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The Role of Dietary Ingredients in Mental Energy – A Scoping Review of Randomized Controlled Trials

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ABSTRACT

Low mental energy can contribute to decreased productivity, altered life balance, decreased physical performance, and ultimately affect quality of life. As such, there is a great demand for food and beverage products that positively impact mental energy. Numerous products claim to alter mental energy making continued review of the scientific evidence critical. The objective of this study was to conduct a scoping review of randomized controlled trials to evaluate the effect of 18 dietary ingredients on mental energy outcomes in adults without severe disease. Methods: A literature search, completed using PubMed, resulted in the identification of 2261 articles, 190 of which met eligibility from initial abstract review. Full-text review was completed on the 190 studies which resulted in 101 articles that fully met eligibility for inclusion in this study. The search strategy for two ingredients did not yield any eligible studies, leaving studies for 16 ingredients that were extracted and summarized by reported significantly improved outcomes for cognition, mood and perceived feelings, and sleep assessments. The preliminary results for several dietary ingredients directionally suggested a mental energy benefit (≥20% of outcomes), including ashwagandha, chamomile, dark chocolate, ginseng, green tea, lavender, lion's mane mushroom, maca, tart cherries, turmeric, and valerian root. The results of this scoping review suggest that of the 16 dietary ingredients reviewed, 11 may be promising for further exploration on their potential benefits in supporting mental energy. Given consumer demand and market growth for food and beverage products that positively impact mental energy; continued efforts in assessment method alignment and additional evaluation in well-designed trials is warranted.

KEY TEACHING POINTS

- Of the 16 dietary ingredients reviewed, 11 (ashwagandha, chamomile, dark chocolate, ginseng, green tea, lavender, lion's mane mushroom, maca, melatonin foods, turmeric, and valerian root) may be promising for further exploration on their potential mental energy benefits.
- Dark chocolate, ginseng, ashwagandha, and lion's mane mushroom were the most promising ingredients for further evaluation in the cognition domain of the ingredients evaluated.
- Turmeric, maca, lavendar, and ashwagandha were the most promising ingredients for further evaluation in the mood and perceived feelings domain of the ingredients evaluated.
- Ashwagandha, chamomile, green tea, melatonin foods, valerian root were the most promising ingredients for further evaluation in the sleep domain of the ingredients evaluated.
- Additional, well-designed, consistent, clinical trials and systematic reviews are warranted as the challenge of heterogeneity in mental energy study design remains.

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Mental energy; cognition; sleep; mood; perceived feelings; fatigue; focus; dietary ingredients

Introduction

A definition and model of mental energy have been developed by the International Life Sciences Committee (ILSI) (1–3). Mental energy was defined as "the ability to perform mental tasks, the intensity of feelings of energy and fatigue, and the motivation to accomplish mental and physical tasks". According to the ILSI committee, mental energy encompasses three dimensions cognition, the mood of energy, and motivation, and assessment tools for these constructs have been previously reviewed (4–6). A number of methods exist that are reportedly linked to positive impacts on mental energy including physical activity, mindfulness and meditation, cognitive behavioral therapy, and improving sleep quality (7–13). The addition of mental energy enhancing ingredients in foods and beverages have resulted in numerous consumer products that claim to positively impact mental energy in a rapidly growing market (14).

Feelings of persistent reduced mental energy is a regular occurrence among individuals worldwide (15). This "lack

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of energy" prevalence is common with studies suggesting ~30% and affecting younger working adults, older individuals, and particularly women the most (16, 17). Low mental energy can contribute to decreased personal and professional productivity, altered life balance, decreased physical performance, and ultimately effect quality of life (1, 18, 19). In addition to the individual burden, the economic burden in the United States of lost productivity as a result of fatigue are costly and highlights the need for methods to address mental energy to support overall wellness (20).

Given the rapid expansion and expected growth of this market and the need for evidenced-based product development, the purpose of this review was to assess the scientific evidence on specific dietary ingredients and their effects on mental energy. A literature search strategy was developed and implemented for 18 ingredients identified from consumer research with perceived benefits on mental energy by consumers. The potential bioactive compounds and mechanisms of action in mental energy are summarized in Table 1. Given the heterogeneity of the identified randomized controlled trials (RCT), the data was summarized providing a

Table 1. Potential mode of action in mental energy for the dietary ingredients evaluated.

