

Studying the Evaluation Model of the Nutritional Quality of Edible Vegetable Oil Based on Dietary Nutrient Reference Intake

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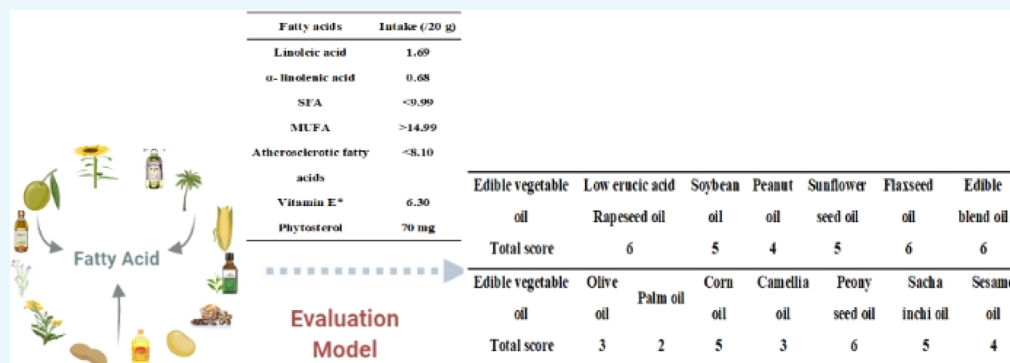


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ABSTRACT: Edible vegetable oils can provide most of the fatty acids, vitamin E, and certain phytochemicals necessary in the daily human diet to facilitate the required physiological activities. However, there are many types of edible vegetable oils on the market, and evaluating their nutritional quality is a matter of significant interest to consumers and producers. Most of the existing research studies that comparatively analyze and qualitatively describe the type, content, and proportion of nutrients in edible vegetable oil lack a comprehensive method for evaluating the nutritional quality of edible vegetable oil. Based on the physical and chemical analysis of fatty acids, vitamins, and phytochemicals in edible vegetable oil, this study aims to establish a model for a comprehensive evaluation of the nutritional quality of edible vegetable oils. The characteristic nutrients in edible vegetable oil were screened as the evaluation index, while the 2013 China Dietary Reference Intake and French Population Reference Intakes For Fatty Acids was considered the evaluation threshold. When each evaluation index in the edible vegetable oil reached the range stipulated by the reference intake of dietary nutrients, the index will get 1 point. The total score of each index was accumulated to evaluate the nutritional quality of the edible vegetable oils comprehensively. In this study, 13 edible vegetable oils, including low erucic acid rapeseed oil (in America, people usually call it canola oil), soybean oil, peanut oil, sunflower seed oil, flaxseed oil, edible blend oil, olive oil, palm oil, corn oil, camellia oil, peony seed oil, sacha inchi oil, and sesame oil, were selected as the evaluation objects because they are very common in China. Seven evaluation indexes were found for total saturated fatty acids (SFAs), atherogenic fatty acids (SFAs with 12, 14, and 16 carbon chains), monounsaturated fatty acids, polyunsaturated fatty acids like linoleic acid and α -linolenic acid, vitamin E, and phytosterol. When the evaluation index met the evaluation threshold, it was scored 1 point. Scores ranged from 2 to 6. The highest scores were obtained from peony seed oil, flaxseed oil, low erucic acid rapeseed oil, and edible blend oil all of which were 6 points. The lowest score belonged to palm oil at 2 points. The higher the score, the higher the degree of satisfaction between the various nutrients in the edible vegetable oil and the dietary reference intake of this model is. This paper establishes a new method for the nutritional evaluation of edible vegetable oils, which is convenient for comparing the overall nutritional quality of different kinds of edible vegetable oils while providing a new technique for the extensive evaluation of edible vegetable oil.

INTRODUCTION

Edible vegetable oil forms a vital part of the human diet and can provide the energy and fatty acids needed by the body and promote the digestion and absorption of fat-soluble vitamins. With the improvement of people's living standards, China's per capita consumption of vegetable oil remains at a high level. According to data provided by the first volume of 2013 Report on the Nutrition and Health Status of Chinese Residents,¹ the

