



## THE ROLE OF PROTEIN IN SATIETY & WEIGHT MANAGEMENT

### SUMMARY

Interest in curbing the obesity epidemic has focused on dietary strategies, including increased protein intake, to achieve and maintain a healthy body weight. It generally is accepted that calorie-for-calorie, protein intake increases satiety (a feeling of fullness) to a greater extent than either carbohydrate or fat under most conditions. This protein-induced satiety may lead to improved appetite control, reductions in energy intake, and, over time, better weight management.

A review of short and longer-term energy balanced, weight maintenance studies indicates that increased dietary protein (18-30% of energy) provided in single meals and throughout a typical day of eating leads to increased satiety and, in some studies, reduced daily energy intake compared to a protein intake of 10 to 15% of energy. Since these amounts of protein are within the Institute of Medicine's Acceptable Macronutrient Distribution Range for protein (10-35% of energy), these findings suggest that increased satiety can readily be achieved using typically consumed foods and prescribed diets.

During longer-term studies of energy restriction as well as during weight-maintenance (after weight loss), dietary protein at a level of 18% of energy or higher has been demonstrated to play a beneficial role in weight loss and/or subsequent weight maintenance, in part through increased satiety, compared to lower protein diets (15% of energy).

Researchers have proposed several mechanisms to explain protein-induced satiety, including increased energy expenditure through increased thermogenesis and changes in the concentration of peripheral and central "satiety" hormones. However, additional research is needed to better elucidate the specific mechanisms contributing to the effect of protein on satiety.

Research demonstrates that increased intake of dairy proteins (casein and whey) and dairy foods enhances satiety, although more studies are needed to determine if the favorable effect of dairy proteins and dairy foods as shown in single meals or preloads on short-term subjective satiety, food intake, and intake regulatory mechanisms can be achieved from usual serving sizes of dairy foods. However, consuming the recommended three servings of low-fat and/or fat-free dairy foods such as milk, cheese, and yogurt throughout the day can help achieve a higher protein intake which, as demonstrated by research, increases satiety and may potentially provide weight management benefits. In addition, the increasing availability of foods and beverages incorporating dairy proteins (e.g., whey protein) as ingredients provides another way to increase protein intake to achieve satiety and weight management benefits.



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## INTRODUCTION

As a result of the increasing incidence of overweight and obesity, along with escalating health care costs associated with weight-related illnesses (e.g., type 2 diabetes, hypertension, cardiovascular disease), prevention and reduction of overweight and obesity is a major public health priority (1,2). In particular, there is heightened interest in dietary strategies to achieve and maintain a healthy body weight. The influence of the macronutrient composition of the diet on appetite control, daily food intake, and weight control has received recent attention, not only by the mainstream media, but also by healthcare professionals, researchers, and industry. Specific emphasis has been placed on increased protein intake for improvements in appetite control, through increased satiety, and better body weight management (3-9).

According to a recent survey, two-thirds of American consumers said that it was extremely important that a food or beverage makes them feel satiated/full (10). This was particularly important to consumers trying to lose weight. Over half of those surveyed agreed that protein-rich foods are the best at satisfying hunger. This Digest reviews recent research examining the effects of protein-induced meal-related and daily satiety during short-term and longer-term energy balanced and energy restricted weight loss studies, proposed mechanisms, and the benefits of dairy proteins on satiety.




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*Research shows that calorie-for-calorie consuming more protein increases satiety (a feeling of fullness), which may lead to improved appetite control, food intake regulation, and, over time, better body weight management.*

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## DIETARY PROTEIN & SATIETY

**Satiety.** Perceived satiety is defined as a feeling of fullness or lack of desire to eat following food intake and can be attributed to a particular nutrient, food, meal, or the overall diet (11). It is often based on subjective ratings of fullness using validated Visual Analog Scales administered before and over a period of time (e.g., 1 to 6 hours) following intake of a preload or test meal. Satiety testing also includes quantifying caloric intake at an *ad libitum* subsequent meal offered at a set time (1 to 8 hours) following the preload or test meal. In longer-term studies, satiety can be measured indirectly by assessing voluntary caloric intake over several days to weeks.

