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REVIEW ARTICLE

Effects of Red Pepper, Ginger, and Turmeric on Energy Metabolism: Review of Current Knowledge

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ABSTRACT

Context • Energy metabolism is the main determinant of obesity etiology. Consumption of some spices, such as red pepper, ginger, and turmeric, can be considered to be an environmental factor affecting energy metabolism.

Objective • This review aimed to examine the effects of red pepper, ginger, and turmeric on weight control, weight loss, and energy metabolism.

Design • The research team performed a narrative review by searching the Google scholar, Scopus, PubMed, ResearchGate, Web of Science, and Science Direct databases. The search used the keywords red pepper, ginger, and turmeric in combination with energy metabolism, energy expenditure, energy balance, thermogenesis, anti-obesity, weight management, weight control, weight loss, metabolic rate, and oxygen consumption, without considering any time limitation.

Setting • This study has been carried out in Ankara / Turkey.

Results • Red pepper, ginger, and turmeric affect energy metabolism through various mechanisms. Dietary red pepper and its pungent principle capsaicin affects satiety and has a promising thermogenic influence. Ginger has positive effects on weight control, obesity prevention, and energy metabolism. In addition, curcumin inhibits the conversion of preadipocytes to mature adipocytes.

Conclusions • Red pepper, ginger, and turmeric affect energy metabolism using mechanisms related to thermal effect, BMR, total energy expenditure, oxygen consumption, and lipid oxidation. These spices haven't been assigned appropriate doses and periods of use, and no definite judgments can be made on their use. Therefore, it's necessary to conduct further randomized controlled research to reach absolute conclusions and determine by which mechanisms these spices show this effect on energy metabolism. (*Altern Ther Health Med.* [E-pub ahead of print.])

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Energy metabolism is the main determinant of obesity etiology.[1] Numerous factors—including body composition, types of foods, and many other individual and environmental factors—affect energy metabolism.[2-4] Consumption of some spices such as red pepper, ginger, and turmeric can be considered to be an environmental factor.[5,6]

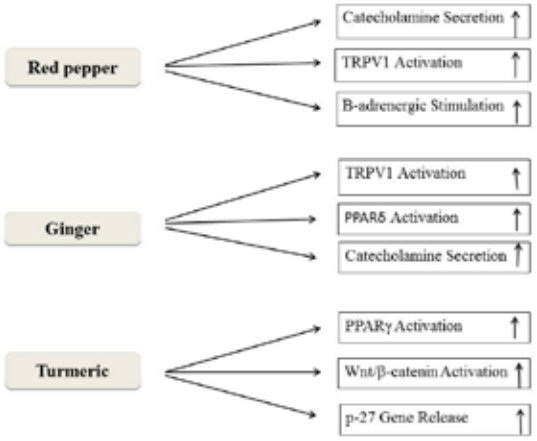
These spices have effects on energy metabolism through different active substances[7,8] and have been used for centuries for therapeutic purposes.[9] In addition to traditional applications, theses spices have modern uses that have been studied extensively in recent years.[10-15] They are known to have protecive effects against many diseases due to their strong anti-inflammatory and antioxidant effects.

Red pepper, which is obtained by drying and grinding a cabbage belonging to *Capsicum annuum L.* from the Solanaceae family, is a spice used to give flavor and bitter taste.[16] A number of studies have reported positive effects for capsaicin, which has shown anti-obesity, antidiabetic, and anticarcinogenic properties.[7,17,18] Red pepper is known to be a good source of vitamins C and E as well as provitamin A, and carotenoid compounds have been found to have strong antioxidant effects.[19,20]

Ginger (*Zingiber officinale*) belongs to the family Zingiberaceae and is one of the most commonly used herbal treatments in traditional Iranian medicine.[21] Isogingerol, isoshogaol, gingerdiones, 3-dihydroshogols, dihydroparadols, acetyl gingerols, gingerdiols, mono- and di-acetyl gingerdiols, dehydrogingerdiones, diarylheptanoids, beta-sesquiphellandrene, beta-bisabolene, ar-curcumene, and

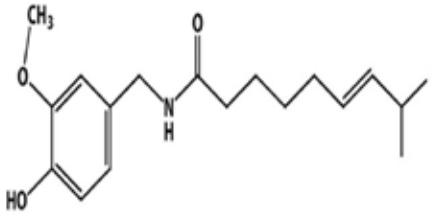
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Figure 1. Basic Mechanisms Related to the Energy Metabolism of Red Pepper, Ginger, and Turmeric



Abbreviations: TRPV1, transient receptor potential vanilloid 1; PPAR δ, peroxisome proliferator-activated receptor delta; PPARγ, peroxisome proliferator-activated receptor gamma; WNT/β, wingless-related integration site/beta.

