

## The starch and total sugar content of Mexican fruit and vegetables

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**SUMMARY.** The starch and total sugar contents of 20 types of fruit, 28 types of vegetables and six different herbs, grown in Mexico, were analysed. The selection was based on dietary surveys to identify those foods most widely consumed. Starch was determined by an enzymatic method whilst total sugar was determined gravimetrically. The foods were grouped according to the Southgate classification. Fruits contained little starch (range 0-4 g/100 g fresh weight (FW) except in the case of the plantain (31 g/100 g FW starch), whereas vegetables showed a higher concentration with tubers in the range 10-20 g/100 g FW starch. Legumes contained 0-5 g/100 g FW; amongst the capsicum group the chilli poblano had the highest concentration at 1.3 g/100 g FW starch. The concentration of sugars in fruits ranged from 0.6 g/100 g FW to 21.1 g/100 g FW.

**RESUMEN.** Contenido de almidón y azúcares totales en frutas y verduras de México. Se analizaron el almidón y los azúcares totales en 20 frutas, 28 verduras y 6 hierbas, cultivadas en México. La selección de estos alimentos se basó en encuestas nacionales de dieta y se identificó aquellas que eran consumidas con mayor frecuencia. El almidón se analizó por un método enzimático mientras que los azúcares totales se determinaron gravimétricamente. Los alimentos se agruparon de acuerdo a la clasificación de Southgate. La concentración de almidón en las frutas baja (rango 0-4 g/100 g peso húmedo (FW) excepto en el caso del plátano macho, mientras que en las verduras, la concentración de almidón fue mayor. Los tubérculos con un rango entre 10-20 g/100 g FW y las leguminosas con un rango entre 0-5 g/100 g FW. Del grupo capsicum, en el chile poblano se encontró la concentración más alta (1.3 g/100 g FW almidón). La concentración de azúcares totales en las frutas tuvo un rango entre 0.6 g/100 g FW hasta 21.1 g/100 g FW.

### INTRODUCTION

Starch is quantitatively the major carbohydrate in the human diet and represents some 80-90% of all polysaccharides eaten. Thus intakes of starch in Europe are usually 8-10 times higher than intakes of non-starch polysaccharides (NSP). Yet information on starch intake is rarely reported in the literature because most papers confine their reports to estimates of total carbohydrate, these being specified in most older food tables «by difference», i.e. after the weight of fat, protein and ash has been subtracted from the dry weight of food. Direct measurements of specific sugars and starches are rarely undertaken.

The increasing recognition of the different physiological properties of starch and of non-starch polysaccharides and of sugars in nutrition has prompted us to measure separately the starch and sugar content of a variety of those fruits and vegetables frequently consumed in Mexico. This is a part of a new national database marking the 50th anniversary of the National Institute of Nutrition Salvador Zubirán in Mexico. New analyses of NSP are already available in Mexico for pulses and cereal products (1) and for vegetables and fruits (2).

### MATERIAL AND METHODS

**Selection of foods for analysis:** The choice of fruits vegetables was based on dietary surveys; these were used to identify those foods

most widely consumed. The fruits, vegetables and herbs were then randomly selected from the storage department of Dicomesa 1992 which was formerly the regional office for the Metropolitan Mexico City of the National Food Distributor Company (CONASUPO). This company was selected to allow easy access and sampling of Mexican foods because, being located in Mexico City's Food Supply Center where fruits and vegetables arrive in trucks from different parts of the country, a representative selection of foods eaten by the general public could be chosen. Four or five samples of each of 20 fruits, 28 vegetables and six herbs were taken and transported to the National Institute of Nutrition for analysis. The scientific names of the foods were described elsewhere (2).

