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Authors:
Ismael San Mauro Martín, Elena Garicano Vilar, Sara López Oliva, Sara Sanz Rojo

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Existing differences between available lists of FODMAP containing foods

Ismael San Mauro Martín; Elena Garicano Vilar; Sara López Oliva; Sara Sanz Rojo
Research Centre in Nutrition and Health. Grupo CINUSA. Madrid, Spain.

Corresponding author: Ismael San Mauro Martin. Research Centre in Nutrition and Health. Paseo de la Habana, 43. 28036, Madrid, Spain. E-mail: info@grupocinusa.es; ORCID: 0000-0002-7415-0293

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Abbreviations: FODMAP, fermentable oligosaccharides, disaccharides, and monosaccharides and polyols; FOS, fructooligosaccharides; GOS, galactoligosaccharides; IBS, irritable bowel syndrome.

Keywords: Oligosaccharides. Disaccharides. Monosaccharides. Polyols. FODMAP diet.

ABSTRACT

Background and aim: Reduced intake of fermentable oligosaccharides, disaccharides, and monosaccharides and polyols (FODMAP) is useful to treat functional gastrointestinal disorders. However, there is no consensus on which foods should be included in the list of FODMAP, due to the lack of FODMAP-profiles characterization of many different foods. This study aimed to emphasize the need to unify the FODMAP lists to prevent patients' confusion. We hypothesized the lists of FODMAP do not comprise all products that can contain high levels of FODMAP. Methods: PubMed, ScienceDirect, Scielo and Cochrane were

searched to identify food composition tables, reviews, food analytical publications, laboratory analysis and clinical trials that contained FODMAP lists. Results: From 1308 articles identified, 10 were selected. 22.6% of the 204 foods listed were classified differently between studies. This included almonds, avocados, banana, broccoli, soft cheese, eggplant and walnuts. Nutritional guidance can be taken from existing FODMAP-literature, but the information given is not always consistent. Conclusion: Unvarying lists of low-FODMAP foods should be elaborated that will provide the patient with accurate information on the FODMAP diet.

1. INTRODUCTION

Dietary carbohydrates, which are fermented by bacteria in the colon and are poorly absorbed in the human intestine, are known as fermentable oligosaccharides, disaccharides, and monosaccharides and polyols (FODMAP) (1). This short-chain carbohydrates were discovered in food by researchers in the Department of Gastroenterology at Monash University (2) in 2005. The ingestion of FODMAP may cause several symptoms, such as abdominal pain or bloating. Dietary therapy with low FODMAP diet has been shown to be helpful in the treatment of those functional gastrointestinal disorders (1).

A poor FODMAP diet is understood to be one with a low content of fermentable oligosaccharides (fructooligosaccharides (FOS), galactoligosaccharides (GOS)), disaccharides (lactose), monosaccharides (fructose) and polyols (xylitol, mannitol, sorbitol, maltitol) (3). This type of dietary treatment consists of two phases. The first phase consists of a severe FODMAP restriction for 4-8 weeks, followed by a second phase in which the initially withdrawn foods are reintroduced, according to each person’s tolerance ("top-down" methodology) (4). This approach is usually applied in patients who do not consume large amounts of FODMAP and are very symptomatic (5). The “top-down methodologhy is the

most frequent treatment. However the amount of FODMAP in the diet can also be managed in the opposite direction (“bottom-up” methodology). Only foods with fairly high amounts of FODMAP are restricted in the first place, followed by a restriction of foods with lower FODMAP contents until reaching the tolerance level (4). This second approach is usually applied in patients who consume a large amount of FODMAP or who have moderate symptoms (5). In order to ensure that the diet is not deficient despite the restrictions, it is necessary that the diet is controlled by experienced dietitians.

Fructans and FOS are found naturally in food such as garlic, onions, rye and wheat, the GOS in legumes, lactose in dairy products like milk, soft cheeses and yogurts, fructose in honey, corn syrups and in some fruits like apple and pear and the polyols in fruits with bones, some vegetables and artificial sweeteners (6). The European legislation lacks of definitions and regulations regarding FODMAP, therefore very few low FODMAP labelled food products are available in the European market (1).