Figure 2. Chemical Structure of Capsaicin



diarylheptanoids are important bioactive compounds in the ginger structure.[22-24] These compounds are widely used for many health problems due to their anticarcinogenic, anti-obesity, antithrombotic, anti-emetic, anti-inflammatory, antidiabetic and antihyperlipidemic features.[24-29]

Turmeric has an importance place in the cuisines of Iran, Malaysia, India, China, Polynesia, and Thailand. It's often used as a spice and has an effect on the nature, color, and taste of foods.[13] Turmeric is derived from the roots of the Curcuma longa plant, a member of the Zingaberaceae family.[30] Turmeric, the main component of curcuminoides—curcumin, demethoxycurcumin, and bisdemethoxycurcumin—is used topically, orally, and by inhalation for the treatment of various diseases, such as obesity, cancer, diabetes mellitus, and neurodegenerative and cardiovascular diseases.[13,31] In addition to its therapeutic use, it's also used to dye silk fabrics and thin leather and to add flavor to various dishes.[32]

This review aimed to examine the effects of red pepper, ginger, and turmeric on weight control, weight loss, and energy metabolism.

METHODS

Procedures

This study has been carried out in Ankara / Turkey. The research team performed a narrative review by searching the Google scholar, Scopus, PubMed, ResearchGate, Web of Science, and Science Direct databases. The search used the keywords red pepper, ginger, and turmeric in combination with energy metabolism, energy expenditure, energy balance, thermogenesis, anti-obesity, weight management, weight control, weight loss, metabolic rate, and oxygen consumption, without considering any time limitation.

This review includes research and review articles published in the English language ,with a focus on the potential effects of these spices and their active compounds. It focuses on the effects of these spices on energy metabolism.

To assure the validity of the data, the research team reviewed all the information based on citation and language. Studies trials investigating the effects of red pepper, ginger, and turmeric on energy metabolism separately, without being in any other combination, were included in the study. Titles and abstracts of the studies were evaluated primarily. After evaluation, researchers found whole texts of selected articles in order to examine.

RESULTS

Red pepper, ginger, and turmeric affect energy metabolism through various mechanisms. Figure 1 shows the basic mechanisms.

Effects of Red Pepper

Red pepper has a bitter taste in capsinoids, and capsaicin is the major pungent component. It's responsible for about 70% of the burn of hot red peppers, followed by dihydrocapsaicin and nordihydrocapsaicin.[5,33] Approximately 3 mg of capsaicinoids are present within one g of dried red pepper.[34]

Capsaicin's molecule structure contains a branched fatty acid linked to a vanillic core (Figure 2).[35] Many studies have examined the effects of red pepper on energy metabolism.[5,7,36] Some studies have reported that capsaicin activates the sympathetic nervous system and increases blood pressure due to an increase in catecholamine secretion,[7,37] and increases thermic efficacy as a result of beta (β)-adrenergic stimulation.[38]

Another possible effect of capsaicin is promotion of thermogenesis by stimulating transient receptor potential vanilloid 1 (TRPV1).[35] This mechanism is consistent with the capsinoids activate the sympathetic nervous system through the gastrointestinal transient TRPV1 channel. Because capsaicin activates a central signal through vagal nerves that is subsequently transmitted to inguinal white adipose tissue (WAT) depots by the beta-2 (β2)-adrenoceptor.[39,40] Triggered sympathetic nervous system produces a signaling cascade involving protein kinase A (PKA) and p38 mitogen activated protein kinase (MAPK), which results in the expression of uncoupling protein 1 (Ucp1) and other key transcription

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factors involved in the activation of thermogenesis.[39,40] One study found that the transcription involves browning-related genes—such as Ucp1, peroxisome proliferator-activated receptor gamma (γ) coactivator 1 alpha (PPARGC1α), T-box transcription factor 1 (Tbx1), and PR domain containing 16 (Prdm16)—that were upregulated by chronic capsaicin treatment on differentiated 3T3-L1 cells.[40]

Studies have also reported that intake of capsaicin and capsinoid suppresses energy intake by suppressing appetite.[41,42] Capsaicin and capinoids affect energy metabolism using different mechanisms of action. Capsaicin, due to its pungency and thus its additional effects on nociceptors, causes a greater increase in heart rate and blood pressure shortly after ingestion than capsinoids.[43-45] Most studies examing capsaicin's effects have focused on its reinforcement of energy metabolism. Therefore, further studies are needed to assess the effects of red pepper consumption on energy metabolism.