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average daily fat intake of Chinese urban and rural residents is 79.7 g, while the 2013 China Dietary Reference Intake-Acceptable Macronutrient Distribution Ranges² suggests that the total fat intake from the diet should be 20–30% of the total energy intake. If the daily energy intake per person is calculated to be 2000 kcal, the total daily fat intake per capita should be 44.4–66.7 g. However, the current total daily fat intake per capita in China is substantially higher than the recommended value. The top five food sources for fat are edible oils (50.1%), animal meat (22.5%), flour (6.4%), others (5.7%), and eggs (3.3%). Edible vegetable oil provides about 50% of the total dietary fat, which is equivalent to about 39 g of edible vegetable oil per day, of which the top three edible vegetable oils are rapeseed oil (12.8%), peanut oil (7.4%), and soybean oil (6.5%).¹ The 2016 Chinese Dietary Guide³ recommends a daily consumption of edible oil per person of 25–30 g. However, the real daily intake is far higher than this guide.¹ Many research studies suggest that the primary fatty acids in edible vegetable oil are palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1), and linoleic acid (C18:2) of which oleic acid and linoleic acid display the highest levels.⁴ However, rapeseed oil, peanut oil, and soybean oil are high in oleic acid and linoleic acid, and maintaining a prolonged diet pattern high in linoleic acid leads to excessive intake of omega-6, damaging the balance between n-6 and n-3 PUFAs. Although the intake of aquatic products and seafood in the coastal areas may be adequate to increase the n-3 levels, it remains too low in some inland regions. The average intake of fish per person per day in China is about 23 g, which is lower than the 40–70 g/d recommended by the 2016 Chinese Dietary Guide.³ The content and proportion of fatty acid intake are closely related to human health. Consuming an appropriate amount of fatty acids is conducive to the normal metabolism of fat, while excessive ingestion leads to the deposition of fat in the body, resulting in hypertension, hyperlipidemia, and other diseases.⁵

The current research on edible vegetable oils mainly focuses on composition analysis and nutritional composition comparison, such as fatty acid composition analysis, content determination, and identification of phytochemicals, which are not linked to human demand.

Analysis of the Nutritional Components of Edible Vegetable Oil. Edible vegetable oil forms an integral part of the human diet and consists of triacylglycerol (95–98%) and other trace compounds (2–5%),⁶ which can provide most of the fatty acids required by the human body for physiological activities. Furthermore, edible vegetable oil also contains certain amounts of vitamin E and phytochemicals, such as phytosterols and squalene.^{7–9}

The content of five major fatty acids in corn oil, sunflower oil, soybean oil, tea oil, rapeseed oil, and peanut oil were compared and indicated that the average unsaturated fatty acid content in all types of edible vegetable oils exceeded 80%, while that of SFA was about 10%.¹⁰ Further experiments compared the vitamin E content in nine edible vegetable oils (138 different brands), showing that it ranged from 5.9 to 1246.6 mg/kg, with an average of 652.4 mg/kg. The vitamin E level was the highest in first-grade soybean oil, ranging from 804.5 to 1246.6 mg/kg.¹¹ Furthermore, edible vegetable oil is rich in phytosterols, providing an excellent way for humans to ingest these compounds.¹² Measuring the phytosterol content, such as campesterol, stigmaterol, rapeseed sterol, and β -sitosterol in 56 edible vegetable oils and 7 edible blend oils, indicated that all of them contained only two of the four sterols, β -sitosterol and

campesterol. Of the tested oils, corn oil and rapeseed oil exhibited the highest total sterol content, with averages of 8916.6 and 8811.1 $\mu\text{g/g}$, respectively.¹³ In addition, edible vegetable oil also contained a small number of plant polyphenols, squalene, and carotenes.¹⁴

Evaluation of the Nutritional Quality of Edible Vegetable Oil. The various ingredients in edible vegetable oil all have their respective functions during the process of human physiological metabolism. For example, n-3 polyunsaturated fatty acids (PUFAs) play a critical role in promoting the health of the brain and retina. α -Linolenic acid, which belongs to n-3 fatty acids, has physiological functions such as antiatherosclerotic, prevention of cardiovascular and cerebrovascular diseases, weight loss, and lowering blood lipids. It can be converted into long-chain n-3 polyunsaturated fatty acids DHA and EPA in the human body, increasing the levels of DHA and EPA in most tissues and exerting similar physiological functions as that of DHA and EPA.¹⁵ Vitamin E is a fat-soluble vitamin, which is a natural antioxidant and immunomodulator. In the daily diet, vitamins are mainly derived from edible vegetable oils of which germ oil and soybean oil are the most abundant.¹⁶ Phytosterols have critical physiological functions that can decrease the risk of cholesterol while playing anti-inflammatory, antiatherosclerotic, antioxidant, and antitumor roles provided that they are present in adequate amounts.^{17,18}

