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Dietary intake of lycopene by the Belgian adult population

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Abstract

Objective: Lycopene is a potent antioxidant, and it has been suggested that intake of tomatoes and tomato products containing lycopene is associated with a decreased risk of various chronic diseases. The aim of the present study was to evaluate the distribution of dietary lycopene intake in the Belgian population and to determine the most important contributors to lycopene intake.
Design: Cross-sectional study.
Setting: National food consumption data from the Belgian Food Consumption Survey (BFCS) 2004 were used for the intake assessment. Determination of the lycopene content in foods was performed with HPLC-UV. Individual food consumption data were multiplied by the actual mean concentrations of lycopene per food.
Subjects: Individuals (*n* 3083) aged 15 years and older participated in the study and provided two 24 h recalls.
Results: The mean lycopene intake among Belgian adults was 4·1 (SD 2·3) mg/d or 0·059 (SD 0·033) mg/kg body weight per d. Lycopene intake among men (4·6 (SD 2·6) mg/d) was higher than among women (3·6 (SD 2·1) mg/d), and was higher in the younger compared with the older age groups. *Cis*-lycopene intake represented about one-third of the total lycopene intake. Tomatoes and tomato products (43 %) and sauces and ready-to-eat meals containing tomato sauces (41 %) were the main contributors to lycopene intake in Belgium.
Conclusions: The lycopene intake of the Belgian adult population was comparable to intakes reported in neighbouring countries and was below the acceptable daily intake.

Keywords
Lycopene
Dietary intake
Belgian population
Tomatoes

Numerous epidemiological studies have shown an inverse association between fruit and vegetable consumption and chronic diseases, including different types of cancer and CVD[1]. Therefore, the interest in the health benefits of fruit and vegetable consumption has increased during the last decades. Moreover, the interest in the types, concentrations and modes of action of the different components from fruits and vegetables responsible for the beneficial health effects has increased as well.

Carotenoids are natural fat-soluble pigments from plants such as orange fruits, red or yellow fruits and vegetables, and some dark green vegetables. The key property of carotenoids is their capacity for quenching singlet oxygen and free radicals depending on the number of conjugated double bonds[2]. Lycopene is an acyclic isomer of β-carotene containing linearly arranged eleven conjugated and two unconjugated double bonds[3]. The unique chemical properties of lycopene derive from its structure, which makes it extremely hydrophobic and soluble in tissues, milk and organic solvents[2].

Lycopene from natural plant sources exists predominantly in an all-*trans* configuration, the most thermodynamically stable form with eleven carbon–carbon double bonds[4]. Of these eleven double bonds, seven can be isomerized from the *trans* form to the mono- or poly-*cis* forms under the influence of excess heat, light or certain chemical reactions. Although the predominant form of lycopene in foods is all-*trans*, human blood and tissues contain mainly *cis*-isomers. The bioavailability of *cis*-lycopene was found to be higher than that of *trans*-lycopene and *cis*-lycopene is preferentially absorbed[5].

Since lycopene lacks the β-ionone ring structure, it cannot form vitamin A. Its biological effects in man have therefore been attributed to mechanisms other than vitamin A including antioxidant effects and immune response modulators[2]. Lycopene is one of the most potent antioxidants, with a singlet-oxygen-quenching ability twice as high as that of β-carotene and ten times higher than that of α-tocopherol[6]. It has been suggested that dietary intake of tomatoes and tomato products

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containing lycopene might be associated with a decreased risk of chronic diseases such as cancer and CVD[7–11]. However, a large-scale study did not find an association between lycopene intake and prostate cancer risk[12]. In addition, a systematic review concluded that, given the limited number of randomized controlled trials published, it is not possible to support or refute the use of lycopene for the prevention or treatment of prostate cancer[13]. It has also been suggested that nutrients with redox modulator properties, such as lycopene, might have beneficial effects on the risk of other chronic diseases such as diabetes, neurodegenerative diseases and ocular disorders, as well as on asthma and viral infections[14].