Ingredient	Biological classification	Potential active ingredient(s)	Potential modes of action	Reference(s) for review
Ashwagandha	*Withania somnifera*	• Withaferin A • Sitoindosides • Withanosides	• Anti-inflammatory • Cyclooxygenase-2 and α2-macroglobulin inhibition • Brain-derived neurotrophic factor exacerbation	Ng et al. (21)
Blueberries	*Vaccinium Cyanococcus*	• Anthocyanidins • Flavanols • Flavonols	• Inducible NO synthase downregulation • Cyclooxygenase-2 downregulation • Inhibit cytokine release • Reactive oxygen species downregulation • Tumor necrosis factor α downregulation	Hein et al. (22) Spencer (23) Henriques et al. (24)
Chamomile	*Matricaria chamomilla*	• Flavonoids • Apigenin	• GABA-A receptor activation	Avallone et al. (25) Srivastava et al. (26)
Citrus	*Citrus*	• Auraptene • Flavonoids	• Anti-inflammatory • Reduce oxidative stress • Neuroprotection	Galluzzi et al. (27) Matsuzaki et al. (28)
Cordyceps mushroom	*Cordyceps*	• Cordycepin	• Brain-derived neurotrophic factor increase • Tropomyosin receptor B increase	Cai et al. (29)
Dark chocolate	*Theobroma cacao*	• Flavonoids • Methylxanthines	• Nitric oxide increase • Brain-derived neurotrophic factor increase • Adenosine receptor inhibition	Yoneda et al. (30) Katz et al. (31) Smit et al. (32)
Ginseng[2]	*Panax*	• Ginsenosides	• Reduce catecholamine secretion • Neuroprotection • Reduce oxidative stress • Anti-inflammatory • Neurogenesis and plasticity enhancement	Lee et al. (33) Feng et al. (34)
Green tea	*Camellia sinensis*	• Catechins • Theanine	• Reduce oxidative stress • Neuroprotection • Monoaminergic pathway regulation	Schmidt et al. (35) Afzal et al. (36) Rao et al. (37)
Guarana	*Paullinia cupana*	• Methylxanthines • Flavonoids • Anthocyanidins	• Neuroprotection • Reduce oxidative stress	Torres et al. (38)
Lavender[3]	*Lavandula*	• Terpenes • Flavonoids	• NMDA receptor antagonism • Serotonin transporter inhibition	Lopez et al. (39)
Licorice root	*Glycyrrhiza glabra*	• Glycyrrhizins • Flavonoids	• T/B cell proliferation • Neuroprotection	Jiang et al. (40) Cho et al. (41)
Lion's mane mushroom	*Hericium erinaceus*	• Hericenones • Erinacines	• Increased nerve growth factor synthesis • Neuroprotection	Kawagishi et al. (42) Ma et al. (43)
Maca	*Lepidium meyenii*	• Alkaloids • Isothiocynates • Glucosinolates • Polysaccharides	• Improve mitochondrial function • Upregulate autophagy proteins • Reduce oxidative stress • Neuroprotection	Guo et al. (44) Zha et al. (45) Pino-Figueroa et al. (46)
Melatonin foods	Various	• Melatonin	• Reduce oxidative stress • Anti-inflammatory • Improve mitochondrial function • Circadian regulation	Salehi et al. (47) Meng et al. (48)
Mint	*Mentha*	• Polyphenols	• Reduce oxidative stress • Anti-inflammatory • Anticholinesterase activity	Fallarini et al. (49) Mushtaq et al. (50) Rocha et al. (51)
Reishi mushroom	*Ganoderma*	• Terpenes • Polysaccharides	• Reduce oxidative stress • Neuroprotection	Lee et al. (52) Huang et al. (53)
Turmeric	*Curcuma longa*	• Polyphenols • Curcuminoids	• Reduce oxidative stress • Anti-inflammatory • Improve mitochondrial function • Anticholinesterase activity • Monoaminergic pathway regulation • Brain-derived neurotrophic factor increase	D'Cunha et al. (54) Ak et al. (55) Lopresti et al. (56)
Valerian root	*Valeriana officinalis*	• Valerenic acid • Valepotriates • Sesquiterpenes	• GABA receptor antagonism • Serotonin receptor agonist	Yuan et al. (57) Dietz et al. (58) Diaper et al. (59)

GABA: gamma-aminobutyric acid; NO: nitric oxide; NMDA: N-methyl-D-aspartate.

Table 2. Search term strategy and records result summary.

Ingredient	Ingredient search terms[a]	Mental energy terms	Records screened (n)	Full-text articles assessed (n)	Full-text articles included (n)
Ashwagandha	*Withania somnifera*, ashwagandha, Indian ginseng, poison gooseberry, winter cherry	brain, cognition, cognitive, fatigue, motivation, mood, affect, energy, vigor, memory, speed, attention, anxiety, calm, vigilance, enthusiasm, determination, sustained attention, mental energy, cognitive performance, mental performance, alert, mental fatigue, sleepiness, tired	16	7	5
Blueberries	blueberry, cyanococcus		57	4	4
Chamomile	chamomile, chamomilla, recutita, camomile, chamaemelum, anthemis, matricaria		33	4	2
Citrus	orange, citrus, citrus, fruit, citrus sinensis		351	18	8
Cordyceps mushroom	caterpillar fungus, caterpillar mushroom, champignon chenille, cordyceps sinensis, cordyceps		9	1	0
Dark chocolate	dark chocolate, cacao, cocoa, cocoa extract, cocoa flavanol, theobromine, theobroma cacao		617	27	16
Ginseng[b]	ginseng, panax, ginsenoside		167	29	13
Green tea	green tea, theanine, catechin, matcha, epigallocatechin gallate, EGCG, camellia sinensis		429	23	13
Guarana	guarana, paullinia cupana		24	13	3
Lavender[c]	lavender, lavandula, silexan		76	7	4
Licorice root	licorice, glycyrrhiza glabra, licorice		46	0	0
Lion's mane mushroom	lion's mane mushroom, hericium erinaceus, hou tou gu, yamabushitake		3	3	3
Maca	maca, lepidium meyenii		15	3	2
Melatonin foods	tart cherry, goji berry, walnut, berry, nut, pistachio, almonds, grain, corn, pineapple, tomato, banana, orange, ginger root, mustard seed, corn, rice, bean, food AND melatonin		45	7	5
Mint	mint, spearmint, mentha		106	14	6
Reishi mushroom	reishi, lingzhi, ganoderma lingzhi, ganoderma lucidum		15	3	1
Turmeric	turmeric, curcumin, curcuma, curcuma domestica, curcuma longa, curcuminoids		212	11	7
Valerian root	valeriana, valeriana officinalis, valerian root, valerian, baldrian		40	16	9

[a]Each group of ingredient terms was combined with the mental energy terms for the PubMed database literature search (see also Supplemental Material).
[b]The term "Indian ginseng" was excluded from this search.
[c]The terms "inhale" and "aroma" were excluded from this search.

scoping state of the science regarding dietary ingredients and mental energy but also highlighting the need for both consistency in methodology and continued research.

Methods

This scoping review was conducted in alignment with the field of nutrition (60–63). A review strategy was developed and refined by all investigators prior to implementing the search and reviewing the records returned. A list of 18 ingredients (Table 2) was identified based on findings from consumer research that examined perceptions of mental energy benefits associated with food ingredients. Caffeine, gingko biloba, and omega-3 fatty acids were also identified from the consumer research findings but were not included in the study because regulatory bodies have previously assessed this scientific evidence (1, 64–68).