**Sample preparation and chemical methods:** On arrival at the Institute in Mexico, the foods were carefully washed with deionized water in order to remove impurities, but care was taken not to overwash them so leaching of the nutrients was minimised. Since the samples were also used for mineral and trace element analysis, extreme care was taken during the preparation to avoid using utensils which could contaminate the samples, i.e. iron knives or boards. Samples of each food were pooled, and aliquots of each pooled sample were taken into weighted plastic containers, weighed, sealed and frozen at -20 °C. Samples were then freeze-dried and reweighed. The dried material from each container was then sealed in polyethylene bags for storage until analysis. A more detailed explanation of the procedure can be found elsewhere (2).

Because of the limited sample size available for analysis a mixture of duplicate and single analyses were made. For sugars, five samples were analysed in duplicate, whilst the rest were analysed singly. The mean coefficient of variation between duplicates was  $1.77 \pm 1.96\%$ . For starch the mean coefficient of variation between duplicates, of the control sample included in each batch of analysis, was  $2.42 \pm 2.43\%$ ; the food samples were analysed singly. Results were corrected for the residual moisture content of the freeze-dried material by

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drying a portion at 100 °C for 4 hours. Then, dry weight (DW) data were converted to a fresh (FW) basis for ease of presentation in a format consistent with the usual practice for food composition tables and dietary surveys.

**Starch:** This was determined by the method of Aman and Hessellman (3). The samples were extracted with 80% ethanol solution to remove free sugars. The sugar-free residue was hydrolysed in pH 5.0 buffer using the thermostable -amylase, Termamyl (Novo Industries Ltd) at 100 °C for 30 min. The released glucose oligomers were further hydrolysed to glucose by overnight incubation with amyloglucosidase (Boehringer). After transferring to a volumetric flask, making up to volume and filtering, the released glucose in solution was determined by a glucose oxidase/peroxidase procedure. The starch content was calculated as glucose x 0.9.

**Sugars:** Sugars were extracted by shaking in warm (<60 °C) water for 30 min (4). The extracts were then clarified using Carrez solutions. An aliquot of the solution was hydrolysed in 0.1M hydrochloric acid to invert sucrose, neutralised, re-filtered, and made up to a known volume (5). The reducing sugar content was determined by the copper reduction method of Munson-Walker(6).

**RESULTS**

A formal classification of fruits and vegetables for nutritional or food compositional purposes is difficult to devise without resorting to arbitrary groupings. Many foods considered as fruits in Mexico are botanically vegetables (e.g. Jicama is eaten as a fruit in Mexico, is very watery, but is considered by many to be a tuber), whereas avocado is eaten as a vegetable but in botanical terms is a fruit.

(Table 1) summarises the results of the analysis in fruits and vegetables grouped according to the Southgate classification (7). (Tables 2,3) show the results in the individual foods.

**TABLE 1**  
Mean starch and total sugar content in fruits and vegetables  
Summary table\*

	n**	Starch g/100 g FW***	Total sugars
<b>Fruits</b>			
Popular	7	0.8	6.9
Apples	2	trace	8.3
Stone fruits	4	ND	5.7
Citrus fruits	3	ND	6.9
Grapes	1	ND	14.4
Banana plantain	1	31.0	21.1
Melons	1	ND	5.4
Melon seeds	1	ND	5.1
<b>Vegetables</b>			
Popular	2	6.6	0.8
Tubers	4	14.4	1.4
Legumes	3	2.1	2.0
Capsicums	3	0.6	1.5
Bulbs	4	trace	8.1
Gourds	2	0.2	2.1
Roots	2	0.2	4.1
Brassicac	1	ND	2.9
Green leafy	3	ND	0.6
Others	3	ND	1.3
Herbs	6	trace	0.7

\* For each category there are several items which are specified in subsequent Tables.