Most studies related to the FODMAP diet provide lists of allowed foods or foods that should be eliminated in a low FODMAP diet. This frequently cited lists comprise the most abundant nondigestible, osmotically active and easily fermentable dietary carbohydrates including fructans and FOS, GOS, lactose, fructose in excess of glucose and polyols (1). However, there is no established consensus on which foods should be included and excluded from the list of FODMAP, probably due to the lack of characterization of the FODMAP-profiles of a wide range of raw ingredients and food products. We hypothesized the lists of FODMAP do not comprise all products that can contain high levels of FODMAP. Therefore, the aim of this study is to emphasize the need to unify the information on the FODMAP content of foods to prevent patients’ and dietitians´ confusion.

2. METHODS AND MATERIALS

2.1 Data sources and search strategies

A bibliographic search was conducted from June to December 2020. Articles published within the last 10 years were included. The databases used were PubMed, ScienceDirect, Scielo and Cochrane. The search strategy was performed using MeSH descriptors and Boolean operators (AND and OR) in each database. The keywords used were ((("Disaccharides/administration and dosage"[Mesh]) OR ("Disaccharides/analysis"[Mesh])

OR ("Monosaccharides/administration and dosage"[Mesh]) OR ("Monosaccharides/analysis"[Mesh]) OR ("Polymers/administration and dosage"[Mesh]) OR ("Polymers/analysis"[Mesh]) OR ("Dietary Carbohydrates/administration and dosage"[Mesh]) OR ("Dietary Carbohydrates/analysis"[Mesh])) AND "Food Analysis"[Mesh].

2.2 Eligibility criteria

The inclusion criteria established for the selection of articles were food composition tables, reviews, food analytical publications, laboratory analysis and clinical trials. Duplicated titles, conference summaries, editorial papers and publications that were not related to the topic were excluded. Languages were limited to English and Spanish. The literature was independently selected by two researchers, and inconsistencies were discussed.

2.3 Data collection

All foods mentioned in each study were listed and divided in low, moderate or high FODMAP content.

Most publications used the Monash Institute food database (7) as a reference for their recommendations. Thus, FODMAP content classification is based on serving sizes and considered as such when not specified.

Following Varney et al. (2017) (8), low FODMAP cut-off values in these publications are as follows: 0.3 g oligosaccharides, 0.4 g polyols, 0.15 g excess fructose, and 1 g lactose per serving size. Nonetheless, food lists from clinical trials did not state their cut-off values (5,9–12).

3. RESULTS

3.1 Search results

Figure 1 shows the articles selection diagram. A total of 1308 articles were retrieved from the search. After reading the titles, abstracts and the methods section and applying the exclusion criteria, only 10 studies were eligible for this article.

3.2 Study characteristics

All of the chosen studies have a low-medium grade of evidence as described by the GRADE system (13). The narrative review of Pensabene et al. (9) synthesized the current

information on the role of a low FODMAP diet in reducing symptoms related with functional abdominal pain disorders in children. Casellas et al. (5) is a consensus document on the purpose of elimination diets in irritable bowel syndrome (IBS) prepared by different experts representing the main Spanish scientific societies. The study by Baraguán et al. (10) analyses the implementation of the low FODMAP diet as a treatment of functional chronic abdominal pain in paediatric population of a Mediterranean area, and its response to it. Dieterich et al. (12) studied how a low FODMAP affected clinical symptoms, stool microbiota, and intestinal integrity and inflammation, versus a gluten-free diet. Pérez y López et al. (11) evaluated the clinical response in patients with IBS, in its different clinical variants, to the low FODMAP diet. Ispiryan et al. (1) characterized the FODMAP-profiles of a vast range of cereal-product ingredients, to develop low FODMAP products. A year after they investigated the impact of malting on the FODMAP content of some cereals and legumes (14). Prichard et al. (15) aimed to quantify the FODMAP content of 20 commonly consumed foods in ethnic minority groups. Tuck et al. (16) focused on measuring the levels of FODMAP in plant-based foods used in vegetarian/vegan diets and investigated whether the levels changed after food processing. Latulippe et al. (17) focused on understanding fructose intolerance and malabsorption derived from its consumption and from other carbohydrates.