Literature search

The scoping literature search was conducted up to February 9, 2021, using the PubMed database for relevant studies. The search term strategy included combinations of the ingredient terms with mental energy terms described in Table 2 (see also Supplemental Material) and developed using published reviews on each ingredient. Human, randomized controlled trials, and best match filters were applied during the PubMed search. The identification of studies eligible for review was performed by scanning titles and abstracts using Abstrackr (69).

Table 3. PICOS table for inclusion of studies.

Parameter	Criteria
Population (P)	Healthy and non-healthy adults (male and female), ≥ 18 years of age, and without any diagnosis of severe disease except for diabetes and metabolic dysfunction (e.g., cancer, autoimmune disease, neurologic disorders, major mental illness)
Intervention (I)	Dietary intervention studies which included an ingredient as the intervention, not solely measured as part of a dietary pattern or administered *via* ingestion
Comparison (C)	Placebo or no intervention
Outcome (O)	A mental energy related outcome[a]
Study design (S)	Randomized controlled trials

[a]Refer to Table 1 for mental energy terms included in the search term strategy.

Study eligibility criteria

Potentially relevant studies were exported from Abstrackr and full-text articles were obtained. The review included RCT published in English that evaluated the effects of dietary ingredients on mental energy outcomes. Animals and topical terms were excluded and no restrictions on publication date were imposed. The population of interest included apparently healthy and non-healthy adults, ≥18 years of age, and without any diagnosis of severe disease (e.g., cancer, autoimmune diseases, neurologic disorders, major mental illness; Table 3 and Supplemental Material). Additionally, studies were considered exclusionary if it: included a dietary ingredient measured as part of a dietary pattern or without a proper control, evaluated dietary ingredients used as a disease therapeutic, included pregnant or lactating women, evaluated ingredients that were

administered *via* inhalation, or studies that did not assess an endpoint related to mental energy.

Abstraction of data and descriptive statistical analysis

Data was extracted from manuscripts that met all of inclusion criteria and none of the exclusion criteria. Data extracted from eligible studies included:

i. General information – PMID, title, authors, journal, year of publication
ii. Study design – population (healthy or unhealthy); disease/condition (if unhealthy), trial type, arm
iii. Participant characteristics – age, sample size (randomized, evaluable)
iv. Intervention – ingredient intervention, comparator, intervention form, intervention dose, intervention duration
v. Results – sample type, results summary

An abbreviated version of the full extraction is included in Supplementary Table 1. If multiple dose levels were evaluated in the study, each dose level was reported separately. In trials that evaluated multiple timepoints, only results from the final timepoint were included in the descriptive statistics. All relevant mental energy outcomes (subjective and objective) were extracted and categorized as either (i) cognition which included outcomes evaluated by individual cognitive tests, test batteries, or brain scanning methods, (ii) sleep including subjective and objective assessments, or (iii) mood and perceived feelings which also included subjective and objective assessments. Cognitive outcomes were additionally subcategorized into six domains as outlined in Figure 1 and initially described by Reger et al. (70). Additional references were utilized to categorize outcomes not originally described. Due to the heterogeneity in trial designs and risk of misinterpretation, a meta-analysis was not completed. The total number of improved outcomes and the total number of outcomes (71) are summarized by subcategory of cognition for each ingredient and by category (mood and perceived feelings, sleep, and overall cognition). Summary statistics for overall cognition are the result of the sum of the six domains. Percentages of improved outcomes are also provided for ease of review and a cutoff of ≥20% of outcomes was applied (72); however, overinterpretation caution is warranted given the heterogeneity of the trial designs.