trace <0.05 %

\*\* n=number of samples

\*\*\* FW=fresh weight

**TABLE 2**  
Starch and total sugar content in Mexican fruits

English Name Dry matter (DM)%	Mexican Name	Starch g/100 FW	Total Sugars g/100 g FW
<b>POPULAR</b>	<b>POPULARES</b>		
Mamey DM=30.3 %	Mamey	1.2	17.9
Mango DM=14.4 %	Mango	trace	11.0
Soursop DM=15.7 %	Guanábana	ND	8.6
Papaya DM=8.4 %	Papaya	trace	5.6
Jicama DM=11.3 %	Jicama	4.1	4.1
Avocado Hass DM=15.1 %	Aguacate, Hass	0.1	0.9
Pineapple DM=11.0 %	Piña	ND	8.2
<b>Apples</b>	<b>Manzanas</b>		
Apple+Skin DM=13.6 %	Manzana con cáscara	trace	8.7
Apple, flesh DM=13.2 %	Manzana, pulpa	ND	7.8
<b>Stone fruits</b>			
Plum-Wilson DM=14.2 %	Ciruela, Wilson	ND	6.9
Plum, Perfumed DM=10.6 %	Ciruela, perfumada	ND	4.6
Plum, black DM=12.3 %	Ciruela, negra	ND	3.2
<b>Citrus fruit</b>	<b>Cítricos</b>		
Orange, no peel DM=14.2 %	Naranja sin cáscara	ND	7.6
Lime DM=8.8 %	Lima	ND	4.9
Lemon, bitter DM=10.6 %	Limón, agrio	ND	0.6
<b>Grapes</b> DM=18.4 %	Uvas	ND	14.4
<b>Bananas</b>	<b>Plátanos</b>		
Plantain DM=59.2 %	Plátano macho	31.0	21.1
<b>Melons</b>	<b>Melones</b>		
Melón, chinese DM=10.9 %	Melón chino	ND	5.4
Melon chinese, seed DM=20.7 %	Melón, semillas	ND	5.1

TABLE 3  
Starch and total sugar content in Mexican vegetables

English Name Dry matter (DM)%	Mexican Name	Starch g/100 g FW*	Total Sugars g/100 g FW
<b>POPULAR MEXICAN</b>			
Corn (grain) DM=27.7 %	Elote	13.2	1.4
Cactus, leaf DM=4.3 %	Nopal	trace	0.2
<b>Tubers</b>			
Potato, new, +skin DM=16.7 %	Papa con cáscara	10.9	0.7
Potato, new, flesh DM=18.8 %	Papa chica sin cáscara	13.6	0.5
Potato + skin DM=17.8 %	Papa con cáscara	13.1	0.3
Potato, sweet DM=29.5 %	Camote	19.8	4.0
<b>Legumes</b>			
Beans, runner DM=8.9 %	Ejotes	0.5	1.9
Pea, sugar DM=10.6 %	Vaina de chícharo	0.1	2.0
Pea DM=21.9 %	Chicharo	5.6	2.1
<b>Capsicums</b>			
Chilli, poblano DM=8.6 %	Chile poblano	1.3	1.9
Chilli, serrano DM=11 %	Chile, serrano	0.4	1.5
Pepper, green DM=5.0 %	Pimiento, verde	ND	1.2
<b>Bulbs</b>			
Leek DM=19.1 %	Poro	0.1	12.0
Onion (bulb) DM=15.1 %	Cebolla, de rabo	ND	8.1
Onion, white raw DM=11.4 %	Cebolla, blanca	ND	7.4
Onion, spring DM=8.3 %	Cebolla, cambray	trace	4.9
<b>Gourds</b>			
Courgette DM=5.7 %	Calabacita	0.1	1.9
Chocho DM=5.2 %	Chayote	0.2	2.3
<b>Roots</b>			
Betroot DM=14.2 %	Betabel	trace	5.6
Carrot DM=11.8 %	Zanahoria	0.3	2.5
<b>Brassicas</b>			
Cabbage, white DM=6.1 %	Col, blanca	ND	2.9
<b>Green leafy</b>			
Lettuce DM=3 %	Lechuga, orejona	ND	0.9
Swiss Chard DM=7.4 %	Acelgas	ND	—
Celery leaves DM=8.3 %	Apio, hojas	ND	0.2