Dietary lycopene is obtained from a limited list of foods only, in contrast to the other major carotenoids. The principal source of dietary lycopene is tomato in most people's diets. It is worth mentioning that the lycopene content varies substantially in different varieties of tomato, in different climates and with the use of different agricultural practices. Besides tomatoes and tomato-derived products (tomato juice, sauces, paste, etc.), watermelon, pink grapefruit, guava and papaya have been shown to be important sources of lycopene[14,15]. Although comparative bioavailability values for lycopene from different tomato products are unknown, lycopene from processed tomato products appears to be more bioavailable than that from raw tomatoes[5,16]. The release of lycopene from the food matrix due to processing has been reported to enhance lycopene bioavailability. Moreover, lycopene is a fat-soluble compound, which implies that absorption is improved when fat is present, and it should therefore be ingested within a mixed meal[17]. It has also been reported that the bioavailability of lycopene is affected by the dosage and the presence of other carotenoids, among which β-carotene. It was shown that the bioavailability of lycopene was significantly higher when it was ingested along with β-carotene than when ingested separately[18].

Results from dietary surveys show mean usual intakes of lycopene from natural dietary sources in different populations between 0·5 and 5 mg/d, with high intakes up to about 8 mg/d[19]. High consumption of fruits and vegetables, especially tomato products, may result in occasional intakes of 20 mg lycopene/d or more[3]. The European Food Safety Authority's Panel on Food Additives, Flavourings, Processing Aids and Materials in Contact with Foods established an Acceptable Daily Intake (ADI) for lycopene in 2008 of 0·5 mg/kg body weight (BW) per d[19]. This ADI value refers to lycopene from all sources, since lycopene is also reported to be used as a food colorant and ingredient in novel foods.

The aim of the present study was to assess the distribution of lycopene intake in the Belgian adult population and to determine which foods are the main contributors to the intake. Both total and *cis*-lycopene intakes were assessed.

Materials and methods

Food consumption data

Consumption data from the Belgian Food Consumption Survey (BFCS; dating from 2004) were used to perform the intake assessment. The target population of the BFCS comprised Belgian adults aged 15 years and older. Aims, design and methods of this survey can be found elsewhere[20]. The study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving human subjects/patients were approved by the medical ethical committee of the Scientific Institute of Public Health. Written informed consent was obtained from all participants. The sample included 3245 individuals who were randomly selected from the National Register using a multistage stratified procedure. Information on dietary intake was collected by two non-consecutive 24 h recalls. During the 24 h recall interviews, the respondent reported the quantity of all foods and beverages consumed during the preceding day. The survey covered one full year and the response rate was on average 41 %.

Food label survey

According to the EU Directive 94/36/EC on colours for use in foods, lycopene (E160d) is allowed to be used in certain categories of foods such those as listed in Annex V part 2 of the Directive[21]. Therefore, a label survey was performed to investigate whether food products on the Belgian market contained lycopene added as colour. The label survey was performed based on the presumption that labelling of food additives is mandatory. The labels of foods from five major Belgian supermarkets were screened for lycopene or E160d between May and August 2011.

Lycopene concentration of foods

Food samples were purchased in supermarkets and local stores. The ingredient lists of purchased foods were checked and all foods that had products containing lycopene among the ingredients listed were analysed.

A total of 322 food samples were selected, which were finely ground and homogenized before analysis. For the determination of total and *cis*-lycopene content in foods, an HPLC-UV method was used as previously described[22].