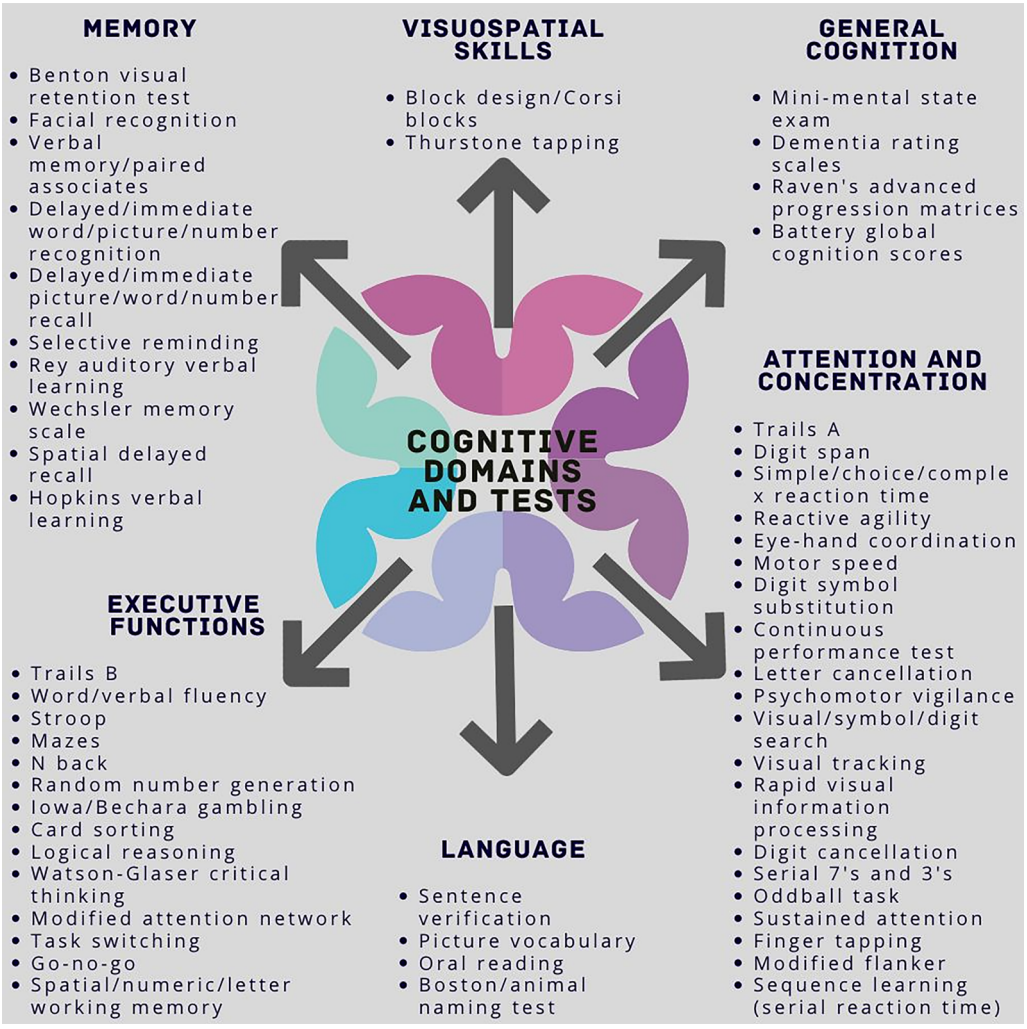

Figure 1. Summary of distribution of cognition tests categorized by domain.

Results

Study selection and characteristics

The initial database search retrieved 2261 articles. After screening these abstracts, 190 of these met eligibility criteria. Full-text articles were retrieved and reviewed in detail resulting in identification of a total of 101 studies for inclusion. The search strategy for cordyceps mushroom and licorice root did not result in any eligible articles and are not described further. The study selection is outlined by ingredient in Table 2 and the extracted data in Table 3. In addition, the tables include intervention, intervention duration, mean age of the sample, sample size, mental energy outcomes evaluated, the total number of improved outcome results, and the total number of outcomes reported by category (Supplementary Table 1). A summary of the number of improved mental energy outcomes by ingredient are included in Tables 4a and 4b.

Ashwagandha

Five trials (73–77) were identified which evaluated the effects of ashwagandha (*Withania somnifera*) extract on mental energy outcomes (Supplementary Table 1). The extract was administered daily in all studies for as little as 2 wk (73) and as long as 16 wk (74) at dosages ranging from 120 mg/day to 1000 mg/day in a range of 20–150 participants. The mean age of the sample population ranged from 25–51 years. Mental energy outcomes evaluated in the identified trials included cognitive tests within the attention and concentration and executive functions domain with a majority of the outcomes evaluating mood and perceived feelings and one study which evaluated sleep (77). Ashwagandha interventions resulted in improvement in 69%, 63%, and 80% of the mood and perceived feelings, sleep, and cognitive function outcomes evaluated, respectively (Table 4a).

Blueberry

The search strategy resulted in four trials (78–81) that met the criteria and evaluated the effects of blueberry powder, extract, or concentrate (liquid) on outcomes of mental energy (Supplementary Table 1). Blueberry was administered chronically at dosages ranging from 24 g/day to 1000 mg/day, or 30 mL/day in one trial which evaluated blueberry concentrate, for 12–24 wk in 21–112 participants (mean age range =

Table 4a. Total number of improved mental energy outcomes for each dietary ingredient.

Mental energy outcome[a]	Ashwagandha	Blueberry	Chamomile	Citrus	Dark chocolate	Ginseng	Green tea	Guarana
Cognition: Attention and concentration								
Total number improved outcomes (n)	3	0	0	1	14	7	5	0
Total outcomes (n)	4	4	0	7	31	45	27	4
Total improved outcomes (%)	75%	0%	–	14%	45%	16%	19%	0%
Cognition: Executive functions								
Total improved outcomes (n)	1	1	0	1	6	5	0	0
Total outcomes (n)	1	8	0	9	10	24	8	0
Total improved outcomes (%)	100%	13%	–	11%	60%	21%	0%	–
Cognition: General cognition								
Total improved outcomes (n)	0	0	0	1	1	0	0	0
Total outcomes (n)	0	0	0	2	7	0	0	0
Total improved outcomes (%)	–	–	–	50%	14%	–	–	–
Cognition: Language								
Total improved outcomes (n)	0	0	0	0	0	0	0	0
Total outcomes (n)	0	0	0	0	0	0	1	0
Total improved outcomes (%)	–	–	–	–	–	–	0%	–
Cognition: Memory								
Total improved outcomes (n)	0	1	0	1	1	4	0	0
Total outcomes (n)	0	14	0	8	18	9	9	2
Total improved outcomes (%)	–	7%	–	13%	6%	44%	0%	0%
Cognition: Visuospatial skills								
Total improved outcomes (n)	0	0	0	0	0	3	0	0
Total outcomes (n)	0	0	0	0	1	6	0	2
Total improved outcomes (%)	–	–	–	–	0%	50%	–	0%
Mood and perceived feelings								
Total improved outcomes (n)	9	1	0	2	6	9	4	0
Total outcomes (n)	13	8	2	18	55	62	45	12
Total improved outcomes (%)	69%	13%	0%	11%	11%	15%	9%	0%
Sleep								
Total improved outcomes (n)	5	0	6	1	0	0	3	0
Total outcomes (n)	8	0	10	1	0	1	7	2
Total improved outcomes (%)	63%	–	60%	100%	–	0%	43%	0%
Overall cognition[b]								
Total improved outcomes (n)	4	2	0	4	22	19	5	0
Total outcomes (n)	5	26	0	26	67	84	45	8
Total improved outcomes (%)	80%	8%	–	15%	33%	23%	11%	0%

[a]Relevant outcomes evaluated in each study were categorized into mood and perceived feelings, sleep, or cognition groups. Cognition outcomes were further subcategorized into six cognitive domains as described in Figure 1. The total (*n* and percent) statistically significant improved outcomes and total number of outcomes evaluated are provided by category and ingredient.