<b>Others</b>			
Tomato, green DM=8.0 %	Tomate verde	ND	3.0
Tomato (red) DM=4.5 %	Jitomate	ND	1.5
Watercress DM=5.8 %	Berros	ND	0.3
Cucumber, skin DM=5 %	Pepino, cáscara	ND	0.4
<b>Herbs</b>			
Chamomile DM=8.8 %	Yerbas Manzanilla	ND	0.3
Coriander DM=13.4 %	Cilantro	ND	1.7
Goosefoot DM=8.7 %	Epazote	trace	0.2
Mint DM=12.4 %	Yerbabuena	trace	0.2
Parsley leaves DM=8.7 %	Perejil, hojas	ND	0.3
Parsley stem DM=8.2 %	Perejil, tallos	ND	1.4
trace <0.05 %			
* Fresh weight			

TABLE 4  
A comparison of starch and total sugar content of Mexican and British foods

Food	Starch g/100 g FW*		Total Sugars g/100 g FW	
	Mexico	UK	Mexico	UK
<b>FRUITS</b>				
Popular				
Mango	trace	0.3	11.0	13.8
Papaya	trace	0	5.6	6.6
Avocado Hass	0.1	trace	0.9	0.5
Pineapple	ND	0	8.2	10.1
<b>Apples</b>				
Apple+skin	trace	trace	8.7	11.8
Apple, flesh	ND	trace	7.8	11.2
<b>Citrus fruit</b>				
Orange, no peel	ND	0	7.6	8.5
Lime	ND	0	4.9	3.2
Grapes	ND	0	14.4	15.4
<b>Bananas</b>				
Plantain	31.0	23.7	21.1	5.7
Melons				
Melon, chinese	ND	0	5.4	4.2
<b>VEGETABLES</b>				
Corn (grain)	13.2	10.5	1.4	1.4
<b>Tubers</b>				
Potato, new, flesh	13.6	14.8	0.5	1.3
Potato + skin	13.1	16.6	0.3	0.6
Potato, sweet	19.8	15.6	4.0	5.7
<b>Legumes</b>				
Beans, runner	0.5	0.4	1.9	2.8
Pea, sugar	0.1	0.8	2.0	3.4
Pea	5.6	7.0	2.1	2.3
<b>Capsicums</b>				
Chilli, serrano	0.4	trace	1.5	0.7
Pepper, green	ND	0.1	1.2	2.4

<b>Bulbs</b>				
Leek	0.1	0.3	12.0	2.2
Onion, spring	trace	0.2	4.9	2.8
<b>Gourds</b>				
Courgette	0.1	0.1	1.9	1.7
<b>Roots</b>				
Beetroot	trace	0.6	5.6	7.0
Carrot	0.3	0.2	2.5	5.6
<b>Brassicas</b>				
Cabbage, white	ND	0.1	2.9	4.9
<b>Green leafy</b>				
Lettuce	ND	trace	0.9	1.7
Celery, leaves	ND	trace	0.2	0.9
<b>Others</b>				
Tomato, red	ND	trace	1.5	3.1
Watercress	ND	trace	0.3	0.4
<b>HERBS</b>				
Mint	trace	ND	0.2	ND
Parsley, leaves	ND	0.4	0.3	2.3

trace <0.05 %

\* Fresh weight

**Starch content:** The fruits contained almost no starch except in the case of the banana plantain, often considered by the public as a vegetable, which had a very high concentration of starch.

The group of vegetables showed, on average, a much higher starch concentration than the fruit, but the tuber showed the highest concentration of all with sweet potato at the top of the list. Sweet potato is a stem tuber of major importance in the Mexican diet and although similar to the potato it has a higher dry matter and starch content (DM=25% versus 18% for potato). Legumes ranked next with an average starch concentration of 2.1 g/100 g FW. Peas had only a third of the starch content of sweet potato, and 2-3 times less starch than potatoes on a wet weight basis. Among the capsicum group, the Chile poblano showed the highest concentration of starch but no starch was detected in the green pepper and negligible amounts of starch were seen in the bulbs, gourds roots, brassicas, in green leafy and the other vegetables and in the herbs.