**Protein Quantity.** The Acceptable Macronutrient Distribution Range (AMDR) (i.e., the range of intake associated with reduced risk of chronic diseases while providing adequate intake) for protein, as established by the Institute of Medicine, is between 10% and 35% of daily calories for adults (i.e., 50-175 g protein per day for an adult consuming a 2,000 kcal/day diet) (12). According to the conclusions published from a recent Protein Summit (in which a majority of the leading protein scientists/researchers from around the world convened to examine the state of the science in the area of protein and health), many adults may achieve health benefits, including reduced risk of obesity, by consuming protein intakes at the upper limit of the AMDR range (13). It is generally accepted that calorie-for-calorie, protein intake increases satiety to a greater extent than either carbohydrate or fat under most conditions, potentially leading to subsequent reductions in caloric intake and, over time, better weight management (3-9,13-15).

**Short-term Studies.** The majority of studies examining protein-induced meal-related and daily satiety have been acute in nature and have contained large amounts of dietary protein (on the order of 80-100% of the meal). However, more recent studies are now including meals

which contain increased but moderate quantities of dietary protein. For example, in a single-blind, randomized crossover study in 30 healthy normal weight adults, satiety was significantly higher after subjects consumed a higher protein lunch containing 25% of energy as dietary protein compared to a lower protein lunch (10% of energy) (16). In an earlier study, researchers compared meals containing 18% or 30% of energy as dietary protein (17). Perceived satiety was measured every 30 minutes throughout the four hour post-meal period and was found to be higher following the 30% vs. 18% protein meal (17).

To monitor perceived satiety throughout an entire day of eating, studies have incorporated controlled environments involving respiration chambers and have demonstrated that increased dietary protein (30% of energy) provided across a typical day of eating led to increased 24-hour satiety compared to a lower protein diet (10% of energy) (18,19). Based on these findings, the researchers conclude that when protein intake is greater than the protein requirement, satiety is positively related to the absolute amount of protein consumed (19).

### **Longer-term Studies Including Weight Loss and/or Weight Maintenance Studies.**

The next fundamental question that needs to be addressed pertains to whether the increases in protein-induced satiety observed during acute studies are maintained over time and during weight loss. Some longer-term studies suggest that increasing protein intake results in a voluntary decrease in food consumption due to the greater levels of satiety (20,21). Researchers examined the effects of a four-week isocaloric weight maintenance diet containing either 15% or 30% of calories as protein in 19 subjects (20). Marked increases in overall satiety were observed following the 30% protein diet (20). Following the four-week period, the subjects were then asked to follow an *ad libitum* diet containing 30% protein for 12 weeks. Throughout this period, the subjects consumed less energy while sustaining the previous level of satiety, and lost weight with a decrease in body fat mass (20).

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*Proposed mechanisms for protein-induced satiety include an increase in energy expenditure and changes in the release of peripheral and central "satiety" hormones.*

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Evidence that a higher protein intake improves perceptions of satiety during periods of energy restriction was demonstrated in a randomized, controlled trial that assessed meal-related satiety and pleasure (22). Forty-six overweight and obese women followed an energy-reduced (-750 kcal/d) diet containing either higher protein (30% of energy) or lower protein (18% of energy) for 12 weeks (22). As expected during energy restriction, both diets led to a reduction in meal-related satiety. However, the consumption of the higher protein, energy-restricted diet led to a smaller reduction in satiety than the consumption of a similar energy-restricted diet with a lower protein intake (22). Additionally, the higher protein diet led to increased feelings of pleasure and greater preservation of lean body mass while losing weight and body fat (22).