An examination of perilla oil, almond oil, and hemp seed oil found that the linoleic acid content was the highest in the hemp seed oil, α -linolenic content was the highest in perilla oil, and MUFA content was the highest in almond oil. The characteristic fatty acids in the three types of edible vegetable oils were all different, displaying a variety of contents.¹⁹ Several studies compared the fatty acid composition of olive oil, camellia oil, peanut oil, rapeseed oil, and soybean oil in which the content was analyzed. Results indicated that both olive oil and camellia oil were rich in n-9 fatty acids; peanut oil, olive oil, and camellia oil were low in n-3 fatty acids; and peanut oil and soybean oil contained high levels of n-6 fatty acids. From a nutritional perspective, edible vegetable oil rich in n-9 fatty acids, i.e., oleic acid is not suitable for single long-term, uninterrupted consumption because it is not an essential fatty acid according to Dietary Reference Intakes (DRIs), and prolonged ingestion will result in an insufficient intake of essential fatty acids.²⁰ Sacha inchi oil represented a new type of vegetable oil whose fatty acid, phytosterol, and vitamin E content were compared with that of common edible vegetable oils. The results indicated that the α -linolenic acid and phytosterol levels were 43.62% and 265.61 mg/100 g, respectively, which exceeded the corresponding levels in common edible vegetable oils.²¹ The calories, SFA content, n-6/n-3 ratio, and vitamin E content of rapeseed oil, soybean oil, peanut oil, rapeseed oil, cottonseed oil, corn oil, and palm oil were also determined. Except for soybean oil, sunflower oil, and cottonseed oil, the ratio of polyunsaturated and vitamin E content was ideal in the rest of the plant oils. Therefore, edible vegetable oil exhibiting sufficient levels of fatty acid saturation, n-6/n-3 ratio, and appropriate vitamin E content should be selected to adequately fulfill human dietary requirements.²²

The methods currently used for evaluating edible vegetable oils focus primarily on describing and comparing the nutrients. Therefore, the nutritional content is simply used as a representation of the nutritional quality of edible vegetable oil, rarely linking with the demand of humans and ignoring the overall nutritional balance. Consequently, it is necessary to build

a comprehensive, scientific, quantitative evaluation model denoting the nutritional quality of edible vegetable oil.

This study referred to the 2013 China Dietary Reference Intake² to establish this model. The scoring model was established by screening the typical nutritional indicators of the edible vegetable oil and following the recommended threshold value suggested by the 2013 China Dietary Reference Intake.² The model focused on the nutritional characteristics of different edible vegetable oils available in the Chinese market and aimed to propose a comprehensive method for evaluating the nutritional quality of edible vegetable oils. Combined with the actual situation in China, the goal is to adjust and correct the current undesirable fatty acid diet structure and meet the growing nutritional needs of consumers while promoting the development of a healthy dietary structure.

■ SELECTION OF EDIBLE VEGETABLE OIL EVALUATION INDEXES

Because the nutritional components of edible vegetable oils are complex, research cannot only focus on a single characteristic. However, because it is not possible to simultaneously include all components in the evaluation scope, it is necessary to reasonably select the evaluation indexes. The fatty acids in edible vegetable oils can be divided into SFA, MUFA, and PUFA. Fatty acids can form triacylglycerols with glycerin, commonly known as fats, which can provide and store energy for the body, promote the absorption of fat-soluble vitamins, and maintain constant body temperature. The human body can synthesize many kinds of fatty acids on its own. However, the linoleic acid and α -linolenic acid in PUFA, which are essential to the human body, cannot be naturally synthesized and are derived via food consumption. Vitamins can be divided into those that are water-soluble and those that are fat-soluble. Neither of these constitutes the body's structural components and do not provide energy, but their metabolites can participate in the body's many metabolic or apoptotic processes. These vitamins can generally not be synthesized by the body and must be derived from food. Fat-soluble vitamin E, which is required for daily human physiological activities, is mainly derived from edible vegetable oil, where germ oil is especially abundant. Edible vegetable oil is also rich in phytosterols, providing an excellent way for humans to ingest these compounds. Phytosterols in the diet can decrease total serum cholesterol, as well as low-density lipoprotein cholesterol (LDL-C) and is beneficially related to decrease the incidence of certain cancers.

