

UNDERSTANDING FOOD THERMOGENESIS: A NARRATED REVIEW

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ABSTRACT

The thermic effect of food (TEF) is the amount of energy required for the digestion, absorption, and metabolization of the food. Various statements appear in the literature such as diet-induced energy or diet induced thermogenesis (DIT) or simply thermogenesis. The thermic effect of food is also known as the specific dynamic action of food (SAF). In simple terms food thermogenesis refers to heat/energy used during the digestion of food consumed. The thermic effect refers to the energy expenditure that occurs during the digestion, absorption, and metabolism of food. When we consume food, our body needs to expend energy to break-down and process the macro-nutrients, resulting in an increased metabolic rate. The macro-nutrients are the key players of the energy balance, however, to extract energy from it, the complementary nutrients such as minerals and vitamins presence is crucial to perform the tasks. This narrated review paper intends to discuss the thermogenic effect of various sources of food.

KEYWORDS: Food, Macronutrients, Mechanism, Induced, Thermogenesis

INTRODUCTION

Food thermogenesis refers to the heat induced with the consumption food sources also termed as diet induced thermogenesis (Harris et al., 2006). The process of converting food into energy is one of the energy expenditures processes in human or animal body. Energy expenditure is the energy used by the body to perform its routine obligatory functions or spontaneous physical activities (SPA) such as breathing and in addition, to that energy is used by organs to circulate blood to all parts of the body (Levine, 2005).

PROCESS OF ENERGY PRODUCTION

The process of energy production from food itself requires energy. The macronutrients (protein, carbohydrates, and fats) for example, one molecule of glucose requires two molecules adenosine triphosphate (ATP) to produce four molecules of ATPs. All the macronutrients, carbohydrate, protein, and fats provide energy to the body with the use of available energy in the form of ATPs (Leach, 1975). The carbohydrates containing foods such as rice, cereals, breads, pastas, and noodles provide four calories of energy per gram consumed. The carbohydrates ingested in the foods are converted into monosaccharides which are utilised for energy through various mechanisms (Donnelly & Finlay, 2015). The second source of energy other than carbohydrates is fat and it produces nine calories of energy per gram. The main function of fat is to maintain the body temperature and to provide protection to the soft organ of the body (Schutz, 2005). The energy extraction from food sources is elaborated for easy understanding elsewhere (Alberts, et al., 2002). The process is longer than carbohydrates because fat needs to be hydrolysed into smaller forms which are fatty acids and glycerol. The glycerol part is converted into glucose via gluconeogenesis and after that the glucose is used for energy. Theoretically, the longer is the process of metabolism, the higher is the amount of energy needed (Swinburn & Ravussin, 1994). Like carbohydrates, protein also contains four calories per gram. However, protein has more crucial function than supplying energy to the body such as building muscles, replacement/regeneration of dead cells, synthesis of enzymes and hormones etc. The only situation like extreme starvation energy is generated from protein a condition where no carbohydrate and fats are available in the body for energy production (Grover & Ee, 2009). The process of converting protein into energy takes longer time unlike that of carbohydrate and fat which is to break down the protein under digestion into smaller units (amino acids). Amino acid undergo process of removing nitrogen before converted to glucose. For all these steps of producing energy is also required to carry out the process of releasing energy for the body use. The energy expenditure is dependent on gender, body size, body composition, genetics, and activity level of a person. The energy expenditure and energy consumption need to be balanced to have a healthy lifestyle and maintain healthy body weight. As an example, the grown-up man needs more energy than younger individuals due to variable tasks (Levine, 2005).

As mentioned earlier that the energy intake depends on the three macronutrients and to smaller extent from other sources like alcohol. However, it still depends on the net absorption and faecal losses. The absorption depends on the ingredients, food types, preparation of foods, and physiological/intestinal factors (Hall, et al., 2012). Therefore, the recommendation of energy is based on the individual body and lifestyles. Ideally it is best to balance the energy intake and energy expenditure keeping good control on the body weight gain and loss since it is always desired to lose or gain body weight. To reduce weight the energy expenditure is needed to be higher than energy consumed by an individual. The suggestion sound simple to be followed but the fact is that people have difficulty to restrain from food that is not needed by the body (Muller, et al., 2016).

MACRONUTRIENTS AND THERMOGENESIS

Thermogenic effect of food is very small in terms of percentages of the total daily energy expenditure of an individual which is in the order of fat < carbohydrates < protein respectively (Tappy, et al., 1996). However, it may vary due to the factors mentioned earlier specifically it would depend on the amount of carbohydrates, proteins, and fats. Let us consider the macronutrients thermic effect and metabolism. As mentioned earlier that protein has the highest thermic effect among the macronutrients and it require 20-30% of the calories for its digestion and metabolism (Tappy, et al., 1996). Carbohydrates have lower thermic effect compared to protein and typically around 5-10% of the calories for its digestion and metabolism (Tappy, et al., 1996). Dietary fat has the lowest thermic effect and requires usually 0-3% of the calories of the calories for its digestion and metabolism (Tappy, et al., 1996).