**Total sugar content:** The total sugar content of fruits was found, as expected, to be high. The range of total sugars, however, was wide, from 0.6 (g/100 g FW) in the bitter lemon to 21.1 (g/100 g FW) in the plantain. The most popular fruits, mango and mamey, contained high concentrations of sugars; pineapple is also widely consumed and had a high total sugar content, the major component of which is sucrose. The three species of plum showed variable amounts of sugars, the Wilson variety having the highest concentration and the black plum the lowest. Variable amounts of sugars were found in citrus fruits as expected because the lemon, with its high acidity content, had almost no sugar. The orange, however, had more than 12 times the sugar content of lemon and 1.5 times the sugar content of lime. Grapes, a widely consumed fruit, were very rich in sugar. The banana, a popular and unusual fruit, is cultivated throughout the tropics and contained starch in its immature form, but during the process of maturation the starch is recognised to be converted into sugars so that in the fully ripened fruit a mixture of glucose, fructose and sucrose is present with sucrose as the principal sugar. Plantain, which is a type of banana, was also found to be high in both sugars and starch (Table 2) and is always eaten ripe.

Finally, the melon with its high water content showed levels of sugar which were similar to those found in papaya. The melon seed, used in Mexico for the preparation or refreshing beverages, had

similar sugar concentrations to those observed in the flesh of the melon.

Table 4 shows a direct comparison of the Mexican data with The British data (8). Although values are not identical they were found to be of the same order.

## DISCUSSION

The method chosen for starch and total sugar analyses are standard techniques which provide, by their enzyme specificity, direct measure of the particular carbohydrate under study. The total value of starch plus sugar cannot be considered equal to the total carbohydrate content inferred from the standard North American food tables because these are constructed by difference and include oligosaccharides, inulins and cell-wall polysaccharides, none of which were measured in these analyses. If comparability is sought by making an allowance for some published fibre measurements, this will still present problems because North American values refer to measurements made with the AOAC Prosky procedure, which measures fibre as a residue containing non starch polysaccharides (NSP), variable amounts of starch and non-carbohydrate components in unknown proportions. The resistant starch, which is resistant in vivo by virtue of not being gelatinised (Type II), should be measurable by the 100 °C Termamyl treatment used in this assay, and Type I resistant starch, which reflects the starch encased within cell-wall structures, would not be expected to be present in these samples. Type III resistant starch, which is not included in this assay, is formed mainly as the result of retrogradation of starch following cooking and is likely to be low in these uncooked foods. Thus this direct assay can be expected to include the majority of the starch in the foods analysed.

Clearly it is important now to analyse the other important carbohydrate fractions directly. This will require new and robust methods for the oligosaccharides which are now emerging as important (9) and for the full array of inulins which are somewhat more difficult to assay accurately. It could be argued that it would be useful to have not only the individual carbohydrate values but also the components of starch divided not only into Types I, II, and III resistant starch but also the rapidly and slowly digestible starches as set out by Englyst et al (10,11). These issues are the subject of future research and will be particularly important if cooked samples are to be measured.

The actual data obtained provided few surprises. The evolution in starch/sugar content of bananas and plantains during the ripening process is well recognised (12) and will materially affect the amount of starch entering the colon for fermentation. Thus, if there is a concern to define the fermentable carbohydrates entering the colon, then more controlled studies with direct measurement of the sugar/starch types are needed in the foods as eaten, bearing in mind the potential effects of cooking.

These data form part of a new information base for updated food composition tables being developed by the Instituto Nacional de la Nutrición. As such these and other data will become available for a wide variety of nutritional and epidemiological studies.

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