Fatty Acids. The SFA, MUFA, and PUFA contained in edible oils vary in type, content, and ratio. Although SFA is commonly found in the fats of animals, such as beef, mutton, and pork, they are also present in plant oils such as coconut oil, cocoa oil, and palm oil. SFAs commonly found in edible vegetable oils are palmitic acid and stearic acid. It is generally believed that SFA in the diet may increase the level of serum LDL-C by inhibiting its receptor activity, resulting in the deposition of cholesterol on the inner walls of arterial blood vessels and increasing the body's susceptibility to various types of cardiovascular diseases (CVDs).^{23–25}

MUFA refers to fatty acids with only one double bond, which can lower blood sugar and cholesterol and regulate blood lipids.^{25,26} In the daily diet, this usually refers to oleic acid. Studies have shown that oleic acid can reduce the risk of a coronary heart disease by lowering LDL-C.²⁷ Of the common edible vegetable oils, olive oil and camellia oil are representative

of oleic oils, and their oleic acid content can exceed 70% of the total fatty acid content.

PUFA refers to straight-chain fatty acids containing two or more double bonds with a carbon chain length of 18 to 22 carbon atoms and mainly includes n-3 and n-6 PUFAs. Linoleic acid is an n-6 PUFA with two double bonds that can reduce the risk of a coronary heart disease by lowering LDL-C²⁸ and the incidence of diabetes.²⁹ Conjugated linoleic acid (CLA) is an isomer of linoleic acid with anticancer and antiatherosclerotic properties, and it can enhance body immunity, regulate fat metabolism, and promote bone tissue metabolism.³⁰ α -Linolenic is an n-3 FA that mainly exists in plant resources, while trace amounts exist in animal resources.³¹ It is an essential unsaturated fatty acid that cannot be synthesized by the human body. α -Linolenic is the precursor of a series of metabolites under the action of desaturase and elongase, the most important of which are eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).³² EPA and DHA are unsaturated fatty acids that cannot be synthesized by the body and can only be obtained from food sources such as fish, shellfish, crustaceans, and microalgae. Studies have shown that EPA and DHA can reduce the mortality rate associated with the coronary heart disease and at different doses have been shown to decrease the risk of coronary artery death from 10 to 30%³³ and prevent the occurrence of CVD and allergic diseases, while promoting the development of the nervous system and cognitive function of newborns and fetuses.³⁴

Vitamin E. In a daily diet, edible vegetable oil denotes the primary source of natural vitamin E, which is generally extracted during the distillation process of vegetable oil refining and deodorization.³⁵ Vitamin E is a characteristic nutritional index of vegetable oil, as well as a micronutrient affecting its oxidative stability and nutritional quality. Moreover, vitamin E is a fat-soluble vitamin with eight isomers, including α , β , γ , and δ , as well as four tocopherols and four tocotrienols. Studies have shown that vitamin E performs certain physiological functions regarding antioxidation, inhibition of cholesterol synthesis and tumor cell growth, improvement of atherosclerosis, and prevention of CVDs.

Phytochemicals. Edible vegetable oil also contains a variety of phytosterols, such as plant polyphenols, squalene, and carotenoids. The most common phytosterols are β -sitosterol, stigmasterol, campesterol, and rapeseed sterol. Plant sterols perform vital physiological functions, such as lowering cholesterol and displaying anti-inflammatory, antiatherosclerotic, antioxidant, and antitumor properties. Plant sterols are essential functional components of edible vegetable oils, while the composition and form of these phytosterols vary significantly and can be used as a characteristic index to distinguish nutritional values between edible vegetable oils.

■ THE EVALUATION MODEL

Evaluation Index. The establishment of the evaluation model was based on the 2013 China Dietary Reference Intake² and French Population Reference Intakes (ANCs) For Fatty Acids³⁶ screening indicators, including SFA, total MUFA, atherosclerotic fatty acids (C12:0 + C14:0 + C16:0), linoleic acid, α -linolenic acid, vitamin E, and phytosterols.

Threshold Calculation. The 2013 China Dietary Reference Intake² stipulates the recommended daily intake of some fatty acids of which linoleic acid and α -linolenic acid are essential, while the acceptable range for the daily intake of EPA and DHA is 0.25–2.0 g. Currently, there are two essential fatty acids in

China, including linoleic acid and α -linolenic acid. In the 2013 China Dietary Reference Intake, the Dietary Reference Intakes (DRIs) are set for linoleic acid and α -linolenic acid, as well as the Acceptable Macronutrients Distribution Ranges (AMDRs) are set for the total fat content, saturated fatty acids, total intake of n-6 PUFAs, and total intake of n-3 PUFAs, as shown in Table 1.