Table 1 shows a compilation of foods from the different studies (1,5,17,7,9–12,14–16) indicating their FODMAP content in each food. A total of 204 foods are listed. 67.6% (n=138) of the listed foods have been classified by the same token by all authors. On the contrary, 22.6% (n=46) of the foods were classified differently between studies. These include foods as common as almonds, avocados, banana, broccoli, fresh/soft cheese, eggplant and walnuts, among others. The 9.8% (n=20) remaining foods were only cited by one study; therefore, no comparison could be made.

4. DISCUSSION

FODMAP are present in a vast number of foods. Current evidence summarized in this article suggests that there is no homogeneous consensus on their levels, and the difference between foods makes it hard for nutritionists and health professionals to accurately advise patients and patients find it hard to correctly follow the diet based on the current lists. Therefore, the hypothesis was accepted.

This article has shown how three different FODMAP contents (high, moderate and low) were attributed to the same food. This was the case of banana, blueberry, broccoli, ice cream, pecan nuts and walnuts. Furthermore, several foods such as celery, corn, eggplant, grapes and squash were classified as opposite (high vs. low FODMAP content) by more than one study in each case; whereas, just one study would differ in the classification of foods like avocado, beetroot, bell pepper, wheat-based biscuits, cashews, soft/fresh cheese, sweet corn, grapefruit, lentils, among others.

Differences in the classification of FODMAP content of foods could be due to the different methodologies employed for their analysis. This makes the rigor of the studies vary widely, as do the findings. All the tools and methods should be standardized to achieve the goal of obtaining reliable information. Each assessed FODMAP must be defined in the same way, the measurement units and the methods used to assign values should be comparable if not the same (18). Other explanations as to why the classifications of FODMAP content may vary could be due to the ripening degree of the food (e.g. in fruits and vegetables) (19), the preparation of the food or the serving size (20). In the ripening banana, the fructose concentration changes after the fruit reaches the climacteric stage (19). The dehydration of fruit to prepare dried fruits concentrates all sugars, including FODMAP, which were present in the fresh fruit initially. Some dried fruits (cranberries for example) are only high in FODMAP if consumed in larger serving sizes (20). Some saccharides, such as fructans, which are not found in the same fresh fruit have also been detected in dried fruit (20). Yeasts and lactobacilli use fructans during fermentation. Hence, the sourdough fermentation process is known to reduce levels of FODMAP. Certain traditionally-fermented sourdough breads made from lower FODMAP flours, such as spelt and oat, are classed as low or moderate in FODMAP content (20). However, sourdough breads made from high FODMAP flours (such as rye and wheat) are still considered to be high in FODMAP (20).

Developing a low FODMAP diet required o the establishment of “cutoff values” to classify foods as low FODMAP. These cutoff values relate to each particular FODMAP sugar present in a food (8). Cutoff values were initially derived by considering (based on clinical experience) the FODMAP content and typical serving size of food, consumed in a single sitting or meal, that potentially triggered symptoms in individuals with IBS. Foods that were generally well tolerated were also considered. This enabled the establishment of threshold levels for each FODMAP, above which most people experience symptoms. Although the

reliability of these FODMAP cutoff values has been tested (21,22) not every study may have relied on the same cutoff levels to classify the FODMAP content of foods (8).

The application of the FODMAP diet is limited by the paucity of food composition data available (15) and no adaptations to different cultures and gastronomies. FODMAP levels should be incorporated in the food composition databases and should be updated frequently. New foods and recipes need to be added promptly so that the results are precise and accurate also over time. Spanish Speakers FODMAP Diet Expert Group (23) is an initiative to this fact, proposing a FODMAP diet guide culturally adapted to different countries for Dietitians-Nutritionists and nutrition experts, to facilitate the management of patients who benefit from the FODMAP diet.