From the above discussion it is obvious that food rich in protein contents is higher in its thermogenic effects. Lean meats, skinless poultry, and fish are rich foods sources that have a higher DIT effect. Among the fishes the fatty fishes such as salmon, mackerel, and trout which are not only excellent

sources of quality protein but also contain omega-3 fatty acids, which are excellent for improving metabolism. Eggs are a source of protein and nutrients, contributing to the DIT effect of food. Many of experiments show that high protein diets lead to lower weight gain, lower respiratory exchange ratio, lower carbohydrate oxidation, and higher fat oxidation compared to low-protein diets (Whitehead, 1996, Mikkelsen, 2000, and Lippl 2010). The reason being for this is that when the diet is higher in protein lead to reduced postprandial hunger and desire to eat (Moon & Koh, 2020). This happen possibly by changing hormones for example it has been reported elsewhere that acute ingestion of protein suppresses appetite, decreases ghrelin, and augments cholecystokinin and GLP-1 (Kohanmoo, et al., 2020). The DIT of protein is dependent on the dose and type of protein, for example whey-protein is having higher thermogenesis because of the protein type, its turnover and oxidation (Kassis, 2019). As mentioned before, when diet contain more protein, it will cause more thermogenesis compared to the other macronutrients being the reason that protein synthesis requires ATP or energy. Therefore, the catabolism of amino acid causes an increase in thermogenesis. When there is deamination of amino acids ATP is formed with exception of threonine or serine deamination which results in net ATP formation with exception when serine and threonine are used for the synthesis of glutamine in the tissues. The formation of urea is a thermogenic using ATP as well as producing ATP from the metabolism of fumarate. In certain situations when the other macronutrients are least/not available in the diet then the amino acid are used for glucose synthesis (gluconeogenesis) which is long process and using energy or in other words it induces thermogenesis (Bender, 2012). In short using amino acids utilization for the purpose of energy must pass through several reactions which use energy and therefore it makes the protein to be more thermogenic compared to carbohydrates and fats which needs least amount of energy upon metabolism. The thermogenetic foods are many and can be presented in different groups of foods such as green vegetables, fruits, nuts, meat, and spices/herbs (Bo, et al., 2020). In the following sections we discuss the thermogenic food sources.

FOOD SOURCES AND THERMOGENESIS

Meat is basically complex in structure with connective tissues and fibres which need degradation/breakdown both mechanically/enzymatically in the digestive tract for its absorption and metabolism. This complexity means that the body needs to work harder to break down and absorb the nutrients from meat, leading to increased energy expenditure. While the thermic effect of meat may have some metabolic benefits (weight reduction), it is essential to consume a balanced diet that meets the individual's nutritional needs that aligns to the health goals. Additionally, individual responses to dietary components can vary, so what works best for one person may not be the same for another. It is worth noting that poultry eggs have DIT like other protein in food. The DIT of the individuals depends on metabolic states, the type of foods consumed, the way it is prepared, the composition of the food consumed (Karst, et al., 1984). Poultry can be used as DIT food for health benefits like maintaining body weight, sense of fullness (satiety) and having good, varied food would be the healthiest options (Keogh, & M Clifton, 2020).

Among the various food sources fish is moderately induce DIT the reason being the type of protein and fish-oils (Yamazaki, et al., 2021). Like other protein-rich foods, fish requires the body to expend energy during digestion and metabolism. It's important to note that the thermic effect of fish can vary depending on factors such as the type of fish, preparation method (e.g., grilled, baked, steamed), and the overall composition of the meal in which the fish is consumed. Additionally, the total thermic effect of diet is influenced by the combination of all the foods consumed (Nielsen, et al., 2019).

Dairy products such as yogurt is higher in protein contents and is good source of probiotics, which can enhance metabolism and improve digestive health (Hursel, & Westerterp-Plantenga, 2011). There are several mechanisms by which it might be responsible for the DIT consuming milk protein (Veldhorst, et al., 2008).