Table 1. Calculation Based on the Daily Energy Requirements of 2000 kcal, According to the 2013 China Dietary Reference Intake - Fatty Acids and the Daily Fatty Acid Intake of Chinese Adults Should Account for the Total Energy Range

	fatty acids	%energy ^b
DRIs	C18:2	4.0
	C18:3	0.6
AMDR	total fat	20–30
	SFA	<10
	n-6 PUFAs	2.5–9.0
	n-3 PUFAs	0.5–2.0
	EPA + DHA ^a	0.25–2.0

^aThe unit of EPA + DHA is g/d ^bEnergy: 2000 kcal

MUFA is widely found in food, such as nuts, vegetable oils, meat, and dairy products and primarily includes palmitoleic acid and oleic acid, which are abundant in common edible vegetable oils. Evidence shows that instead of carbohydrates, it can increase high-density lipoprotein (HDL) levels, and by replacing SFA, especially atherosclerotic fatty acids, it can reduce the ratio of (LDL + total cholesterol)/HDL. Based on the recommended intake of MUFA = total fatty acid intake (%E) – SFA (%E) – PUFA (%E) – trans fatty acids (%E), the maximum amount is between 7–17 %E.³⁷ A meta-analysis found that in two groups with six months of high and low MUFA (<12 %E) ingestion, respectively, the higher group (MUFA >12 %E) significantly decreases the blood pressure and diastolic blood pressure of the high consumption group.³⁸

France has formulated appropriate reference amounts of oleic acid intake, recommending that the daily intake of oleic acid content be within 15–20 %E,³⁶ while the 2013 China Dietary Reference Intake does not provide a recommended value for MUFA. To ensure the appropriate ingestion of MUFA, the daily intake should be no less than 15 %E.

The 2013 China Dietary Reference Intake specifically recommended that the daily intake of phytosterol is 900 mg, and the maximum tolerable intake is 2400 mg.² According to the nutrition and health surveys of Chinese residents in 2002 and 2013, the total per capita daily sterol intakes in China were 322.41 and 372.52 mg, respectively, which were far below the specifically recommended value. In 2013, the nutrition and health data of residents showed that the vegetable oil intake was 41.8 g, providing 42.86% of the total sterol content, which is equivalent to 140.38 mg.¹ Therefore, the suggested daily intake of edible vegetable oil was 20 g, while it was recommended that all types of edible vegetable oils be evaluated with 70 mg of phytosterols as the minimum threshold.

Table 2 shows that 2000 kcal is taken as the daily total energy intake, and the proportion of fatty acid energy is converted into daily intake, and the unit is expressed in g. EPA + DHA, vitamin E, and phytosterol were directly expressed as daily intake. In Table 2, the evaluation index of total atherosclerotic fatty acids (C12:0 + C14:0 + C16:0) is added, which is according to French Population Reference Intakes (ANCs) For Fatty Acids. At

Table 2. Recommended Intake of Different Fatty Acids, Vitamin E, and Phytosterol and the Total Daily Energy Intake per Person is 2000 kcal

fatty acids	%E	calories (kcal)	recommended intake (g)
linoleic acid	4.0	80	9
α -linolenic acid	0.6	12	1.5
total fat	20–30	400–600	44.4–66.7
SFA	<10	<200	<22.2
MUFA	>15	>300	>33.3
atherogenic fatty acids			<18 g
total value of n-6 PUFAs	2.5–9.0	50–180	5.6–20.0
total value of n-3 PUFAs	0.5–2.0	10–40	1.1–4.4
EPA + DHA ^a			0.25–2.0
vitamin E			14 mg
phytosterol ^b			0.9–2.4

^aThe unit of EPA + DHA is g/d ^bRepresents the specific recommended value of phytosterols and the maximum tolerable intake

present, there is no reference intake threshold of atherosclerotic fatty acids in China. However, atherosclerosis is a common disease seriously endangering human health. In recent years, the incidence rate of this disease has increased significantly in China. According to the results of autopsy, the detection rates of coronary and aortic atherosclerotic lesions were 58.36 and 88.31%, respectively, in 40–49 year old people and gradually increased with age.³⁹

The 2013 Report on the Nutrition and Health Status of Chinese Residents¹ shows that the current daily intake of edible oil per person in China is 41.8 g of which vegetable oil accounts for 37.1 g, which varies slightly from 39 g. The recommended amount of edible vegetable oil accounted for 50% of the total dietary fatty acids because the daily fat intake of edible vegetable oil per person should be 22.2–33.3 g. When the actual model was established, the daily intake of vegetable oil per person was 20 g, accounting for approximately 45% of the total daily fat intake per capita.