[b]Improved and total outcomes for overall cognition are the sum of the six cognitive domains.

Table 4b. Total number of improved mental energy outcomes for each dietary ingredient (continued).

Mental energy outcome[a]	Lavender	Lion's mane mushroom	Maca	Melatonin foods	Mint	Reishi mushroom	Turmeric	Valerian root
Cognition: Attention and concentration								
Total number improved outcomes (n)	0	0	0	0	3	0	1	0
Total outcomes (n)	0	0	0	0	25	0	8	21
Total improved outcomes (%)	–	–	–	–	12%	–	13%	0%
Cognition: Executive functions								
Total improved outcomes (n)	0	0	0	1	3	0	1	0
Total outcomes (n)	0	0	0	6	10	0	3	0
Total improved outcomes (%)	–	–	–	17%	30%	–	33%	–
Cognition: General cognition								
Total improved outcomes (n)	0	2	0	0	0	0	0	0
Total outcomes (n)	0	2	0	1	0	0	1	0
Total improved outcomes (%)	–	100%	–	0%	–	–	0%	–
Cognition: Language								
Total improved outcomes (n)	0	0	0	0	0	0	0	0
Total outcomes (n)	0	0	0	0	0	0	2	0
Total improved outcomes (%)	–	–	–	–	–	–	0%	–
Cognition: Memory								
Total improved outcomes (n)	0	0	0	0	0	0	1	0
Total outcomes (n)	0	2	0	19	16	0	7	5
Total improved outcomes (%)	–	0%	–	0%	0%	–	14%	0%
Cognition: Visuospatial skills								
Total improved outcomes (n)	0	0	0	0	0	0	0	0
Total outcomes (n)	0	0	0	0	2	0	1	0
Total improved outcomes (%)	–	–	–	–	0%	–	0%	–
Mood and perceived feelings								
Total improved outcomes (n)	5	0	6	0	3	0	17	0
Total outcomes (n)	8	2	7	16	48	1	38	37
Total improved outcomes (%)	63%	0%	86%	0%	6%	0%	45%	0%
Sleep								
Total improved outcomes (n)	0	0	0	11	2	0	0	9
Total outcomes (n)	1	1	0	24	20	0	0	37
Total improved outcomes (%)	0%	0%	–	46%	10%	–	–	24%
Overall cognition[b]								
Total improved outcomes (n)	0	2	0	1	6	0	3	0
Total outcomes (n)	0	4	0	26	53	0	22	26
Total improved outcomes (%)	–	50%	–	4%	11%	–	14%	0%

[a]Relevant outcomes evaluated in each study were categorized into mood and perceived feelings, sleep, or cognition groups. Cognition outcomes were further subcategorized into six cognitive domains as described in Figure 1. The total (n and percent) statistically significant improved outcomes and total number of outcomes evaluated are provided by category and ingredient.
[b]Improved and total outcomes for overall cognition are the sum of the six cognitive domains.

20–71 years). One trial looked at acute administration of freeze-dried blueberry (80) with evaluation of outcomes 2 h after consumption ($n = 21$; mean age = 20 years). Mental energy outcomes evaluated included mood and perceived feelings and a majority of the outcomes assessed cognitive function including tests of attention and concentration, executive functions, and memory. Blueberry interventions resulted in improvement in 13% and 8% of the mood and perceived feelings and cognitive function outcomes evaluated, respectively (Table 4a).

Chamomile

Two trials (82, 83) were identified which evaluated the effects of chamomile extract or tea on mental energy outcomes (Supplementary Table 1). The extract was administered daily in both studies for four weeks at 400 mg/day extract ($n = 60$; mean age = 70 years) (82) or 2 g/day dried flowers ($n = 72$; mean age = 33 years) (83) steeped in 300 mL water. Mental energy outcomes evaluated in the identified trials included mood and perceived feelings and a majority of outcomes evaluated sleep. Chamomile interventions resulted in improvement in 60% of the sleep outcomes but none of the mood and perceived feelings outcomes evaluated (Table 4a).

Citrus

The citrus search strategy resulted in eight trials (84–91) that met inclusion/exclusion criteria and evaluated the effects of bitter orange extract, dried flowers, or orange juice (liquid) on outcomes of mental energy (Supplementary Table 1). Orange was administered chronically at dosages of 1000 mg/day orange (bitter) dried flower (87, 88) or 125–500 mL/day orange juice (85, 86). Outcomes were evaluated following chronic administration of orange for 8–24 wk in 36–156 participants (mean age range = 53–71 years). Four of the trials (84, 89–91) also evaluated acute administration of 20–103 mg orange (bitter) extract or 240 mL orange juice with evaluation of outcomes 1.25–6 h after consumption in 16–50 participants (mean age range = 22–48 years). Mental energy outcomes evaluated included mood and perceived feelings, one sleep outcome, and a majority of the outcomes assessed cognitive function including tests of attention and concentration, executive functions, general cognition, and memory. Orange interventions resulted in improvement in the sleep outcome and

11 and 15% of the mood and perceived feelings and cognitive function outcomes evaluated, respectively (Table 4a).

Dark chocolate

Sixteen studies (92–107) were identified which evaluated the effects of dark chocolate on mental energy outcomes (Supplementary Table 1). The extract was administered both acutely in seven trials (93–95, 100, 104, 105, 107) and chronically in nine trials (92, 96–99, 101–103, 106). Chronic administration occurred at dosages ranging from 0.25–100 g/day dark chocolate or cocoa for 2–12 wk (n = 18–90; mean age range = 23–73 years). Acute administration was provided at 0.25–1 g theobromine with a 4 h follow-up (n = 84; mean age = 23) (100) and 0.4–50 g dark chocolate or cocoa with a 1– 2.5 h follow-up (n = 20–258; mean age range = 19–36 years) (93–95, 104, 105, 107). Mental energy outcomes evaluated in the identified trials included mood and perceived feelings and cognitive function. These interventions resulted in improvement in 33% of the cognitive function outcomes, a majority in attention and concentration and executive functions. In addition, 11% of the mood and perceived feelings outcomes evaluated showed improvement (Table 4a).