Intake assessment

Both 24 h recalls, which were carried out using the EPIC-SOFT software[23], were completed by 3083 participants; 1546 men and 1537 women (hence 6166 recalls).The individual intake of lycopene from a certain food product was calculated using the equation:

$$Y_i = (c_i \times x_i)/BW_i,$$

where Y_i is the intake of the lycopene by individual i from a particular food on an interview day (mg/kg BW per d); c_i is the concentration of the lycopene in the food (mg/kg);

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x_i is the consumption of a certain food by individual i (kg); and BW_i is the self-reported BW of individual i (kg). To estimate the total intake of lycopene/food group per d, individual daily intakes of lycopene from different foods were added up. The arithmetic means of the levels of lycopene in tomatoes, tomato products and foods containing lycopene derived from fruits and vegetables were calculated.

The usual intake distribution for lycopene was estimated with the Nusser method[24] using the C-SIDE software[25]. This statistical procedure adjusts for within-person or day-to-day variability. The usual intake distribution was weighted and adjusted for the age and sex distribution of the Belgian population and adjusted for day of the week and season.

In order to assess the contribution of several foods to lycopene intake, foods were classified into the following groups: tomatoes and tomato products (raw tomatoes, tomato concentrate, tomato paste, chopped/canned tomatoes); fruits and fruit products (watermelon, papaya, grapefruit, fruit salads); dairy products (cheeses with herbs, yoghurts with fruits); cereals and cereal products (chips, salted biscuits, breakfast cereals, raw pasta); biscuits; meat salads and products (meat salads, tête pressée and sausages); fish salads and products (fish salads and fish products in tomato sauce); butter with herbs; confectionery (jam, candies containing fruits); tomato and fruit juices; soups; and a group of sauces (such as ketchup, pesto rosso, pasta sauces, other sauces, tapenades) together with ready-to-eat meals containing tomatoes (such as pasta, pizza, lasagne).

The population proportion formula was used to determine the percentage contribution of each food group to the intake of lycopene[26], which includes summing the amount of the component provided by the food for all individuals and dividing by the total intake of that component from all foods for the entire study population.

Results

The label study performed on the Belgian market (represented by the five main supermarkets) indicated that no lycopene as either a food colour or a novel food ingredient was used in foods. Taking into account this observation, only the intake of lycopene from natural sources was further considered in the present study.

Table 1 shows the *cis*- and total lycopene concentration levels in different foods. As expected, the foods containing the highest lycopene level were tomatoes and tomato-derived products such as juices, paste, concentrate and sauces. However, high variability in the lycopene content was observed for all analysed food products. In the case of fresh tomatoes for example, total lycopene content ranged from 33·3 to 103·7 mg/kg. The concentration of *cis*-lycopene varied between the food groups as well. As expected, highly processed foods (sauces, soups, ready-to-eat meals) contained the highest amounts of *cis*-lycopene compared with non-processed foods (raw tomatoes and fruits).

The mean total lycopene intake of the general population (n 3083) was 4·1 (SD 2·3) mg/d and 8·5 mg/d at the

Table 1 *Cis*- and total lycopene contents of some common foods on the Belgian market

	No. of samples analysed	*Cis*-lycopene (mg/kg product)			Total lycopene (mg/kg product)		
		Mean	Min	Max	Mean	Min	Max
Raw tomatoes	5	4·0	1·9	5·1	69·0	33·3	103·7
Tomato concentrate	2	17·8	17·3	18·3	328·3	298·1	358·4
Tomato double concentrate	5	27·6	27·0	30·6	512·0	455·7	604·3
Canned tomatoes, whole or chopped	19	6·9	5·8	8·7	121·8	70·4	218·3
Tomato juice	5	3·5	2·2	5·7	72·2	60·6	82·5
Sun-dried tomatoes	2	5·5	4·9	6·0	86·5	79·2	93·8
Pasta with various tomato sauces	21	5·5	1·2	20·5	23·5	11·2	37·1
Pizza	6	3·2	0·7	7·6	22·9	11·0	41·3
Ketchup	4	4·3	1·0	7·1	81·4	28·8	148·5
Pesto rosso	4	10·2	8·0	16·0	68·2	41·8	121·2
Pasta sauces	18	13·2	3·8	18·9	68·0	28·9	120·0
Other sauces	14	4·2	1·5	5·0	33·9	6·9	80·8
Soup	16	6·5	0·3	14·5	27·4	1·3	77·9
Chips and popped snacks*	8	n/d	n/d	n/d	0·8	0·2	1·8
Cheeses*	7	0·9	0·2	1·3	6·0	1·0	17·5
Candies*	6	0·1	0·3	0·4	1·2	0·6	2·9
Water melon	2	2·9	1·5	4·3	134·7	98·1	171·3
Papaya	3	0·6	0·6	0·7	17·1	5·3	33·2
Grapefruit	1	0·4	–	–	28·2	–	–
Fruit salads	6	0·2	0·0	0·4	7·0	1·3	19·5
Fish products and salads	10	3·9	1·0	10·6	25·2	2·2	44·4
Meat salads, merguez, tête pressée	9	2·3	0·6	6·0	8·3	0·1	28·7