Because there are no EPA and DHA in edible vegetable oil, we decided to select saturated fatty acid, monounsaturated fatty acid, linoleic acid, α -linolenic acid, total atherosclerotic fatty acid (C12:0 + C14:0 + C16:0), vitamin E, and phytosterol as evaluation indexes finally. Table 3 shows the daily performance of the seven indicators.

Table 3. Evaluation Threshold

fatty acids	intake (20 g)
linoleic acid	1.69
α -linolenic acid	0.68
SFA	<9.99
MUFA	>14.99
atherosclerotic fatty acids	<8.10
vitamin E ^a	6.30
phytosterol	70 mg

^aDaily recommended is multiplied by ratio, $14 \times 0.45 = 6.30$, and the unit is mg.

Table 4. Evaluation Results for the 13 Edible Vegetable Oils

edible vegetable oil	saturated fatty acids	atherosclerotic fatty acids	monounsaturated fatty acids	linoleic acid	α -linolenic acid	vitamin E	phytosterol	total score
low erucic acid rapeseed oil	1.32	0.76	12.28	3.75	1.51	12.18	114.03	6
soybean oil	5.00	2.01	5.54	9.88	1.25	18.6	63.42	5
peanut oil	3.68	2.12	8.50	6.56	0.02	8.4	51.94	4
sunflower seed oil	2.18	1.08	6.04	10.40	0.04	10.9	74.45	5
flaxseed oil	1.62	0.94	3.74	2.83	10.71	7.50	116.98	6
edible blend oil	2.26	1.45	8.92	6.35	1.03	16.61	102.80	6
olive oil	2.70	2.01	15.02	1.20	0.11	4.40	54.02	3
palm oil	8.78	8.01	8.24	2.05	0.04	3.05	3.05	2
corn oil	2.80	2.35	5.84	9.89	0.11	10.20	206.41	5
camellia oil	1.90	1.55	15.76	1.30	0.00	6.50	23.58	3
peony seed oil	2.44	1.54	3.22	4.25	8.07	11.20	92.00	6
sacha inchi oil	2.15	1.92	1.23	7.32	8.29	22.32	53.12	5
sesame oil	2.78	1.63	7.56	8.34	0.06	13.71	62.34	4

RESULTS

Thirteen kinds of edible vegetable oils, including low erucic acid rapeseed oil, soybean oil, peanut oil, sunflower seed oil, flaxseed oil, edible blend oil (edible blend oil is a mixture oil with two or more kinds of oil, which is also a type of vegetable oil), olive oil, palm oil, corn oil, camellia oil, peony seed oil, sacha inchi oil, and sesame oil, were selected for evaluation, according to the data provided by the 2016 China Food Composition Tables⁴⁰ and several other studies. Erucic acid is a long-chain MUFA. The long-term consumption of rapeseed oil rich in erucic acid will cause the excessive accumulation of this compound, leading to the thickening of blood vessel walls and the deposition of cardiac fat.⁴¹ Therefore, to better meet human health requirements, China began to research on the effect of low erucic acid and low glucosinolate rape around 1980. After 2000, China began to promote and apply it on a large scale. The Chinese national standard for rapeseed oil and the industry standard for low erucic acid rapeseed oil respectively stipulate that the erucic acid in rapeseed oil should be lower than total fat contents of 3 and 5%. At present, Chinese rapeseed oil is low in erucic acid. Therefore, it was decided to use the low erucic acid rapeseed oil data for model verification.

According to the data consulted, the content of evaluation indexes in each vegetable oil was calculated and evaluated, and the evaluation results are shown in Table 4.

The scores of the thirteen vegetable oils ranged from 2 to 6. The highest scores were obtained from low erucic acid rapeseed oil, flaxseed oil, and peony seed oil, while the lowest score was evident in palm oil. The results indicated that peony seed oil, flaxseed oil, and low erucic acid rapeseed oil have the highest scores, which were similar to those of Li.⁴² The score of edible blend oil is also 6 points, but edible blend oil is a kind of artificial edible vegetable oil. It is an edible oil made from two or more refined oils (except aromatic oil) in proportion according to the needs of use, hence the score is also high.

The model reflects the relationship between types as well as contents of fatty acid in different edible vegetable oils and the human demand. Therefore, the higher the score of edible vegetable oil, the higher the fit of the edible vegetable oil with the human fatty acid demand is. Consumers should try to choose edible vegetable oils with a higher score.