Ahuja et al's study on human volunteers evaluated the effects of 30 g/day of supplementation with red pepper in a chili-containing diet on the energy-expenditure level, insulin secretion, C-peptide/insulin ratio, and blood glucose levels.[18] The highest concentrations of insulin were found in the group eating a bland diet (BAB) and the lowest in the group eating the chili-containing diet (CAC). Conversely, the C-peptide/insulin quotient was found to be higher in the CAC group than in the BAB group ($P=.002$). In addition, the researchers reported that ingesting red pepper regularly for 4 weeks decreased activation of the sympathetic nervous system and thermogenesis by decreasing postprandial hyperinsulinemia.

A Canadian study found that red-pepper consumption increased heart rate and increased energy expenditure at rest by increasing sympathetic nervous system activation.[46] Moreover, Janssens et al evaluated the oxygen consumption, blood pressure, body composition, energy intake, and nutrient choices by giving 7.68 mg/day of capsaicin to 15 healthy individuals.[7] Seven females and 8 males, aged between 18 and 50 years and with a body mass index (BMI) between 20 and 30, calculated as kg/m^2, were recruited for this study. The study concluded postintervention that the consumption of capsaicin can increase energy expenditure by increasing the diet-induced thermogenesis and basal metabolic rate (BMR), without changing food intake.

The literature also reveals that capsaicin has an indirect effect on energy metabolism by affecting lipid metabolism as well as enhancing thermogenesis.[18,47] Capsaicin, the active compound of red pepper, has been reported to increase energy expenditure by increasing the thermal effect of brown fat tissue through lipid oxidation and actions of the sympathetic nervous system.[7,33,48]

In addition, Josse and colleagues[43] gave individuals 10 mg of capsaicin, with its intake resulting in increased levels of plasma epinephrine and norepinephrine and increased oxygen consumption, thereby increasing BMR and lipid oxidation. Fan et al evaluated the effects of a combination of capsaicin and capsiate on the induction of browning in white adipose tissue and determined that capsaicin increased protein levels of peroxisome proliferator-activated receptor gamma (PPARγ) and beta3 (β3)-adrenergic receptor (β3-AR).[49] These results indicated that a combination of capsaicin and capsiate could induce browning in white adipocytes via activation of the PPARγ/β3-AR signaling pathway.

In Kawabata et al's study, the diet of the intervention group was supplemented with 0.4 g/kg/day of red pepper for 2 weeks.[50] Postintervention, the study found that the intervention group had significantly greater weight loss, sympathetic-nervous-system activity, and oxygen-consumption rates at rest compared to the control group. Another study found that the consumption of capsaicin triggers the conversion of WAT to brown fat tissue by stimulating TRPV1.[51]

Dietary red pepper and its pungent principle capsaicin affects satiety and has a promising thermogenic influence that could play an important role in the prevalence and severity of obesity.[52] Although some studies have focused more on the effects of capsaicin supplementation on thermogenesis,[49,51,53-55] other studies have shown that consumption of red pepper in the diet may have effects on thermogenesis and energy metabolism similar to capsaicin.[18,56-58] Three studies[49-51] seem to indicate that the thermal efficiency of red pepper and capsaicin can increase the BMR and total energy expenditure. However, it's necessary to determine the appropriate dose and duration to be routinely administered. Also, it should be remembered that taking capsaicin supplement without the control of a doctor may pose health risks.

Effects of Ginger

Ginger, with its many bioactive compounds, has different effects on energy metabolism.[6,59] Figure 3 shows these compounds.[8] Ginger's major bioactive compounds are 6-shogaol, 6-gingerol, and zinger, and 6-gingerol is the strongest isolated compound for ginger.[8]