Instructing patients on a low FODMAP diet to limit their intake of high FODMAP content products would seem a reasonable recommendation. However, following such a recommendation will be challenging for several reasons. First, simply knowing that a product contains FODMAP does not allow an accurate estimate of its content. Second, FODMAP are generally not listed in the labels, making it difficult to identify the presence of a specific FODMAP. Third, FODMAP-free or low products may require more effort to identify. The foods listed in the Monash FODMAP App (7) are an average of a number of products that have been tested, therefore they are unable to name brands in the app. Any action taken by manufacturers (e.g., analyze their products for FODMAP content and make the data available) and policy makers (e.g., mandate to include FODMAP content on the nutrition facts label) will help patients limit their FODMAP intake, will help providers to better instruct patients, and will help researchers to accurately assess dietary intake.

The situation afore-described can lead patients to assume erroneous or insufficiently verified information, and generates incomplete or ineffective dietetic treatments. Existing FODMAP-literature predominantly serves as nutritional guidance for individuals adhering to the low FODMAP diet, but the information given is not always consistent. Consensus and unvarying lists of low-FODMAP foods should be elaborated that will provide the patient with adequate an accurate information on the FODMAP diet. Further studies are necessary to provide a dry matter-based characterization of the FODMAP-profiles of a wider range of foods, to homogenize the list of FODMAPs and allow patients handle their symptomatology that the FODMAP may cause in a more accurate way.

Limitations: This is a descriptive analysis of the literature available to date. Data are highly variable and may significantly differ between studies. The classification of FODMAP content of foods is ambiguous due to the scarce detail given in the studies relating to the methodology employed for the analysis or the lack of describing factors that influence the results. In this regard, more attention should be paid to the characterization of the FODMAP-profiles and the creation of low-FODMAP foods databases. Further studies are necessary to establish safety limits for FODMAP in food, and the intolerance they may cause.

5. Ethical Statements

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Declarations of interest: The authors declare that there is no conflict of interest.

Ethical approval: does not apply.

Research data: available on demand to the corresponding author.

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Table 1. Compilation of foods indicating their low, medium or high content in FODMAPs

	Monash App (7)	Pensabene (9)	Casellas (5)	Pérez y López (11)	Dieterich (12)	Baranguán (10)	Ispiryan (1)	Prichard (15)	Tuck (16)	Latulippe (17)	Ispiryan (14)
Cereal and tubercle											
Barley											H (fn)
Barley (malted)											H (fn)
Barley (sprouted)	L								L		
Biscuits (gluten-free)	L				L	L	L				
Biscuits (wheat-based)	L				H	H	H (g,fn,l)				
Buckwheat	L		L								L
Buckwheat (malted)											L
Cassava	L							L			
Corn	H (s)	L	L		H	L					
Corn pasta		L			L						
Corn (sweet)	H (s)		H (p)			L					
Crackers (gluten-						L	L				

free oat)											
Crackers (wheat-based plain)	L					H	L				
Crackers (wheat-based garlic)						H	H (f,fn)				
Gluten-free products	L	L			L	L					
Noodles	H (f,fn)	L									
Oat	L	L	L		L						L
Oat (malted)											L
Polenta	L	L			L	L					
Potato	L	L	L		L	L					
Rice	L	L	L		L	L					
Rye	H (fn)		H (fn)	H (o)	H	H					
Rye (sprouted)	H (fn)							H (fn)			
Soda bread (brown)						H	H (g,fn,l)				
Soda bread (whole wheat)						H	H (g,fn,l)				
Sorghum flour	L							L			

Sourdough		L								
Spaghetti, gluten-free (cooked, uncooked)	L				L	L				
Spaghetti, wheat (cooked, uncooked)	H (fn)		H (fn)		H	H	H (fn)			
Taro	L							L		
Tortilla chips		L			L	L				
Wheat	H (g,fn)		H (fn)	H (o)	H	H				H (fn)
Wheat germ	H (g,fn)								H (g,fn)	
Wheat sourdough bread	L						L			
Wheat (malted)										H (fn)
Wheat (sprouted)	H (fn)								H (fn)	
White loaf (gluten-free)	L						L			
White loaf (wheat)	H (f,fn)				H	H	L			
Yam (fresh, pounded)	L							L		