Ginseng

The ginseng search strategy identified 13 studies (108–120) that met inclusion/exclusion criteria and evaluated the effects of ginseng extract on mental energy (Supplementary Table 1). Ginseng was administered at doses ranging from 100–1200 mg for acute administration with 1–6 h follow-up (n = 20–52; mean age range = 20–52 years) (108, 110–112, 115–117). Outcomes were evaluated following chronic administration of ginseng at 200–1000 mg/day for 1–16 wk in 23–284 participants (mean age range = 22–61 years) (109, 113, 118–120). Mental energy outcomes evaluated included mood and perceived feelings, one sleep outcome, and a majority of the outcomes assessed cognitive function including tests of attention and concentration, executive functions, memory, and visuospatial skills. Ginseng interventions resulted in no significant improvement in the single sleep outcome and 15% and 23% of the mood and perceived feelings and cognitive function outcomes evaluated, respectively (Table 4a).

Green tea

A total of 13 studies (121–133) were identified which evaluated the effects of green tea on mental energy outcomes (Supplementary Table 1). The extract was administered acutely in a majority of the trials ranging from 0.3–5 h follow-up and a dose of 50 mg to 200 mg theanine (122, 123, 125, 126, 128, 131–133), 270 mg epigallocatechin gallate (EGCG) (127), or 4 g matcha powder (124)(n = 9–27; mean age range = 22–28 years). Chronic administration occurred in three trials (121, 129, 130) at 200 mg/day theanine (121), 500 mg/day green tea polyphenols (129), or 800 mg/day EGCG (130) for 4, 24, and 8 wk, respectively (n = 30–150 participants; mean age range = 48–58 years). Mental energy outcomes evaluated in the identified trials included cognitive tests within the attention and concentration, executive functions, language, and memory domains, mood and perceived feelings, and sleep. These interventions resulted in improvement in 9%, 43%, and 11% of the mood and perceived feelings, sleep, and cognitive function outcomes evaluated, respectively (Table 4a).

Guarana

Three trials (134–136) were identified which evaluated the effects of guarana on mental energy outcomes (Supplementary Table 1). The extract was administered daily in all studies at ~1 g/day (n = 27–45; mean age range = 25–65 years) for 3 (136), 5 (134), or 150 (135) days. Mental energy outcomes evaluated in the identified trials included mood and perceived feelings, sleep, and cognitive outcomes within attention and concentration, memory, and visuospatial skills domains. Guarana interventions resulted in no improvement in any of the reported outcomes (Table 4a).

Lavender

Four studies (87, 88, 137, 138) were identified which evaluated the effects of lavender oil, dried flowers, or tea on mental energy outcomes (Supplementary Table 1). The extract was administered daily in three of the studies (87, 88, 137) for 2–8 wk at 1–4 g/day (n = 60–156; mean age range = 53–67 years). Bradely et al. (138) evaluated the acute effects of 100 or 200 µL lavender oil with a 0.5 h follow-up assessment (n = 96; mean age = 36 years). Mental energy outcomes evaluated in the identified trials included mood and perceived feelings and one sleep outcome. Lavender interventions resulted in improvement of 63% of the mood and perceived feeling outcomes but not the reported sleep outcome (Table 4b).

Lion's mane mushroom

Three studies (139–141) were identified which evaluated the effects of lion's mane mushroom on mental energy outcomes (Supplementary Table 1). The mushroom extract was administered daily in all studies for 4–16 wk at 2–3.2 g/day (n = 26–31; mean age range = 41–70 years). Mental energy outcomes evaluated in the identified trials included cognitive function outcomes within general cognition and memory domains, two mood and perceived feelings outcomes, and one sleep outcome. Lion's mane mushroom interventions resulted in improvement of 50% of the cognitive function outcomes. None of the mood and perceived feelings and sleep outcomes were reported as improved (Table 4b).

Maca

Two studies (142, 143) evaluated the effects of maca on mental energy outcomes (Supplementary Table 1). The mushroom extract was provided at 3.3 (143) or 3.5 (142) g/day (n = 52–54) for 12 wk in both studies. Mental energy

outcomes evaluated in the identified trials included only mood and perceived feelings outcomes. Maca interventions resulted in improvement of 86% of the seven mood and perceived feelings outcomes assessed (Table 4b).

Melatonin foods

The melatonin foods search strategy identified five studies (144–148) that met the criteria and evaluated the effects of cherry (juice and powder) (145, 147, 148) and walnuts (144, 146) on outcomes of mental energy (Supplementary Table 1). Cherry juice concentrate (16 oz/day or 60 mL/day) and cherry powder (37.7 g/day) were administered for 5–14 days (n = 15–30; mean age range = 27–72 years) in three studies (145, 147, 148). Two studies (144, 146) evaluated the effects of walnut consumption at 60 g/day for 8 wk (n = 47 in both studies). Mental energy outcomes evaluated included mood and perceived feelings, sleep, and cognitive function including tests of executive functions, general cognition, and memory. Walnut and cherry interventions resulted in improvement in 46% and 4% of the sleep and cognitive function outcomes evaluated, respectively. There were no significantly improved outcomes reported for mood and perceived feelings (Table 4b).

