all preloads, higher insulin and glucagon response in PPH was demonstrated [35]. Despite this, appetite hormones were not examined to assess the correlation between satiety and consumption of pea protein.

Pea protein intake also affected appetite hormones including CCK, peptide YY (PYY), and GLP-1 in both lean and obese participants. Findings show CCK levels to increase 10 minutes following oral ingestion and 15 minutes following intraduodenal administration of pea protein. GLP-1 showed to increase in both lean and obese participants. The effect of GLP-1 increase in lean participants was demonstrated to occur 15 minutes following oral treatment whereas obese participants needed up to 90 minutes following intraduodenal treatment to demonstrate increase of GLP-1 levels. Similarly, PYY showed an increase in lean and obese participants. The effect of PYY increased in lean participants 15 minutes after intraduodenal administration whereas obese participants required a minimum of 30 minutes for both methods of ingestion [28].

When findings related to the effects of pea protein isolates on postprandial responses of satiety and appetite and its benefits were investigated, many proved the positive effect of pea protein consumption and decreased food intake [24,26-28]. Nonetheless, out of the 450 participants included in this review, there were inconsistencies in the results with some studies showing that there was no impact on food intake [30] or no difference between other types of protein and levels of satiety [31].

Discussion

Findings have shown inconsistencies on the effects of pea protein consumption on satiety and food intake. Pea protein preload was seen to induce higher levels of satiety or show no difference when compared to other sources of protein. Oral administration of pea protein while effective, was found to be less successful in reducing food intake compared to intraduodenal administration. Pea protein affected appetite hormones including increased levels of CCK, PYY, and GLP-1 at different time lapses after the preload consumption in lean and obese participants.

Satiety was perceived to be higher when consuming pea protein preloads compared to other sources of protein and non-protein comparators such as carbohydrates [24,26,33]. One significant difference when comparing different types of protein consumed orally with pea protein is the rate of digestion. Pea protein was found to induce similar levels of appetite hormones, particularly CCK, GLP-1, and PYY as whey protein. It was also observed that pea protein delayed intestinal bioavailability and prolonged gastric retention that could be a result of prolonged action of intestinal proteases which likely led to higher levels of satiety [36]. Johnston *et al.* (2014) used a control with a lower amount of protein and higher amount of carbohydrate to conclude the correlation between higher satiety levels with higher protein intake [33]. This showed the importance of concluding that effects of protein consumption increased satiety levels when compared to other sources of nutrition commonly consumed or associated with protein.

Oral administration of pea protein was found to be effective in inducing satiety that led to reduced energy intake [24,37,38]; however, intraduodenal administration demonstrated to have a greater effect in increasing satiety levels [28]. This alternate method of administration was due

to intact pea protein entering the duodenum rather than the oral cavity, proving to be more satiating than its digested products [28]. Intraduodenal administration evaluation was convenient in studies with participants already having the required equipment to proceed with this method. Otherwise, it was considered a more challenging method of administration. The ecological validity was low with studies considering unconventional methods of administration. However, the stomach's nutrient-sensing's location was not yet explored in humans and was concluded that gastric accommodation and hormone release is key to determining hunger and satiety levels [39]. This validates the alternate method of administration to be a reliable source of data but a lower ecological valid one as it examines the bioavailability of the protein throughout the digestive tract. The demonstrated lower intake of foods and higher scores of perceived satiety were more pronounced when educational messaging was included. When participants were given the autonomy to choose snacks, those exposed to educational messaging chose healthier snacks. Similarly, it was observed that reading caloric information prior to a meal led to choose low-calorie meals [40] and a 30% lower energy intake than those without the information [42].

The results obtained on increased level of satiety after pea protein consumption conformed with additional benefits such as weight loss and better nitrogen balance. It was demonstrated in some studies that the perceived level of satiety was correlated to the amount of pea protein consumed. It was observed that between 15 and 30 grams of pea protein, the higher dose was optimal to induce satiety [27]. This is supported by the notion that to lose weight, an increased amount of protein should be consumed to increase satiety and lower energy intake from other food sources. The correlation between higher pea protein intake and increased satiety could be due to an improved nitrogen balance [27] in the gut. Although more research needs to be conducted in the field, nitrogen balance can be a marker for adequate protein intake in critically ill patients [42], demonstrating its critical role in protein consumption. Furthermore, pea protein's high digestibility easily breakdowns amino acids preparing them to be readily absorbed in the small intestine [43]. This readiness in absorption from the small intestine could contribute to the differences in time lapse seen by different studies between preload consumption and VAS scores indicating higher levels of satiety.

While the majority of the research showed an increase in satiety levels with pea protein intake following a specified time lapse, Mollard *et al*. (2014) and Geraedts *et al*. (2011) found that there were no significant differences between intake of pea protein preload compared to the control or comparators. The lack of difference was suggested to have been a result from the mixture of high glycemic food incorporated with the pea protein [30]. Other dietary components such as the addition of fibre could significantly affect food intake [30]. This could lower food intake because dietary fibre is known to slow gastric emptying, lower carbohydrate absorption and postprandial blood glucose concentration [44]. As Calbet *et al.* (2002) examined, pea protein is digested in approximately 30 min after consumption as seen in the peak amino acid concentrations [45]; therefore, it is suggested that fibre, when consumed with protein, slows gastric emptying [46]. Lowered postprandial blood glucose levels also reduces insulin secretion which in turn may promote satiety. GLP-1 may also regulate postprandial satiety due to its role in insulin secretion which is reduced in this case [47].