Rapeseed oil is a traditional Chinese edible vegetable oil with a balanced fatty acid content and ratio and contains high vitamin E and phytosterol levels. The advent of low erucic acid rapeseed oil

has led to a significant reduction in the erucic acid content of traditional rapeseed oil, thereby reducing the risk of thickening blood vessel walls and cardiac fat deposition.

However, combined with the analysis of the current Chinese dietary structure, the per capita intake of linoleic acid in China has exceeded the recommended value, and the ratio of n-6/n-3 PUFAs has become unbalanced. Therefore, the current dietary fatty acid intake and the ingestion ratio of the Chinese people need to be adjusted to reduce the consumption of linoleic acid to the recommended level, while increasing the intake of α -linolenic acid and ensuring that the n-6/n-3 PUFAs are within a reasonable range.

Rapeseed oil has a low linolenic acid content and cannot be adjusted sufficiently within a certain intake range. Peony seed oil and sacha inchi oil are new food resources approved by the National Health Commission of the People's Republic of China, and both have higher α -linolenic acid levels. Therefore, appropriately increasing the intake of peony seed oil and sacha inchi oil is beneficial for modifying the current dietary pattern exhibiting an n-6/n-3 PUFA imbalance.

The evaluation model of fatty acids in this study mainly focuses on the evaluation of nutritional quality of fatty acids, but in daily consumption, consumers may also consider other factors, such as flavor and taste. For example, sesame oil, in China, is a type of seasoning oil, which is often used in all kinds of salad mix. Therefore, in this study, even the consumption of sesame oil is small, we also take this in consideration in our research.

DISCUSSION

This article is based on the 2013 China Dietary Reference Intake, and after thoroughly studying the fatty acid intake of Chinese residents, a reasonable range of daily per capita consumption of edible vegetable oils was determined (a recommended daily intake of 20 g). Furthermore, to establish the model, the nutritional characteristics of edible vegetable oils as well as China's recommended intake values regarding fatty acids, vitamin E, and phytosterols were examined. The scoring results mainly indicate whether each evaluation index in the edible vegetable oil meets the reference intake requirements. More importantly, the scoring result level only represents the degree of satisfaction and does not directly reflect the level of its nutritional value. However, the reference intake of dietary nutrients is revised by the Chinese Nutrition Society (CNS), according to the nutritional survey data and dietary character-

istics of Chinese residents. Based on the Chinese Recommended Daily Allowance (RDA) and referring to foreign DRI documents, CNS revised the current DRIs, including the estimated average requirement (EAR), recommended nutrient intake (RNI), adequate intake (AI), and tolerable upper intake level (UL), reflecting the reasonable dietary pattern that Chinese residents should be following. Therefore, to a certain extent, the model reflects whether the indexes of the fatty acids, vitamin E, and phytosterols in the edible vegetable oil can meet the daily intake levels required by the human body.

Worldwide, there are currently various types of research involving edible vegetable oils, including toxicological research,^{43–45} the determination of micronutrient components,⁴⁶ fatty acid composition,^{47,48} identification of edible vegetable oil components,⁴⁹ and discussions concerning body markers after edible vegetable oil intake.^{50,51} In terms of nutritional evaluation, as mentioned above, the current focus is on the type, content, and proper proportion of fatty acids in edible vegetable oil. Additionally, during the nutritional analysis process, the comparison and description sentences are often used to characterize the nutritional properties of edible vegetable oil, thus dividing the two concepts of body demand and food supply. However, it is challenging to perform a complete evaluation of edible vegetable oil only by comparing several nutrient contents. The impact of various components in edible vegetable oil on human health can only be highlighted in combination with the needs of the body or authoritative recommendation.

The result showed that peony seed oil, flaxseed oil, and low erucic rapeseed oil exhibited the highest scores. The analysis of the nutritional composition of rapeseed oil, a traditional Chinese edible vegetable oil, indicates that it contains higher MUFA levels, which is consistent with the findings of Deng.⁵¹

Furthermore, the SFA content in rapeseed oil is low, while the linoleic acid and α -linolenic acid levels also meet the range requirements of the DRI intake prescribed in China. Moreover, vitamin E and phytosterol levels are prominent as well. The content of each nutritional component reached the range prescribed by the reference intake of dietary nutrients, causing the rapeseed oil to score higher.

However, although the rapeseed oil received a high score according to the evaluation indicators discussed in this paper, its characteristic nutritional composition was not more prominent compared with peony seed oil and flaxseed oil both of which containing higher α -linolenic acid levels.