Seeds										
Chia seeds	L	L								
Egusi seeds	L						L			
Fenugreek seeds	L						H (g,o)			
Flax seeds	L	L								
Poppy seeds	L						L			
Pumpkin seeds	L	L								
Legumes										
Adzuki beans (canned, dried, cooked)	H (g)		H (g)		H	H		H (g)		
Bean sprouts		L	L		L					
Chana dal	H (g)						H (g)			
Chickpeas			H (p)	H (o)	H	H				H (g)
Chickpeas (canned)	M (g)	L								
Chickpeas (malted)										H (g)
Chickpeas (sprouted)	H (g)							H (g)		

Fava beans	H (f)				H						
Kidney beans, red (canned)									L		
Kidney beans, red (dried, cooked)	H (g,fn)		H (g)	H (o)	H	H			H (g,fn)		
Kidney beans, red (sprouted)	H (g,fn)								H (g,fn)		
Lentils	L		H (g)	H (o)	H	H					H (g)
Lentils (canned)	L	L									
Lentils (malted)											H (g)
Lentils (red)	M (g)				H				H (g)		
Mung beans (sprouted)	L								L		
Soy roll									L		
Tempeh	L	L							L		
Tofu (firm)	L	L									
Urid dal	L							L			
Nuts											
Almonds	H (g)	L				H					
Cashews	H (g,fn)	L				H					

Cashews (activated)	H (g)							H (g)		
Macadamia nuts	L	M				H				
Pecan nuts	L	M				H				
Pistachios	H (g,fn)					H				
Pistachios (activated)	H (g,fn)							H (g,fn)		
Walnuts	L	M				H				
Fruit										
Ackee	L						L			
Apple	H (f,s)		H (f)	H (f,p)	H	H			H (f)	
Avocado	H (s)		M	H (p)		H				
Blackberry	H (s)		L							
Blueberry	H (fn)	L	L		M	L				
Breadfruit	L						L			
Carambola	L	L			H					
Banana	H (fn)	L	M		L	L			H (f)	
Cherry	H (f,s)		H (p)	H (p)	H	H				
Choko/Chayote	L	L					L			
Coconut	M (s)	L								

Coconut flour	H (f,fn,s)								H (f,fn,s)	
Cranberries		L			L					
Dragon fruit	L									
Durian	L	L								
Grapefruit	H (fn)	L	L		L	L				
Grapes	L	L	L		H	L				H (f)
Guava (tinned in syrup)	H (f,fn)				H			H (o,fn)		
Kiwi fruit	L	L	L		L	L				
Lemon			L		L					
Lemon juice	L	L								
Lime		L	L		L	L				
Lychee	H (s)				H					
Mango	H (f)		H (f)	H (f)	H	H				
Melon (Cantaloupe)	M	L								
Melon (Honeydew)	H (fn)	L			H					
Nectarine	H (fn,s)				H	H				

Orange	L	L	L		L					H (f)
Papaya	L	L	L		H	L				
Passion fruit	L	L	L							
Paw paw	H (fn)	L								
Peach	H (s)		H (p)	H (p)	H	H				
Pear	H (f,s)		H (f)	H (p)	H	H				H (f)
Pineapple	L		L		L					
Plantain	L							L		
Plum	H (fn,s)		H (p)	H (p)	H	H				
Raisin	H (fn)		H (p)	H (f)	H	H				
Raspberry	H (fn)	L	L		L	L				
Strawberries	L	L	L		L	L				
Tamarind	L							H (o,fn)		
Tomato	L	L	L		L	L				
Watermelon	H (f,fn,m)		H (f)	H (p)	H	H				H (f)
Vegetables										
Asparagus	H (f,fn)		H (fn)	H (o)	H	H				
Bamboo shoot	L	L	L							
Beetroot	H (g,fn)	L	H (fn)		H	H				