Some longer-term studies have demonstrated that a high protein diet limits weight re-gain after weight loss (23-25). After completion of very low energy diets for four weeks, overweight adults who consumed a higher protein diet (18% of energy) during a six-month weight-maintenance period, reported higher overall satiety compared to subjects who consumed a lower protein weight-maintenance diet (15% of energy) (24). They also experienced reduced weight regain after three and six months, and tended to regain only fat-free mass (24). A more recent investigation in 48 subjects showed that after an initial substantial weight loss, a low-fat, high protein diet (~28% of energy) consumed *ad libitum* for three months prevented weight gain and led to further modest losses in weight and body fat compared with a low-fat, high carbohydrate diet (~16% of energy as protein) (25).

### **PROPOSED MECHANISMS**

Several mechanisms have been proposed to explain protein-induced satiety, including increased energy expenditure, changes in the concentrations of "satiety" hormones, and changes in central pathways (3,7-9,26).

An increase in energy expenditure, through increased thermogenesis, has been proposed to induce satiety (7,9,18,

19,26,27). Since dietary protein stimulates diet-induced thermogenesis to a greater extent than do other macronutrients, it is reasonable to include this as a potential “satiety” mechanism of action. While a relationship between energy expenditure and protein-induced satiety has been observed, most of these findings result from longer-term studies containing fairly large quantities of dietary protein (5,9,19).

Satiety may also be mediated through protein-induced increases in the concentrations of appetite-suppressing hormones such as glucagon-like peptide-1 (GLP-1), cholecystokinin (CCK), and peptide tyrosine tyrosine (PYY) and/or decreases in appetite-stimulating hormones such as ghrelin (9,26,28). However, the effect of increased protein intake on changes in hormone levels is inconsistent (4,9,16,29). For example, a change in hormone levels after a high protein preload occurred in one short-term study (29), whereas in another short-term study no differences in ghrelin, GLP-1, and PYY responses between the high protein and adequate protein intake appeared (16).

Protein-induced changes in “satiety” hormones appear to be related to the amount and type of protein consumed and are mainly involved in short-term protein-induced satiety (5,26,28,30). Whether protein-induced changes in “satiety” hormones are related to satiety ratings or energy intake remains to be conclusively established. Some researchers have shown that while increased intake of specific proteins results in significant differences in hormone responses, these are not necessarily related to satiety ratings or energy intake (31-33).

Along these lines, higher protein diets may also activate specific regions of the brain involved in the central regulation of food intake (26). A study in laboratory rats showed that high protein meals activated satiety-related neuronal pathways in the brainstem and hypothalamus (34).




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*Dairy proteins – casein and whey – as part of a high protein diet have been shown to increase satiety. However, more research is needed to determine the optimal amount of these proteins and/or servings of dairy foods to reduce energy intake.*

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## DAIRY PROTEINS & SATIETY

Recent evidence indicates an increased satiety response when consuming higher amounts of dairy foods such as fat-free milk (35), chocolate milk (36), high protein cheese (37), and low-fat yogurt (38). Specifically, when overweight women consumed a fixed-energy breakfast containing fat-free milk (25 g protein) or an equal amount of fruit juice (<1 g protein), less energy was consumed at lunch following the breakfast containing fat-free milk than fruit juice (35). Likewise, consumption of a cheese snack (22 g protein) containing either casein or a mixture of casein and whey proteins one hour before lunch reduced energy intake at lunch and over 24 hours (37). Based on these findings, the researchers suggest that regular consumption of a high protein, moderate calorie cheese as a snack should “not promote overweight because energy intake appears to be regulated during subsequent meals on the same day” (37). While increased satiety translated into reduced *ad libitum* energy intake in some of these studies (35,37), it failed to do so in others (36,38), perhaps due to differences in the time lapse between consumption of the dairy food and the test meal.

Numerous studies, mostly of short duration, have demonstrated that both casein (~80% of milk protein) and whey proteins (~20% of milk protein) positively influence satiety (5,8,9,28-31,39-43). A randomized, single-blind study of 25 healthy adults found that a breakfast with 25% of energy from casein was more satiating than a breakfast with 10% of energy from casein and coincided with prolonged elevated plasma amino acid levels (39). However, there were no differences in energy intake at lunch (39). In a longer-term randomized crossover study in which 24 healthy adults remained in a respiration chamber for 36 hours, a diet containing 25% of energy as casein increased 24-hour total energy expenditure and feelings of satiety, and resulted in a positive

protein balance compared to a 10% casein diet (44). Because casein was the only protein source in this study, it is unknown whether the findings are specific to casein or to the higher protein intake in general.