n/d, not detected.
*Only samples with 'tomato extract' or 'tomato powder' mentioned on the label were considered.

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95th percentile (Table 2). The total lycopene intake of men was significantly higher than that of women (4·6 (SD 2·6) mg/d on average *v.* 3·6 (SD 2·1) mg/d on average respectively; $P < 0·001$). For men the intake at the 95th percentile was 9·5 mg/d while for women the lycopene intake at the 95th percentile was 7·6 mg/d. The higher intake among men compared with women was mainly due to the higher lycopene intake via sauces and ready-to-eat meals among men (1·75 mg/d) compared with women (1·17 mg/d). For both men and women, the total lycopene intake was lower in the older than among the younger age groups.

The mean total lycopene intake was 0·059 mg/kg BW per d. At none of the percentiles was the ADI of 0·5 mg/kg BW per d exceeded. Even at the 99th percentile, the total lycopene intake was only 0·165 mg/kg BW per d which is about 33 % of the established ADI value (Table 2 and Fig. 1). The intake of *cis*-lycopene among the Belgian population was 0·019 (SD 0·011) mg/kg BW per d, which represents about 30 % of the total lycopene intake. Similar to total lycopene, *cis*-lycopene intake was higher among men than women, although to a slightly lower extent (Table 3).

Table 4 shows the food sources contributing to lycopene intake for the Belgian adults. From Table 4 it is obvious that the main contributors to lycopene intake in the Belgian population were the group of tomatoes and tomato products (43 %), together with the group of sauces and ready-to-eat meals (41 %). These two food groups accounted for about 85 % of the total lycopene intake.

Discussion

The results of the present study show that the mean intake of lycopene among Belgian adults was 0·059 mg/kg BW per d. The lycopene intake of the Belgian population was well below the ADI which was set by the European Food Safety Authority. Intake of *cis*-lycopene, which may be formed upon processing of foods involving heat and which is more bioavailable than *trans*-lycopene, represented about one-third of total lycopene intake. When comparing the lycopene intake of the Belgian adult population with that of populations in other countries, it was observed that the intake in Belgium is comparable to the intake of adults in the Netherlands, France, Republic of Ireland and Australia (Table 5)[27]. Reported lycopene intakes in the USA and Canada were much higher due to the difference in dietary assessment methods used. It was previously shown that mean dietary intakes of lycopene estimated with FFQ (as in the case of intake assessment for the USA and Canada) may be higher than those

Table 2 Estimated total lycopene intake from natural sources (in mg/kg BW per d and mg/d) of the Belgian adult population; Belgian Food Consumption Survey (BFCS), 2004