Bell pepper	L	L	H (p)		L	L					
Bok choy	L	L									
Broccoli	L	M	H (fn)	H (o)	H	H					
Brussel Sprouts	H (fn)		H (fn)	H (o)		H					
Callaloo	L							L			
Capsicum	L	L									
Carrot	L	L	L		L					L	
Cauliflower	H (m)		H (p)	H (p)	H	H					
Celery	H (m)	L	L		L	H					
Chives	L	L	L		L						
Choy sum	L	L									
Dulse	L								L		
Eggplant	L	L	H (fn)		H	L					
Fennel	H (fn)				H	H					
Fenugreek leaves	L							L			
Garlic	H (fn)		H (fn)	H (o)	H	H					
Green bean	L	L	L		L	L					
Karela	H (g)							H (g)			
Lettuce	L	L	L		L	L					
Mushrooms	H (fn,m)		H (p)	H (p)	H	H					

Onion	H (g,fn)		H (fn)	H (o)	H	H			L
Parsnip	L	L							
Pickled artichoke	H (f,fn)							H (fn)	
Pickled beetroot	L							L	
Pickled garlic								L	
Pickled onion	L							L	
Pumpkin		L	L	H (p)	L	L			
Pumpkin (canned)	L	L							
Rhubarb	L	L	L						
Silver beet	L	L							
Spinach	L	L			L	L			
Spring onion	H (fn)	L							
Squash	H (g,m)		L	H (p)		L			
Wheat grass								L	
Zucchini	M (fn)	L	L		L	L			
Dairy									
Brie	L	L	L		L	L			
Camembert	L	L	L		L	L			
Cheddar	L	L							
Cheese (fresh)	L		H (l)	H (l)	H	H			

Cheese (soft)	L			H (l)	H	H			
Cheese (hard)		L	L		L	L			
Ice cream	M (l)		H (l)	H (l)	H	H			L
Lactose free milk	L	L	L		L	L			
Mozzarella	L	L			L				
Parmesan		L			L	L			
Whole milk	H (l)		H (l)	H (l)	H	H			
Yoghurt	H (l)		H (l)	H (l)	H	H			
Dairy substitute									
Coconut milk (canned)	L							L	
Coconut milk (UHT)	H (fn)			H (p)				H (fn,s)	
Coconut milk (with inulin)	H (fn)							H (fn)	
Coconut yoghurt	L							L	
Macadamia milk	L							L	
Quinoa milk (agave sweetened)								H (f,fn)	

Quinoa milk (unsweetened)	L								H (fn)		
Rice milk	L	L				L					
Soy cheese	L								L		
Soy milk	H	L			L						
Soy yoghurt (plain, vanilla)									H (fn)		
Sweeteners, additives and seasonings											
Agar-agar	L								L		
Aspartame		L	L								
Corn syrup			H (f)	H (f)						L	
Fructose syrup			H (f)	H (f)						H (f)	
Garlic infused oil	L	L									
Glucose		L	L		L	L					
Gluten (fresh)									L		
Golden syrup	H (fn)	L				L					
Honey	H (f)		H (f)	H (f)	H	H				H (f)	
Maple syrup	L	L	L		L					L	
Molasses	H (f,fn)	L	L							L	
Stevia	L	L				L					

Sucrose	L	L	L	L	L	
Vegan substitutes						
Egg replacer	L					L
Egg yolk (vegan)						L
False bacon						H (g,fn)
False pork						L
False chicken (soybean extract)						H (g)
False chicken (soybean)	H (g,fn)					H (g,fn)
False chicken (canned fried gluten)						L
False chicken (soy protein, soybean)						H (fn)
False chicken (gluten, soybean)						H (fn)
Others						
Kelp noodles	L					L
Kombucha	H (fn)					H (fn)

Kvass	L								L	
Pea protein isolate	L								L	
Rice protein isolate									L	
Soft drinks (light)				H (p)	H	H				H (f)
Sorbet		L	L			L				
Soy protein (textured)	H (g,fn)								H (g,fn)	
Spirulina	L								L	
Wakame flakes	M (m)								H (m)	
Wasabi (powder)	L							L		
Wheat gluten	L								L	
Yeast (nutritional)	L								L	

L, low FODMAP content; M, medium FODMAP content; H, high FODMAP content; G, galacto-oligosaccharides; o, oligosaccharides; f, fructose; fn, fructan; l, lactose; s, sorbitol; m, mannitol; p, polyols. Red color = disagreement between studies on FODMAP content; Blue color = only one reference on FODMAP content; Green color = agreement between studies on FODMAP content.