Mint

Six studies (149–154) were identified which evaluated the mint (oil) or spearmint (extract) on mental energy outcomes (Supplementary Table 1). Ingredient interventions were administered chronically at 600–900 mg/day for spearmint for 17–90 days in 10–106 participants (mean age range = 28–59 years) (149, 150, 152, 153). Acute administration was provided at 50 µL or 100 µL peppermint oil (151) or 100 mg menthol (154) (n = 22, 22, and 12, respectively) with assessment at 1.5–6 h. Mental energy outcomes evaluated in the identified trials included mood and perceived feelings, sleep, and cognitive function which included tests of attention and concentration, executive functions, memory, and visuospatial skills. These interventions resulted in improvement in 11% of the cognitive function outcomes. In addition, 6% of the mood and perceived feelings and 10% of the sleep outcomes evaluated showed improvement (Table 4b).

Reishi mushroom

Only one study resulted from the search strategy which evaluated the effects of reishi mushroom on mental energy outcomes (Supplementary Table 1). Chu et al. (155) administered the mushroom extract at 1.44 g/day for 12 wk in 23 participants (mean age = 55 years). The study evaluated a single measure of mood and perceived feelings which did not improve with the intervention (Table 4b).

Turmeric

Seven trials (156–162) were identified which evaluated the effects of turmeric on mental energy (Supplementary Table 1). The extract was administered daily in all studies for as little as 10 days and as long as 18 months at dosages ranging from 200 mg/day to 1000 mg/day in 30–134 participants (mean age range = 25–69 years). Mental energy outcomes evaluated in the identified trials included cognitive tests within all six domains with a majority of the outcomes evaluating mood and perceived feelings. Turmeric interventions resulted in improvement in 45% of the mood and perceived feelings and 14% cognitive function outcomes evaluated (Table 4b).

Valerian root

The valerian root search strategy resulted in nine studies (59, 163–170) that met the criteria and evaluated the effects of valerian root on outcomes of mental energy (Supplementary Table 1). Valerian root was evaluated chronically at dosages ranging 6.2 to 600 mg/day for 3–28 days (n = 57–405; mean age range = 26–44 years) in four studies (163, 165, 166, 170). Five studies (59, 164, 167–169) evaluated the effects of acute intake of valerian root at dosages ranging from 300–1800 mg (n = 9–40; mean age range = 22–56 years). Mental energy outcomes evaluated included mood and perceived feelings, sleep, and cognitive function including tests of attention and concentration and memory. Valerian root interventions resulted in improvement in 24% of the sleep outcomes evaluated. There were no significantly improved outcomes reported for cognitive function or mood and perceived feelings (Table 4b).

Discussion

The results of this scoping review suggest that some dietary ingredients may be promising for further evaluation on improving aspects of mental energy in individuals. Although, improvements varied by ingredient and category but according to the current definition of mental energy, there is not a need to alter all domains to affect mental energy (1). To our knowledge, one scoping review has been previously completed evaluating the effect of dietary ingredients (gingko biloba, ginseng, glucose, and omega-3 fatty acids), on mental energy and published more than a decade ago. In addition, a recent expert narrative review provided an overview of the evidence on glucose, ginseng, sage, rosemary, peppermint, and gingko biloba (171). Similarly, our review provides additional evaluation of ginseng and mint and spearmint but further evaluated the scientific evidence on 16 additional ingredients based on consumer perceptions of dietary ingredients that provide focus or energy.

Cognition

The largest evidence-base for trials on cognition evaluated the effects of dark chocolate in 21 trials with 22 out of 67 outcomes (33%) reporting improved effects. Although, the results here should be met with caution given the heterogeneity in administration of the chocolate intervention. Chocolate contains a wide range of compounds with the

potential to alter cognition including antioxidants and methylxanthines. Flavanols, a flavonoid subclass, has been proposed to deter age-related decline in cognitive performance by increasing the quantity and interaction between neurons and on opposing neuron degeneration in regions of the brain responsible for memory (172). Theobromine is a methylxanthine compound, like caffeine, that is naturally found in cocoa and has also been hypothesized for its role in cognition and mood. This effect may occur through inhibition of adenosine receptors, similarly to caffeine but with less affinity, speeding up neural activity (32).

Similarly, ginseng was evaluated in 17 trials with a total of 19 out of 84 outcomes (23%) reporting improved effects. Ginsenoside compounds in ginseng are hypothesized to be responsible for its bioactivity through the cholinergic system (112). A number of additional studies have been published since the prior review (1), supporting improved mental energy from ginseng interventions consistent with the recent narrative review (171). A limited number of studies were identified which evaluated the effects of ashwagandha (5 trials) and lions mane mushroom (3 trials) on cognition, however a majority of outcomes indicated improvement of cognition outcomes 80% (4 of 5 outcomes) and 50% (2 of 4 outcomes), respectively. The mechanism of action associated with ashwagandha may be through cyclooxygenase-2 enzyme inhibition, α2-macroglobulin reduction, and increasing the expression of brain-derived neurotrophic factor (21).

Blueberry, citrus, melatonin foods, mint, and turmeric resulted in improvements in <20% of the outcomes evaluated. The remaining ingredients, chamomile, guarana, lavender, maca, reishi mushroom, and valerian root require further evaluation as the search strategy identified no improved outcomes or cognitive outcomes were not evaluated.

Mood and perceived feelings

Among the dietary ingredients most promising for their effect on mood and perceived feelings, turmeric were evaluated in 6 trials with 45% (17 of 38) of outcomes reported as improved. Curcumin is the main curcuminoid of the spice turmeric with a wide array of reported effects *in vivo* and *in vitro* including antidepressant, anti-inflammatory, and antioxidant properties. Specifically, *in vivo* studies suggest curcumin may regulate the monoaminergic pathways by influencing levels of serotonin, dopamaine, and noradrenaline in the central nervous system (56).