	n	Mean	SD	P50	P95	P97·5	P99	% ADI
		Results in mg/kg BW per d						
Total population	3083	0·059	0·033	0·052	0·123	0·142	0·165	11·8
Men								
Total population	1546	0·061	0·036	0·054	0·129	0·149	0·176	12·2
15–18 years	381	0·066	0·027	0·062	0·115	0·128	0·143	13·2
19–59 years	394	0·071	0·031	0·068	0·128	0·142	0·160	14·2
60–74 years	399	0·033	0·015	0·032	0·058	0·065	0·073	6·6
>74 years	372	0·030	0·020	0·026	0·068	0·081	0·098	6·0
Women								
Total population	1537	0·057	0·033	0·050	0·122	0·142	0·167	11·4
15–18 years	379	0·074	0·029	0·071	0·128	0·141	0·159	14·8
19–59 years	436	0·065	0·036	0·057	0·136	0·157	0·183	13·0
60–74 years	390	0·042	0·020	0·039	0·078	0·087	0·099	8·4
>74 years	332	0·026	0·016	0·022	0·059	0·070	0·086	5·2
		Results in mg/d						
Total population	3083	4·1	2·3	3·6	8·5	9·8	11·4	–
Men								
Total population	1546	4·6	2·6	4·1	9·5	10·9	12·7	–
15–18 years	381	4·3	1·8	4·1	7·6	8·5	9·5	–
19–59 years	394	5·4	2·4	5·2	9·7	10·8	12·2	–
60–74 years	399	2·6	1·1	2·5	4·4	4·9	5·5	–
>74 years	372	2·2	1·4	1·9	5·0	5·9	7·2	–
Women								
Total population	1537	3·6	2·1	3·1	7·6	8·8	10·3	–
15–18 years	379	4·3	1·6	4·1	7·1	7·9	8·8	–
19–59 years	436	4·1	2·1	3·7	8·1	9·2	10·5	–
60–74 years	390	2·8	1·3	2·6	5·1	5·7	6·5	–
>74 years	332	1·7	1·1	1·4	3·8	4·5	5·6	–

BW, body weight; P, percentile; ADI, acceptable daily intake.

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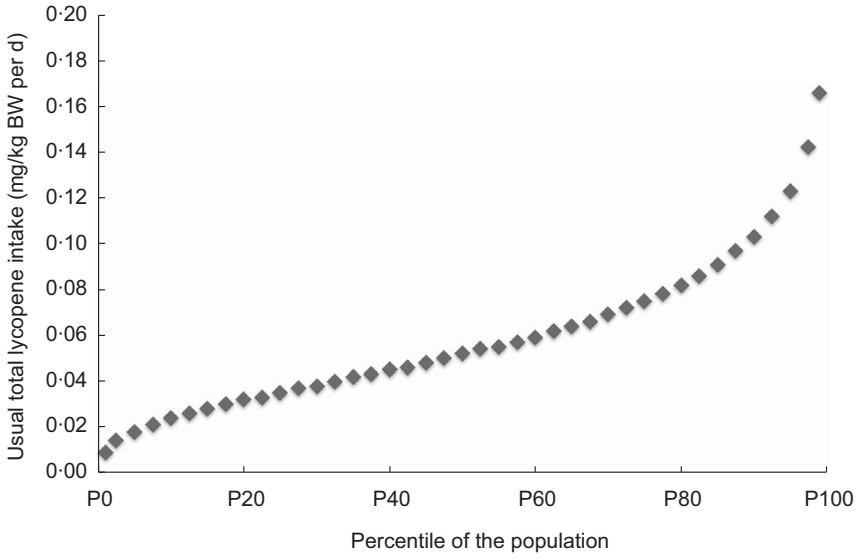

Fig. 1 Estimated usual daily intake of total lycopene from natural sources (mg/kg body weight (BW) per d) of the Belgian adult population (*n* 3083, all days, all population); Belgian Food Consumption Survey (BFCS), 2004