Green leafy vegetables are rich sources of fibres, minerals and vitamins which might be promoting DIT (Opazo-Navarrete, 2021). The capsaicin and capsiate found peppers like capsicum or chili peppers increase the metabolism and promote calorie burning which is suggested in the weight management (Ludy et al., 2012). The celery is lower in calories but requires energy to chew and digest, leading to

thermogenesis and good for fat burning (Mohsenpour, et al., 2023). It is an excellent source of Apigenin, hesperidin, luteo-lin, quercetin, and rosmarinic acid are flavonoids (Priecina & Karklina, 2014) and minerals, such as sodium, potassium, magnesium, calcium, vitamins such as beta carotene, vitamin C and higher amounts of fibres (Fazal & Singla, 2012). Sweet Potatoes is a rich source of complex carbohydrates and is an excellent factor for thermogenesis which provide sustained energy release, contributing to thermogenesis (Qin, et al., 2022). The nutrients in sweet potato cause faeces bulk improve blood lipids, insulin sensitivity and gut microflora (Alam, et al., 2016 and Neela & Fanta, 2019). The starch which is often known as resistant starch cause reduction in total cholesterol and LDL cholesterol concentrations (Nichenametla, et al., 2014). Furthermore, it is a rich source of minerals, vitamins (A, B, C), anthocyanin, β -carotene, and fibres (Neela & Fanta, 2019 and Obomeghei, et al., 2020).

Legumes and pulses such as black beans, kidney beans, and chickpeas are high in fibres and protein, also rich in complex carbohydrates thus increasing the DIT and food satiety (Yin, et al., 2022 and Kristensen, et al., 2016).

Several fruits such as berries like blueberries, strawberries, raspberries, and apples contain dietary fibres and antioxidants that can enhance metabolism and improve health with low caloric densities with higher DIT (Abdul Hakim, et al., 2019 and Horgan, et al., 2022).

Certain fat sources like avocado and olive oil are considered healthier rich in monounsaturated fats that can alter metabolism and satiety. In other words, both contain healthy antioxidants that promote metabolic health (Segovia-Siapco, 2021 and Carvajal-Zarrabal, et al., 2014). Dry fruits such as almond, apricot, pine nuts, brazil nuts, chestnut, cashew nut, peanuts, betel nuts, walnuts, hazelnuts, almonds, pistachios figs, raisins, prune, dates, plums, dried coconut, and sunflower, flax, sesame, pumpkin, chia, and poppy seeds are healthy sources of fats and fibre contributing to DIT and satiety (Ros. 2010 and Alasalvar, et al., 2020).

Whole grains such as quinoa and others are DIT foods due to complex composition and the metabolic processes involved in digesting and utilizing it (Karl, et al., 2017). The reason behind this is that these have higher complex carbohydrate contents including starch and dietary fibre. It is reported that whole grain increases the balance of protein in the body which is happening due to increased protein turnover (Mey, et al., 2021).

Spices and herbs such as cinnamon, turmeric, ginger, lemon grass curry leaf and many more contains bioactive compounds which induce thermogenesis and enhance metabolism and improve insulin sensitivity (Viuda-Martos et al., 2011 and Wang, et al., 2023). For example, turmeric contains curcumin, which has anti-inflammatory and metabolic benefits, supporting thermogenesis and ginger contain gingerol known for its potential to increase metabolism and DIT (Zhang, et al., 2021). Ginger is often considered thermogenic due to its natural compounds that can promote heat production and increase metabolism in the body. Ginger contains several bioactive compounds, with the most notable one being gingerol (Mao, et al., 2019). Gingerol is known for its various health benefits, including its potential thermogenic properties (Mansour, et al., 2012). In addition, there are also herbs and spices those are higher in their thermic effect. The hot chillies/peppers and black/white peppers both are having ability to produce heat via sweating while eating the taste of spicy food. This is all because the existence of capsaicin and piperine in the peppers (Nagy, 1999).

Chilies peppers in particular black peppers are DIT spice due to piperine presence in it. It is causing the spiciness and stimulating flavour. It is the active component in it and is also found in less quantity in white and green peppers. It also has capsaicinoids, luteolin, and quercetin (Batiha, et al, 2020). It induces thermogenesis and burns calories therefore reducing body weight (Zheng, et al., 2017). Garlic contain allicin and some other components which are its active and among them allicin is the most prominent one. It is released upon crushing or chopping, and it is responsible for the strange aroma (Bar, et al., 2022). Garlic is DIT spice in the food, it improves metabolism, blood hyperglycaemia/insulin

sensitivity, appetite, weight, fat metabolism, contains antioxidants and reduce oxidative stress (Sunanta, et al., 2023).

Beverages such as green tea, coffee contain caffeine and catechins that can boost metabolism and cause DIT (Stubbs & Whybrow, 2004). Apple cider vinegar help stabilize blood sugar levels and improve insulin sensitivity and affect energy balance (Ousaaid, et al., 2020).

CONCLUSIONS

This review paper explored the thermogenic effect of digesting protein, carbohydrates, and fats. Among the macronutrients protein require higher amount of energy followed by carbohydrates and fats. The thermogenesis of food is depending upon its composition. The higher the protein the more is the thermogenesis. The increase in thermogenesis also occurs due to the complexity of structure and other food components with in it. The other food components such is beverages, spices, and herbs in which there are antioxidants as well as bioactive compounds induce DIT.

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