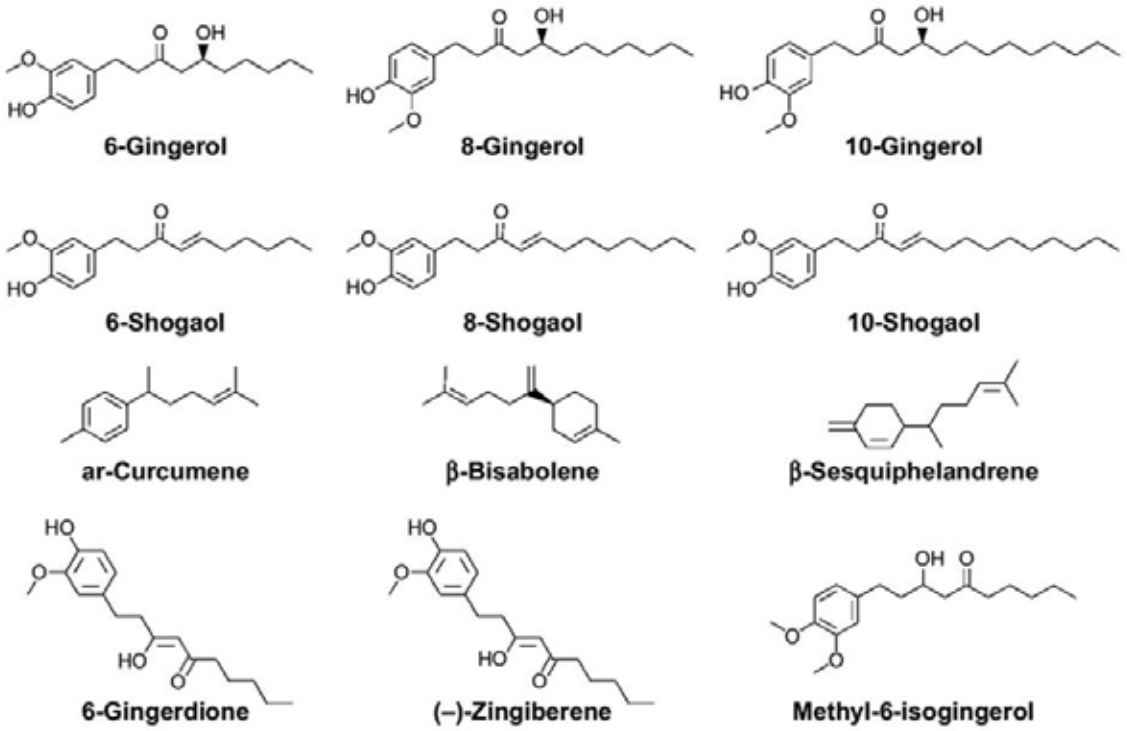
These compounds have different effects on energy metabolism. For example, gingerol and shagaol increase thermogenesis by activating TRPV1 and increasing epinephrine secretion.[6] In addition, gingerol inhibits the conversion of preadipocyte cells into mature adipocytes by inhibiting adipocyte differentiation. Tzeng and Liu have reported that the suppression of this transformation by the gingerol compound can increase the thermogenic activity of cells.[59]

Another possible mechanism is to stimulate lipid oxidation by stimulating peroxisome proliferator-activated receptor delta (PPARδ), the basic regulator of energy metabolism in the skeletal and adipose tissue of 6-shogaol.[8] Many studies have examined these basic mechanisms of ginger and also have evaluated the effects of ginger and bioactive compounds on energy metabolism.[8,60,61]

Misawa et al investigated the effects of ginger extract on energy metabolism in mice that recieived a high-fat diet and

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Figure 3. The Chemical Structures of 6-Gingerol, 8-Gingerol, 10-Gingerol, 8-Shogaol, 10-Shogaol, Ar-Curcumene, Beta (β)-Bisabolene, Beta (β)-Sesquiphelandrene, Beta (β)-Gingerdione, (-)-Zingiberene, and Methyl-6-Isoginerol.



found that the mice receiving a 0.3% ginger extract in their diet had higher oxygen consumption and a higher lipid-oxidation rate than the control group's.[8] In addition, Tzeng et al[59] examined the effects of a gingerol compound on 3T3-L1 preadipocytes and found that the gingerol compound suppressed the conversion of those preadipocyte cells to mature adipocytes by PPARδ activation and that this mechanism increased thermogenesis.

Wang et al's study found that the modulation of the gut microbiota as a result of ginger supplementation had a therapeutic effect on obesity in mice.[61] Another study conducted with high-fat-diet-induced obese mice found that ginger can prevent obesity through regulation of energy metabolism and activation of browning.[62]

Another study showed that ginger water had positive effects on weight control, obesity prevention, and energy metabolism through stimulation of lipolytic pathways and downregulation of lipogenic pathways.[63] Table 1 summarizes the human studies examining the effects of ginger on weight control, obesity prevention, and energy metabolism in the literature.[64-69] These studies suggest that ginger use in weight-loss diets may have an adjunctive effect.