An appetite-suppressing effect of whey has been demonstrated in a number of short-term studies, but, like other proteins, the effects on energy intake are inconsistent (14,29-31,35,40-43,45-47). Recently, researchers have demonstrated a beneficial effect of whey protein on appetite control in concentrations within the normal range in realistic mixed meals (30). In this randomized, single-blind, within-subject study of 25 healthy adults, intake of a breakfast with whey protein (10% of energy) reduced hunger more than an equicaloric breakfast with a similar percentage of calories from casein or soy (30). However, at the level of 25% of energy from protein, there were no differences in appetite ratings. Since there were differences in appetite ratings between these types of protein at the level of 10% of energy but not at the level of 25% of energy, the researchers suggest that it may not be possible to distinguish satiating effects of different proteins when the concentration of amino acids is above a threshold level (30).

Whey protein is high in beta-lactoglobulin, alpha-lactalbumin, branched chain amino acids, especially leucine, and, when prepared by ultrafiltration, the peptide glycomacropeptide (GMP). GMP, which stimulates "satiety" hormones (e.g., CCK), potentially impacting subsequent energy intake and satiety, is gaining scientific attention (31,47,48). However, the findings regarding its influence on satiety are inconsistent (47). In a study of 25 healthy adults, *ad libitum* energy intake was 10% lower three hours after a breakfast with whey containing GMP compared to a whey-based breakfast without GMP, irrespective of the concentration of whey protein (25% of energy or 10% of energy) (31). In contrast, another study found that GMP is not critical in pre-meal whey-induced satiety (48). More




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*Three servings of low-fat and/or fat-free dairy foods such as milk, cheese, and yogurt, as well as foods and beverages containing dairy protein ingredients such as whey protein, eaten throughout the day can help achieve a high protein diet which increases satiety and may provide weight management benefits.*

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research with consideration of the dose, timing, and delivery mode of GMP is needed to determine this peptide's role in food intake regulation and potentially management of body weight (48).

Limited research has compared the effect of different proteins on satiety, especially dairy proteins. However, because whey protein is considered to be a relatively "fast" protein (i.e., digested and absorbed faster, causing a quick increase in circulating amino acids) (42,49,50), it may be more satiating than casein in the near term (27). In contrast, casein, which is considered to be a relatively "slow" protein (i.e., digested and absorbed more slowly, providing a more consistent release of amino acids), may have a later satiating effect (7,42).

A whey protein preload has been reported to be more satiating (i.e., lower energy intake) than a preload of casein in one short-term study (29) and equally satiating as casein in another study (40). In the first study (29), the buffet meal was offered at 90 minutes after the preloads, which likely is too soon for casein to exhibit an effect on satiety. In the second study (40), the absence of significant differences in appetite ratings between different protein types (e.g., casein vs. whey) may be explained by the high level ( $\geq 50\%$  of energy or 55 g) of protein intake (i.e., a concentration of amino acids above a threshold level) (9,30).

Although dairy-induced satiety may be influenced by a synergistic action of whey proteins providing early satiety and casein providing overlapping but later satiety signals (42), it remains unclear if the favorable effect of dairy proteins on subjective satiety, food intake, and intake regulatory mechanisms can be achieved from usual serving sizes of dairy foods (42). The effects of dairy proteins on satiety are largely shown in short-term studies in which these proteins are consumed in much higher amounts in meals or preloads than found in usual serving sizes of dairy foods. However, since dairy foods are often consumed with other foods at a meal, they can help achieve a higher protein meal.