Maca was evaluated two trials and 86% (6 of 7) of mood and perceived outcomes were reported as improved, respectively. Maca is the root of the plant Lepidium meyenii and may modulate androgenic and estrogenic activity *in vitro* (142). The mechanism by which Maca may alter mood and perceived feelings in humans has yet to be elucidated. Lavender was evaluated in four trials and 63% (5 of 8 outcomes) were reported as improved. The bioactive constituents of lavender including linalool, linalyl acetate, ocimene, camphor, and flavonoids may exert their effect through anxiolytic, antioxidant, and antidepressant activities (87, 173). Finally, the search strategy suggests ashwagandha may also be a promising ingredient to support mood and perceived feelings. Ashwagandha was evaluated in four trials and 69% of outcomes (9 of 13 outcomes) were reported as improved following treatment.

Finally, blueberry, citrus/orange, dark chocolate, ginseng, green tea, and mint, resulted in improvements in <20% of the outcomes evaluated. The remaining ingredients, chamomile, guarana, lion's mane mushroom, lavender, melatonin foods, reishi mushroom, and valerian root require further evaluation as the search strategy identified no improvement or mood and perceived feelings outcomes were not evaluated.

Sleep

Given the importance of the role of sleep for overall wellness and particularly cognition, energy, and emotional health, key facets of mental energy, sleep outcomes were also evaluated as part of the search strategy (174–177). The search strategy suggested the role of the 18 dietary ingredient interventions in sleep was the least evaluated of the three categories. Ashwaghanda, chamomile, green tea, melatonin foods, and valerian root provided the most promising effects.

Ashwaghanda improved in 63% (5 of 8) of reported outcomes but was only evaluated in a single study, although a mechanism of action for the effect of ashwaghanda on sleep in humans is not understood. Chamomile interventions improved 60% (6 of 10) of sleep outcomes evaluated in two trials. Chamomile may produce tranquilizing effects as a result of flavonoid compounds like apigenin, which bind benzodiazepine receptors in the brain (178). Green tea interventions improved 43% (3 of 7) of sleep outcomes but was evaluated in only one trial. L-theanine is an amino acid found in green tea and may be responsible for its sleep effects by monoaminergic modulation through glutamate, serotonin, and dopamine transmission (37). The effect of melatonin foods on sleep outcomes was evaluated in three trials, all evaluated cherry as an ingredient, and 46% (11 of 24) sleep outcomes improved. Cherries contain high amounts of melatonin, serotonin, and tryptophan which are hypothesized to be responsible for the sleep-promoting properties (145). Valerian root was the most studied ingredient (7 trials) for sleep outcomes. The valerian root search strategy resulted in improvement in 24% (9 of 37) of sleep outcomes evaluated. Mechanisms of action for the effects of valerian root on sleep are not well defined and may be attributed to valepotriates and sesquiterpenes compounds inducing sedative and tranquilizing effects (59).

Mint resulted in improvements in <20% (2 of 20) of the sleep outcomes evaluated and citrus/orange intervention was evaluated in one study which reported improvement in one sleep outcome. The remaining ingredients, blueberry, dark chocolate, ginseng, guarana, lavender, lion's mane mushroom, maca, reishi mushroom, and turmeric, require further evaluation as the search strategy identified no improvement or sleep outcomes were not evaluated.

Strengths and limitations

A major strength of this study is the broad inclusivity of ingredients which allows a picture of the state of the evidence on the role of dietary ingredients in mental energy for further exploration. Although with this strength comes the challenge of the heterogeneity of the studies in a limited mental energy field with inconsistent, often non-objective methods, resulting in the need for caution in overinterpreting the results. Moreover, the heterogeneity of the studies continues to limit the interpretation of the science, particularly as a result of differing study durations, dose and form of dietary ingredients, participant adherence/compliance, and the lack of consistent objective methods. This is particularly difficult for cognition assessments. There is not only a vast array of tests utilized and control variation (practice effects, for example) but the methods of analysis (individual tests vs. domains for example) make comparisons between studies difficult. The ILSI mental energy committee suggested that sustained attention was the best cognitive measure (1). Previous work by O'Connor and Lieberman suggests cognitive tests that evaluate vigilance, sustained attention, and choice reaction time, and for mood, the Profile of Mood State vigor scale were ideal for the evaluation of mental energy (6, 179). Future studies should focus on objective outcomes, and potentially set recommended cognitive tests for nutrition research to reduce heterogeneity (180), and may also benefit from mechanistic evaluation using multi-omics technologies (181). Inherent bias cannot be ruled out; although Abstrackr is a powerful tool for abstract screening, an oversight of eligible studies was possible. In addition, given the design of this study as a scoping review to allow for further hypothesis-driven exploration, the search strategy was designed for one database and did not include grey literature which would be beneficial in future investigation. Finally, the study did not include a review of interactions and potential adverse effects associated with consumption of these dietary ingredients which should be considered in mental energy product formulations.

Conclusion

Consumer demand as well as consumer belief in the effectiveness of mental energy ingredients that have yet to be proven, drives the need for continued evaluation of the evidence-base on dietary ingredients that positively impact mental energy. Of the 16 dietary ingredients reviewed, 11 show promise for further exploration on their mental energy effects including ashwagandha, chamomile, dark chocolate, ginseng, green tea, lavender, lion's mane mushroom, maca, melatonin foods, turmeric, and valerian root. The challenge still remains in interpreting the mental energy evidence base due to the heterogeneity in the study designs and methods of assessment and analysis. Additional, well-designed, consistent, clinical trials and systematic reviews are warranted given the limited number of studies on some of these ingredients to determine the mental energy effects in individuals without severe disease.

Author contributions

All authors contributed to the study design and manuscript development. KMN lead and developed the search strategy, conducted the search, reviewed abstracts and full-text articles, completed the data extraction and descriptive statistics, and lead manuscript development. YZ, MT, and KK acquired funding. YZ directed the study. All authors read and approved the final manuscript.

Disclosure statement

KMN has no relevant interests to declare. MT and KK are currently employed by General Mills, Inc. YZ was employed by General Mills, Inc. during the study.

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