Effects of Turmeric

Since the discovery of the presence of naturally occurring phenolic compounds and cucuminoids in turmeric's structure, the number of studies investigating the health effects of turmeric has increased.[70] Although the mechanisms of action on energy metabolism of high amounts of curcumin, a phenolic component of turmeric, aren't fully clear yet, different possible mechanisms may be responsible for its effects. One possible mechanism is that an uptake of curcumin increases p27 gene release, which suppresses the conversion of preadipocytes to mature adipocytes.[71] Other possible mechanisms include suppressing the conversion of preadipocytes to mature adipocytes and increasing resting energy expenditure by activating PPARγ and inhibiting wingless-related integration site/beta (Wnt/β)-catenin signal activation and lipid oxidation.[71-73] In a study on 3T3-L1 preadipocyte cells, curcumin suppressed of the conversion of preadipocyte cells to mature adipocytes by increasing the accumulation of the p27 gene.[71]

Other studies have reported that curcumin supplementation inhibits adipocyte differentiation by activating the Wnt/β-catenin signal.[74-76] Another study showed that administration of curcumin to 3T3-L1 preadipocyte cells suppressed adipocyte differentiation by stimulating AMP-activated kinase (AMPK) activation.[77] In studies evaluating the effects of curcumin on energy metabolism, curcumin was found to inhibit the conversion of preadipocytes to mature adipocytes.[71,74-76]

Table 2 summarizes the human studies examining the effects of ginger on weight control and energy metabolism in the literature.[78-84]

More human studies are needed to make sound definitive judgments about the effects of turmeric on energy metabolism.

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Table 1. Review of Human Studies Examining the Effects of Ginger Powder and Extracts on Weight Control and Energy Metabolism

Study	Intervention/ Control Participants (n)	Duration	Study Design	Conclusions
Attari et al, 2015[64]	39/31 Obese women	12 weeks	Participants were randomly assigned to receive either 2 g of ginger rhizomes powder as 2 one-g tablets per day or a placebo.	Ginger supplementation reduced body weight, BMI, WC and HC as compared to placebo ($P < .05$). However, no significant difference existed in the changes in total energy and macronutrient intake between the groups.
Attari et al, 2016[65]	39/31 Obese women	12 weeks	Participants were randomly assigned to receive either 2 g/day of ginger powder or a placebo	Ginger consumption significantly decreased BMI ($P < .05$). The study demonstrated a beneficial effect on weight loss for supplementation with 2 g of ginger powder for 12 weeks.
Taghizadeh et al, 2017[66]	25/25 Overweight women	8 weeks	Intervention group received dietary supplements containing 125 mg green tea, 25 mg capsaicin, and 50 mg ginger extracts twice with lunch and twice with dinner daily.	Compared with placebo, taking the dietary supplements resulted in a significant decrease in weight and body mass index ($P < .001$).
Atashak et al, 2014[67]	8/8 Obese men	10 weeks	Ginger group consumed one g of ginger/day. At baseline and after 10 weeks, body composition and anthropometric indices were measured.	No change occurred in body weight in the group receiving ginger supplements.
Miyamoto et al, 2015[68]	23 Healthy male	24 hours	The effects of ginger supplementation on thermoregulation were evaluated by giving one g of dried ginger root powder orally in the morning and afternoon.	The study found that the effect of a single oral-ginger administration on the peripheral and central thermoregulatory function was miniscule.
Mansour et al, 2012[69]	10 Overweight men	6 hours	Participants' resting-state energy expenditures were measured using indirect calorimetry and for 6 h after consumption of a breakfast meal, with or without 2 g of ginger powder dissolved in a hot-water beverage.	The study found a significant effect for ginger on the thermic effects of food, showing enhanced thermogenesis and reduced feelings of hunger with ginger consumption and suggesting a potential role for ginger in weight management.

Abbreviations: BMI, body mass index; WC, waist circumference; HC, hip circumference.