Table 3 Estimated *cis*-lycopene intake from natural sources (in mg/kg BW per d and in mg/d) of the Belgian adult population; Belgian Food Consumption Survey (BFCS), 2004

	n	Mean	SD	P50	P95	P97·5	P99	% ADI
		Results in mg/kg BW per d						
Total population	3083	0·019	0·011	0·017	0·041	0·046	0·053	3·8
Men								
Total population	1546	0·020	0·012	0·018	0·042	0·048	0·055	4·0
15–18 years	381	0·020	0·010	0·018	0·040	0·045	0·051	4·0
19–59 years	394	0·020	0·011	0·019	0·041	0·046	0·053	4·0
60–74 years	399	0·017	0·010	0·015	0·036	0·040	0·045	3·4
>74 years	372	0·020	0·011	0·020	0·038	0·042	0·048	4·0
Women								
Total population	1537	0·019	0·011	0·017	0·040	0·045	0·052	3·8
15–18 years	379	0·019	0·010	0·018	0·039	0·044	0·051	3·8
19–59 years	436	0·019	0·010	0·018	0·037	0·041	0·048	3·8
60–74 years	390	0·018	0·010	0·017	0·036	0·040	0·045	3·6
>74 years	332	0·017	0·012	0·015	0·040	0·046	0·053	3·4
		Results in mg/d						
Total population	3083	1·33	0·75	1·2	2·8	3·1	3·5	–
Men								
Total population	1546	1·49	0·85	1·3	3·1	3·5	4·0	–
15–18 years	381	1·30	0·64	1·2	2·5	2·8	3·2	–
19–59 years	394	1·55	0·83	1·4	3·1	3·5	4·0	–
60–74 years	399	1·29	0·74	1·2	2·7	3·0	3·4	–
>74 years	372	1·47	0·74	1·5	2·7	3·0	3·3	–
Women								
Total population	1537	1·17	0·62	1·1	2·3	2·6	3·0	–
15–18 years	379	1·12	0·59	1·0	2·2	2·5	2·9	–
19–59 years	436	1·17	0·50	1·1	2·1	2·3	2·6	–
60–74 years	390	1·23	0·58	1·2	2·3	2·5	2·8	–
>74 years	332	1·09	0·77	0·9	2·5	2·8	3·3	–

BW, body weight; P, percentile; ADI, acceptable daily intake.

obtained with diet records[28], both estimated records and weighed records[29,30]. The high intakes obtained with FFQ may result from a tendency of individuals to overestimate the consumption of vegetables and fruits when presented with a long list of food items. Differences between countries may also be linked to different dietary habits, the quality of the food composition database used and the variation of lycopene concentration within foods.

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Table 4 Contribution of several food groups to the mean intake of total lycopene from natural sources (mg/kg BW per d) of the Belgian population (all population, 6166 interviews, 3083 respondents); Belgian Food Consumption Survey (BFCS), 2004

Food group	Mean	SD	P95	% contribution to mean total intake	% contribution to the ADI
Tomatoes and tomato products	0·0230	0·0574	0·1446	42·99	4·60
Sauces and ready-to-eat meals	0·0220	0·0613	0·1584	41·12	4·40
Tomato and fruit juices	0·0027	0·0252	0·0127	5·04	0·54
Fruits and fruit products	0·0025	0·0287	0·0011	4·67	0·50
Cereals and cereal products	0·0009	0·0027	0·0066	1·68	0·18
Soups	0·0008	0·0117	0·0000	1·50	0·16
Confectionery	0·0006	0·0013	0·0030	1·12	0·12
Fish salads and products	0·0004	0·0028	0·0000	0·75	0·08
Biscuits	0·0003	0·0011	0·0022	0·56	0·06
Meat salads and products	0·0003	0·0022	0·0000	0·53	0·06
Cheeses and yoghurt	0·0002	0·0006	0·0009	0·37	0·04
Butter with herbs	0·0000	0·0003	0·0000	0·00	0·00
Total	0·0535	0·0914	0·2358	–	–

BW, body weight; P, percentile; ADI, acceptable daily intake.