The 2013 Report on the Nutrition and Health Status of Chinese Residents¹ shows that the per capita daily intake of Chinese freshwater fish is about 15 g, the ingestion of marine fish is about 5.9 g, while the consumption of shrimp and crab is about 2.8 g. In some inland areas, the consumption of seafood will obviously be less. Such a diet can easily lead to insufficient intake of EPA and DHA. Also, α -linolenic acid can be converted into EPA under the catalysis of Δ -6 dehydrogenase, elongase, Δ -5 dehydrogenase, and other enzymes, and then it can be transformed to DHA by β -oxidation.⁵² Colussi also pointed out in his research that omega-3 PUFA is an important component of mammalian cell membranes, and its content can affect cell function.⁵³

Furthermore, the results showed that the olive oil scores were low, only exceeding that of palm oil, which was inconsistent with the results obtained by Li.⁴² Olive oil is the main source of fat in the Mediterranean diet. Studies show that the MUFA in olive oil accounts for about 72 to 77%⁵⁴ of the total fat content.

Additionally, because olive oil exhibits a low SFA content (2 to 21%) and high antioxidant phenolic substances,⁵⁵ it is favored by consumers.

The olive oil score in this model was 3, which was the same as camellia oil and slightly higher than palm oil. Therefore, except for MUFA, the remaining fatty acid content in olive oil did not meet the recommended fatty acid intake requirements in China. Furthermore, the model employed in this study used the total amount of vitamin E as an evaluation index. Therefore, it did not separately distinguish the respective activities of α -, β -, γ -, δ -tocopherol and tocotrienol of which α -tocopherol is the most active form of vitamin E in the body,⁵⁶ while olive oil is rich in α -tocopherol.⁵⁵

The evaluation in this article only involves the total amount of vitamin E and does not assess the physiological activity of different forms of vitamin E. Therefore, because the total content level of the vitamin E in the olive oil is low, the score is not high.

CONCLUSIONS

This study uses the recommended intake as the threshold for the comprehensive evaluation of edible vegetable oil and the quantification of various related nutrients and its quality. The scoring method is used as an effective tool to provide clear values for objectively evaluating the nutritional quality of these nutrients, as well as common and unknown edible vegetable oils.

The final score of the model indicates whether the edible vegetable oil meets the recommended range of the reference amount, while the level of the score represents the degree of satisfaction with the dietary reference amount. Within a certain range, the score can assist consumers in choosing between different edible vegetable oils, but the score is limited to a comparison with dietary reference values.

However, many deficiencies regarding this research remain. For example, only the total amount of vitamin E is considered in this model, while different forms of vitamin E are involved in different physiological activities. Moreover, in addition to phytosterols, edible vegetable oils also contain other phytochemicals, such as the abundance of polyphenols in olive oil, but this model does not include polyphenols as evaluation indicators, resulting in a lower olive oil score.

Therefore, follow-up research is necessary that includes a wider range of indicators to improve the model and make it more suitable for the evaluation of edible vegetable oils. However, the recommended dietary amount is not completely equal to the individual demand. Consequently, the evaluation results of this article are only for the reference of Chinese residents and cannot be accurately applied to all individuals.

In addition to edible vegetable oils, meat also provides some fatty acids, while seafood, such as some deep sea fish, is also rich in DHA and EPA. Therefore, the next step is to establish a suitable model for assessing the fatty acids in meat to improve the current Chinese dietary structure.

In conclusion, this study established a preliminary model to evaluate the nutritional quality of fatty acids for 13 kinds of edible vegetable oils in the Chinese market. Among them, peony seed oil, flaxseed oil, low erucic acid rapeseed oil, and edible blend oil had the highest score of 7. Palm oil had the lowest score of 2. However, the model established in this paper only considers fatty acids as a nutritional component. From the perspective of fatty acid evaluation, people can get more balanced fatty acids from edible vegetable oils with a higher score. However, as mentioned above, although olive oil has a low

score, it has a high content of vitamin E, low saturated fatty acids (2–21%), and high antioxidant phenols. Therefore, in daily dietary consumption, consumers can try to choose edible vegetable oils with a higher score easily because edible vegetable oils with a higher score can provide more balanced fatty acids. But at the same time, vegetable oil is only a food material, and the final dietary structure has more influence on human health. Therefore, consumers also need to pay attention that different kinds of vegetable oils have different effects. Although some edible vegetable oils may have a lower score, such as olive oil, they may provide other nutrients. Therefore, in addition to edible vegetable oils with a high score, we also could eat various kinds of edible vegetable oils at the same time, which will be more conducive to improving the current fatty acid diet structure in China.

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Notes

The authors declare no competing financial interest.

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