## CONCLUSION

It generally is accepted that calorie-for-calorie, protein intake increases satiety to a greater extent than either carbohydrate or fat under most conditions. Short-term and longer-term studies indicate that increasing protein intake promotes satiety, which in turn may have a beneficial role in body weight management. Moreover, a number of mechanisms have been proposed to explain protein-induced satiety.

Although emerging evidence suggests that dairy proteins (e.g., casein, whey) and dairy foods may enhance satiety, more research is needed to determine the optimal amounts of dairy proteins and dairy foods needed to help manage body weight. However, consuming the recommended three servings of low-fat and/or fat-free dairy foods such as milk, cheese, and yogurt throughout the day can help achieve a higher protein diet which, as shown by research, enhances satiety and may potentially provide weight management benefits. In addition, the increasing availability of foods and beverages incorporating dairy proteins (e.g., whey protein) as ingredients provides another way to increase protein intake to achieve satiety and weight management benefits. **D**

## REFERENCES

1. U.S. Department of Health and Human Services. *The Surgeon General's Call to Action to Prevent and Decrease Overweight and Obesity*. Washington, DC: US Government Printing Office, 2001.
2. The American Dietetic Association. *J. Am. Diet. Assoc.* 109: 330, 2009.
3. Halton, T.L., and F.B. Hu. *J. Am. Coll. Nutr.* 23: 373, 2004.
4. Paddon-Jones, D., E. Westman, R.D. Mattes, et al. *Am. J. Clin. Nutr.* 87(suppl): 1558s, 2008.
5. Soenen, S., and M.S. Westerterp-Plantenga. *Curr. Opin. Clin. Nutr. Metab. Care* 11: 747, 2008.
6. Westerterp-Plantenga, M.S., A. Smeets, and A. Nieuwenhuizen. *Nutr. Bull.* 32(suppl 1): 22, 2007.
7. Westerterp-Plantenga, M.S. *Regul. Pept.* 149(1-3): 67, 2008.
8. Westerterp-Plantenga, M.S., A. Nieuwenhuizen, D. Tome, et al. *Annu. Rev. Nutr.* 29: 21, 2009.
9. Veldhorst, M., M. Smeets, S. Soenen, et al. *Physiol. Behav.* 94: 300, 2008.