Table 5 Dietary lycopene intake from natural sources in selected countries[27]

	Dietary intake (μg/d)				Theoretical intake (mg/kg BW per d)*	
	Males		Females			
Study	Mean	Range	Mean	Range	Males	Females
Spain (*n* 70)	1640	500–2640	1640	500–2640	0·023	0·023
France (*n* 76)	4750	2140–8310	4750	2140–8310	0·067	0·067
Republic of Ireland (*n* 76)	4430	2730–71 307	4430	2730–71 307	0·063	0·063
Netherlands (*n* 75)	4860	2790–7530	4860	2790–7530	0·069	0·069
	Mean	SD	Mean	SD		
UK (*n* 42)	1068	865	–	–	0·015	0·015
USA (*n* 307)	10 497	6177	10 405	7278	0·149	0·148
Canada (*n* 1543)	6363	11 849	6363	11 849	0·090	0·090
Australia (*n* 115)	3813	9752	3813	9752	0·054	0·054

BW, bodyweight.
*Considering that mean BW is 70 kg.

The current study presents data on lycopene intake of the Belgian adult population. The total and *cis*-lycopene intakes were calculated based on their determination in a number of food products using an in-house analytical method[22]. Therefore no variability regarding differences in analytical method influenced the results for intake.

Since no food products with added lycopene as a colour were found on the Belgian market, the reported intake represents the intake from natural sources only. The lack of an E160d number of lycopene on food labels is probably due to the fact that industry uses tomato-based powders or paste as addition instead of the additive.

To date, no recommended dietary intake levels have been established for lycopene. However, based on the established ADI value we can imply that no more than 35 mg of lycopene (0·5 mg/kg BW per d × 70 kg average BW) should be ingested on a daily basis. Lycopene may have beneficial effects to health. One meta-analysis reported a protective effect of lycopene on serum cholesterol and blood pressure[31]. The study on serum lipids revealed a significant cholesterol-lowering effect of lycopene for serum total cholesterol (mean change: −7·55 (SE 6·15) mg/dl; $P = 0·02$) and LDL cholesterol (mean change: −10·35 (SE 5·64) mg/dl, $P = 0·0003$) in the subgroup of trials using lycopene dosages of ≥25 mg daily, whereas subgroup meta-analysis of trials using lower lycopene dosages was not significant. Meta-analysis of the effect of lycopene on systolic blood pressure of all trials suggested a significant blood-pressure-reducing effect (mean systolic blood pressure change: −5·60 (SE 5·26) mmHg, $P = 0·04$). In our study however, lycopene intakes were lower than the 25 mg/d for the whole distribution of intake. On the other hand, increasing evidence suggests that a single serving of tomatoes or tomato products ingested daily may contribute to protection from DNA damage. As DNA damage seems to be involved in the pathogenesis of prostate cancer, the regular ingestion of tomatoes or tomato products might reduce the risk of disease[32]. Another study among 27 261 US women suggested that consuming ≥10 compared with <1·5 servings of tomato-based food products weekly results in clinically modest but significant improvements in total cholesterol,

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total cholesterol:HDL cholesterol ratio and glycated Hb (HbA1c) but not in other coronary biomarkers[33].

Limitations of the current study include the fact that products were analysed as purchased instead of as consumed, which may have underestimated especially *cis*-lycopene intake. Many factors affect lycopene bioavailability and absorption such as food processing, the presence of fat and individual variability in absorption capacity. These were not taken into account in the present study. Another important aspect to consider is that any given food source may vary greatly in lycopene content, because of differences in cultivar, technological processing, domestic cooking, etc. This was also not taken into account. Many more analyses on lycopene concentration in foods would be needed and a probabilistic intake assessment would have to be performed to take into account variation in lycopene concentration within foods.

Conclusions

The results of the present study showed that the mean lycopene intake of the Belgian adult population was about 4·1 mg/d or 0·059 mg/kg BW per d. This intake was comparable to the lycopene intake in neighbouring countries and was well below the ADI value established by the European Food Safety Authority. Tomatoes and tomato products together with ready-to-eat meals containing tomato sauces were the products contributing the most to the lycopene intake.

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