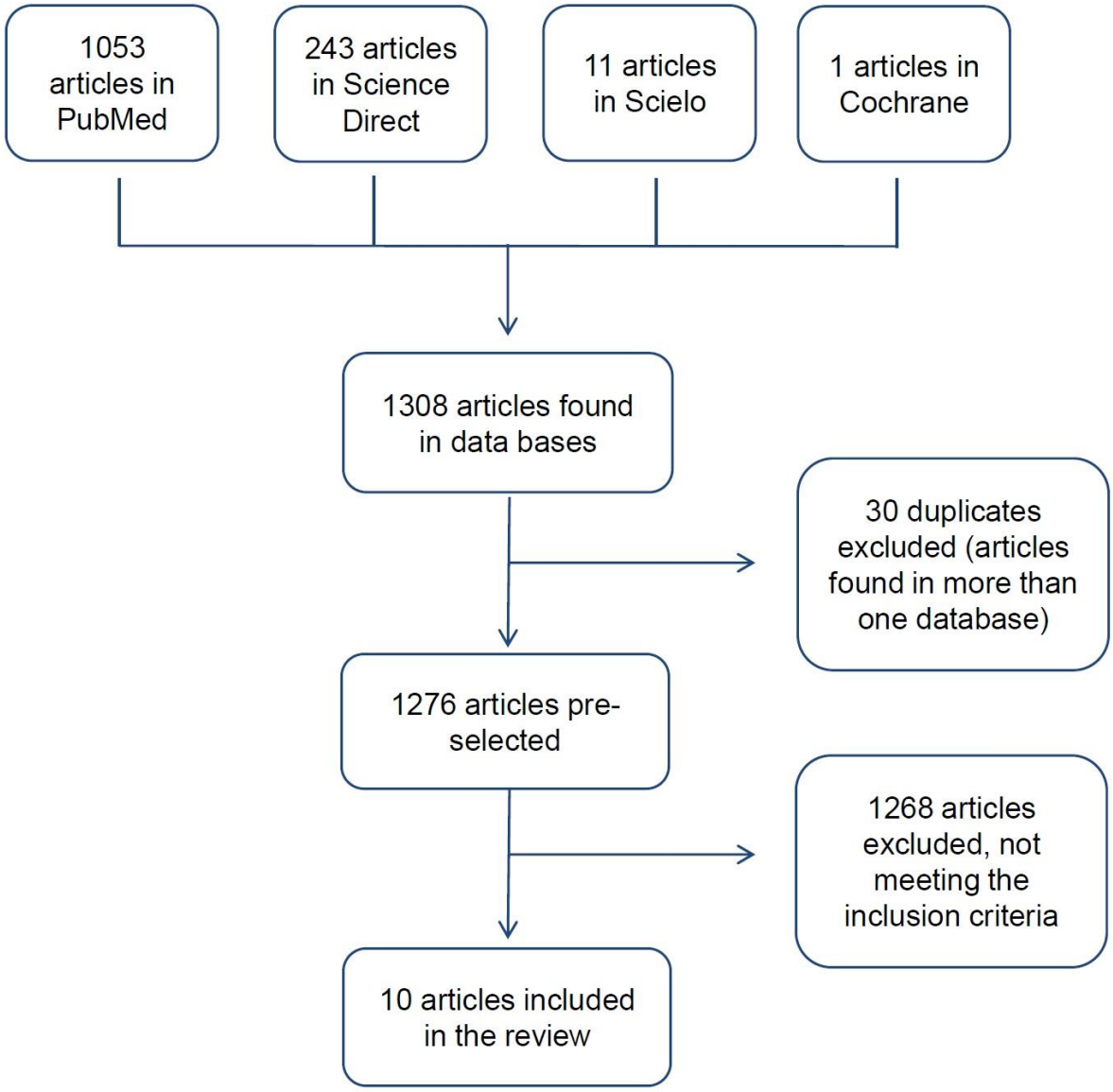

Fig. 1 Flowchart of selected studies.