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10. NPD Group conducted for Dairy Management, Inc. Satiety and the Consumer. Rosemont, IL: Dairy Management Inc., July 28, 2008.
11. Reid, M., and M. Hetherington. *Neurosci. Biobehav. Rev.* 21: 295, 1997.
12. Institute of Medicine of the National Academies, Food and Nutrition Board. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. Washington, DC: The National Academies Press, 2002, p. 843.
13. Wolfe, R.R. *Am. J. Clin. Nutr.* 87: 1582s, 2008.
14. Bertenshaw, E.J., A. Lluch, and M.R. Yeomans. *Physiol. Behav.* 93: 427, 2008.
15. Anderson, G.H., and S.E. Moore. *J. Nutr.* 134(suppl): 974s, 2004.
16. Smeets, A.J., S. Soenen, N.D. Luscombe-Marsh, et al. *J. Nutr.* 138: 698, 2008.
17. Leidy, H.J., R.D. Mattes, and W.W. Campbell. *Obesity* 15: 1215, 2007.
18. Westerterp-Plantenga, M.S., V. Rolland, S.A. Wilson, et al. *Eur. J. Clin. Nutr.* 53: 495, 1999.
19. Lejeune, M.P., K.R. Westerterp, T.C. Adam, et al. *Am. J. Clin. Nutr.* 83: 89, 2006.
20. Weigle, D.S., P.A. Breen, C.C. Matthys, et al. *Am. J. Clin. Nutr.* 82: 41, 2005.
21. Skov, A.R., S. Toubro, B. Ronn, et al. *Int. J. Obes. Relat. Metab. Disord.* 23: 528, 1999.
22. Leidy, H.J., N.S. Carnell, and R.D. Mattes. *Obesity* 15: 421, 2007.
23. Westerterp-Plantenga, M.S., M.P. Lejeune, I. Nijs, et al. *Int. J. Obes. Relat. Metab. Disord.* 28: 57, 2004.
24. Lejeune, M.P., E.M. Kovacs, and M.S. Westerterp-Plantenga. *Br. J. Nutr.* 93: 281, 2005.
25. Claessens, M., M.A. Van Baak, S. Monsheimer, et al. *Int. J. Obes.* 33: 296, 2009.
26. Potier, M., N. Darcel, and D. Tome. *Curr. Opin. Clin. Nutr. Metab. Care* 12: 54, 2009.
27. Crovetti, R., M. Porrini, A. Santangelo, et al. *Eur. J. Clin. Nutr.* 52: 482, 1998.
28. Bowen, J., M. Noakes, and P. Clifton. *Nutr. Dietetics* 65(suppl 3): 71s, 2008.
29. Hall, W.L., D.J. Millward, S.J. Long, et al. *Br. J. Nutr.* 89: 239, 2003.
30. Veldhorst, M.A.B., A.G. Nieuwenhuizen, A. Hochstenbach-Waelen, et al. *Physiol. Behav.* 96: 675, 2009.
31. Veldhorst, M.A., A.G. Nieuwenhuizen, A. Hochstenbach-Waelen, et al. *Appetite* 52: 388, 2009.
32. Diepvens, K., D. Haberer, and M. Westerterp-Plantenga. *Int. J. Obes.* 32: 510, 2008.
33. Blom, W.A.M., A. Lluch, A. Stafleu, et al. *Am. J. Clin. Nutr.* 83: 211, 2006.
34. Faipoux, R., D. Tome, S. Gougis, et al. *J. Nutr.* 138: 1172, 2008.
35. Dove, E.R., J.M. Hodgson, I.B. Puddey, et al. *Am. J. Clin. Nutr.* 90: 70, 2009.
36. Harper, A., A. James, A. Flint, et al. *Br. J. Nutr.* 97: 579, 2007.
37. Potier, M., G. Fromentin, J. Calvez, et al. *Br. J. Nutr.* 102: 625, 2009.
38. Tsuchiya, A., E. Almiron-Roig, A. Lluch, et al. *J. Am. Diet. Assoc.* 106: 550, 2006.
39. Veldhorst, M.A., A.G. Nieuwenhuizen, A. Hochstenbach-Waelen, et al. *Br. J. Nutr.* 101: 295, 2009.
40. Bowen, J., M. Noakes, C. Trenerry, et al. *J. Clin. Endocrinol. Metab.* 91: 1477, 2006.
41. Bowen, J., M. Noakes, and P.M. Clifton. *J. Clin. Endocrinol. Metab.* 91: 2913, 2006.
42. Luhovyy, B.L., T. Akhavan, and G.H. Anderson. *J. Am. Coll. Nutr.* 26(suppl): 704s, 2007.
43. Bowen, J., M. Noakes, and P.M. Clifton. *Int. J. Obes.* 31: 1696, 2007.

44. Hochstenbach-Waelen, A., M.A.B. Veldhorst, A.G. Nieuwenhuizen, et al. *Am. J. Clin. Nutr.* 89: 831, 2009.
45. Anderson, G.H., S.N. Tecimer, D. Shah, et al. *J. Nutr.* 134: 3011, 2004.
46. Bellissimo, N., M.V. Desantadina, P.B. Pencharz, et al. *Int. J. Obes.* 32: 362, 2008.
47. Lam, S.M.S.C.C., P.J. Moughan, A. Awati, et al. *Physiol. Behav.* 96: 162, 2009.
48. Burton-Freeman, B.M. *Physiol. Behav.* 93: 379, 2008.
49. Boirie, Y., M. Dangin, P. Gachon, et al. *Proc. Natl. Acad. Sci. USA* 94: 14930, 1997.
50. Dangin, M., Y. Boirie, C. Garcia-Rodenas, et al. *Am. J. Physiol. Endocrinol. Metab.* 280: E340, 2001. **D**

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