Table 2. Review of Human Studies Examining the Effects of Curcumin Supplementation on Weight Control and Energy Metabolism

Study	Intervention/ Placebo Participants (n)	Duration	Study Design	Conclusions
Mohammadi et al, 2013[78]	15/15 Obese participants	30 days	Participants were randomly assigned to one of 2 treatments; the intervention group was provided with one g of curcuminoids per day and the control group received a placebo.	Weight, BMI, WC, HC, arm circumference, and body fat remained statistically unchanged postintervention ($P > .05$).
Campbell et al, 2017[79]	11/11 Obese men	12 weeks	Obese individuals were randomly assigned either to a placebo or a curcumin group that received 500 mg/day of the intervention.	No difference existed between the groups in terms of BMI, WC, hip circumference, or body fat ($P > .05$).
Saraf-Bank et al, 2019[80]	30/30 Overweight or obese adolescents	10 weeks	The adolescents consumed one 500 mg tablet per day containing either standardized 95% turmeric extract or a placebo.	Curcumin supplementation significantly reduced BMI, WC, and HC in the intervention group ($P < .05$).
Esmaily et al, 2015[81]	15/15 Obese participants	30 days	Thirty obese participants were randomly assigned to receive either one g/day of curcumin or a placebo, for a period of 30 days.	Anthropometric variables did not change significantly ($P > .05$).
Saadati et al, 2019[82]	25/25 Non-alcoholic fatty liver disease	12 weeks	Participants received either 500 mg of curcumin 3 times a day or a matched placebo.	Within both groups, weight, BMI, WC, and daily energy intake decreased significantly, while no significant differences existed between the groups ($P > .05$).
Rahmani et al, 2016[83]	40/40 Non-alcoholic fatty liver disease	8 weeks	Eligible individuals were randomly assigned to receive either 500 mg/day of curcumin in an amorphous dispersion preparation comprising 70 mg of curcuminoids or a placebo.	Curcumin supplementation significantly decreased BMI and weight ($P < .05$).
Mohammadi et al, 2017[84]	40/40 Metabolic syndrome	6 weeks	Participants were randomly assigned to receive 200 mg of pure curcumin per day or a placebo.	No difference existed between the groups in terms of weight, BMI, or WC ($P > .05$).

Abbreviations: BMI, body mass index; WC, waist circumference; HC, hip circumference.

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Reliable Dosage and Toxicity

For use in foods, *Capsicum annuum L.* and its derivatives are on the generally regarded as safe (GRAS) list.[34] However, it has been reported that the use of capsaicin of up to 33 mg/day for 4 weeks or up to 4 mg/day for 12 weeks can produce responses such as digestive problems, increased insulin levels, and decreased high density lipoprotein (HDL) levels.[85]

Studies carried out in Thailand and India have indicated the populations' use of up to 5 grams of Capsicum annuum per person per day. In the USA, consumption of pepper per person in 2017 was 0.19 kg/year, and it was 0.15, 0.18, and 0.04 kg/year in Canada, the Netherlands, and Italy, respectively.[86]

In Deshpande et al's study, 12 healthy obese individuals were given 2, 4, 6, 8, and 10 mg/day of a capsaicin supplement for 6 weeks; no toxic effects were observed postintervention.[34] Long-term consumption of turmeric in high doses may cause gastrointestinal problems.[85] However, no toxic effects are known for curcumin, which is generally considered to be safe by the FDA.

According to reports by the Joint Expert Committee on Food Additives (JECFA) of the Food and Agriculture Organization (FAO) of the United Nations and the World Health Organization (WHO), the daily safe intake (ADI) amount of curcumin is 0-3 mg/kg.[87] Morever, it has been reported that use of curcumin of up to 12 g/day doesn't have any harmful effects on humans.[88]

The FDA has stated that the consumption of ginger as defined on the GRAS list is reliable.[89] Sharifi-Rad have reported that uptake of ginger metabolites—6-, 8-, and 10-gingerols and 6-shogaols—of up to 200 mg/day by healthy individuals isn't toxic.[90] The intake of ginger from 500 mg/day to 1000 mg/day by the oral route has rarely had adverse health effects. Some studies have proposed that the adverse effects that do occur are often accompanied by gastrointestinal problems.[90-92]

CONCLUSIONS

Red pepper, ginger, and turmeric affect energy metabolism using mechanisms related to thermal effect, BMR, total energy expenditure, oxygen consumption, and lipid oxidation. Because of these effects, red pepper, ginger, and turmeric can be used as adjunct treatments in weight-loss diets during medical nutritional therapy. It's very difficult for these spices to reach toxic doses because of their intake in foods or in the form of spices. Therefore, medical practitioners should consider use of these spices in patients' daily diets but remember that these spices and their bioactive compounds as supplements at high doses can cause toxic effects. However, due to the fact that these spices haven't been assigned appropriate doses and periods of use, no definite judgments can be made on their use. Therefore, it's necessary to conduct further randomized controlled research to reach absolute conclusions and determine by which mechanisms these spices show this effect on energy metabolism.

CONFLICTS OF INTEREST

The authors have no conflicts of interest. No external funds supported this work.

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