GLP-1 is a key appetite-regulating hormone that has shown to improve glycemic control and stimulate satiety which in turn can decrease food intake and maintain a healthy body weight [48]. The pathways involved in appetite and reward were detected to be higher in obese T2D participants compared to lean participants not diagnosed with T2D when shown food pictures [48]. This could be due to higher GLP-1 agonists present in lean individuals that could lead to weight loss or lower activation patterns in T2D patients to help maintain a healthy weight.

The addition of fibre to pea protein could lower food intake but Hawley *et al.* (2020) showed that the source of protein did not have a significant effect on food intake. There were minimal reported effects on the difference in participants' VAS scores when comparing whey and pea protein. This could be due to the lack of non-protein comparators or control that would have distinctly contrasted the results of protein's satiety levels of consumption with its different chemical component. Bendtsen *et al.* (2014) also found that there were no significant differences in appetite regulation in the following 24-hour window after the consumption of a fast or slow protein meal [49]. Although pea protein is an intermediate fast protein [36], if the difference between whey and casein is not detectable, it is reasonable to predict that whey and pea protein show similar results.

Other parameters examined were of glucose and appetite hormone levels that yielded inconsistent results. Smith *et al.* (2012) found that plasma amino acid concentrations peaked at 30 mins after preload consumption correlating with participants' higher satiety responses at time interval [32]. This is supported by Claessens *et al.* (2009) who also found that all test drinks, including pea protein, induced a glucose response that reached peak levels between 15 and 30 min after consumption and reaching baseline values after 120 min. [35]. However, these results cannot be due to various rates of gastric emptying since the protein hydrolysates used were of similar volume and conditions such as pH and temperature [50]. Contrastingly, Johnston *et al.* (2021) found lower blood glucose in participants who consumed more protein, this could be due to higher protein meals having a prolonged residence time in the small intestine, giving more time for nutrient

absorption and appetite hormone release [33]. An example of hormone is GLP-1, one that slows gastric emptying [51], helping lower blood glucose. This hormone could have been released in moderate quantities when participants of Sirtori *et al*. (2012) consumed two daily bars of pea protein with oat fibre which reduced their low-density lipoprotein cholesterol (LDL-C) a total of 5.8% after 4 weeks [34].

Despite all benefits mentioned in this review for the consumption of pea protein, limitations need to be considered. Most of the studies assessed satiety using VAS [24,26-33], though it is validated, interindividual variance of levels of satiety exist that make it challenging to compare results. Additionally, the studies' designs had various time lapses after preload consumption and various tests. Also, the purpose of the protein preload varied from serving as a breakfast drink [31] or a meal [27], varying the amount of pea protein served per portion. Contrasting the limitations of the review are the strengths of this study. The driving research questions of the chosen researchers were in some cases similar and others vastly different. This allows for a broad overview of the field of pea protein as it relates to appetite and postprandial response. The components studies explored such as satiety after a time lapse, appetite hormones in response to pea protein preload consumption, or the benefits of educational messaging in combination with a breakfast preload drink showed that there is research conducted in varying aspects surrounding pea protein consumption. Findings of this review suggests that more studies need to be conducted to investigate the effects of pea protein isolates on postprandial responses of satiety and appetite hormone levels with designated time lapses. From this review, no exact conclusion can be drawn due to the lack of consistency between studies' designs, the ambiguity of participants' feelings of satiety, benefits of pea protein consumption, and appetite hormones mostly investigated separately and not linked as one.

Conclusion

Although the research investigating the effects of pea protein isolates on postprandial responses of satiety and appetite alongside appetite hormones is limited, there is a significant amount of literature supporting the benefits of pea protein consumption on increasing satiety. Further research exploring this relationship could improve dietary measures for T2D. This, in turn could increase awareness of the benefits of plant proteins for nutrient and health outcomes. Further research must be conducted to better understand pea protein isolate consumption as it relates to postprandial responses and appetite hormones. Suggestions include having a group of a minimum of 100 participants of both sexes to include a larger demographic as many research studies focused on young healthy men. For the design of the study, increasing palatability of given food that includes pea protein should be a factor of utmost importance due to many people not familiar with its taste, resulting in strong bias against the products from an importantly large number of participants. Additionally, monitoring blood glucose throughout the length of each trial as well as pre- and post-experiment to detect the range in concentration deemed to increase or maintain similar levels of satiety to elucidate the physiological effects of glucose intake more clearly. Having a clear comparison of 10 g compared with 20 g of given protein intake shows the effects in a more linear fashion as VAS are ambiguous, thus there is a need for complimentary yet comparative factors. Finally, having non-protein comparators will also be beneficial in comparing the effects in ratio and importance of amount needed to reach the desired satiety levels. This review analysed different aspects of the existing research as it pertained to satiety and appetite regulation of pea protein. As this is an evolving field, there were limited statistical analysis that could be concluded. Each individual study conducted their own method of analysis to match their sub-area of research hence, rather than a statistical analysis-driven conclusion, a general trend of either a positive or neutral effect after pea protein consumption was reported. This overview of statistical analysis was a representation of the combination of an ever-evolving field of research.

List of Abbreviations Used

CCK: cholecystokinin
DIT: diet-induced thermogenesis
F: female participants
GLP-1: glucagon-like peptide 1
LDL-C: low-density lipoprotein cholesterol
M: male participants
PPH: pea protein hydrolysate
PYY: peptide YY
REE: resting energy expenditure
SO: shifts in substrate oxidation
T2D: type 2 Diabetes
VAS: visual analogue scales

Conflicts of Interest

The author declares that they have no conflict of interests.

Ethics Approval and/or Participant Consent

The study performed was a literature review and did not require ethics approval and/or participant consent.

Authors' Contributions

AC: contributed to the design of the study; collected, interpreted, and analyzed data; drafted and revised the manuscript; and gave final approval of the version to be published.

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