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The importance of sucrose for cognitive functions; knowledge and behaviour

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Abstract

Sucrose is not present in the internal milieu as such, so it is physically impossible that it may have a direct influence on cognitive functions, behaviour and knowledge. However, during the digestive process, disaccharides are released into monosaccharides, in the case of sucrose into glucose and fructose, which reach the liver via the portal vein. Finally, they go into bloodstream in the form of glucose and in some cases as very low-density lipoproteins (VLDL).

Brain needs almost exclusively a constant supply of glucose from the bloodstream. Adult brain requires about 140 g of glucose per day, which represents up to a 50% of total carbohydrates consumed daily in the diet.

The consumption of a food or beverage enriched with sucrose has been associated with improved mental alertness, memory, reaction time, attention and ability to solve mathematical problems, as well as a reduction in the feeling of fatigue, both in healthy individuals and patients with Alzheimer disease.

An adequate nutrition of brain contributes to structural and functional integrity of neurons. It has been shown that in major mental illnesses such as schizophrenia, depression and Alzheimer's disease, nutritional deficiencies at cellular level are implicated.

At present, several studies highlight the need to improve understanding of the processes involved in the deterioration of cognitive functions and mechanisms through which, the nutritive components of the diet, particularly the sucrose, may modulate such functions.

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Key words: *Sucrose. Cognitive functions. Knowledge. Behavior. Memory.*

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IMPORTANCIA DE LA SACAROSA EN LAS FUNCIONES COGNITIVAS; CONOCIMIENTO Y COMPORTAMIENTO

Resumen

La sacarosa no se encuentra en el medio interno, por lo tanto, es materialmente imposible que pueda influir directamente sobre las funciones cognitivas, el comportamiento y el conocimiento. No obstante, durante el proceso digestivo, los disacáridos se escinden en los monosacáridos correspondientes, en el caso de sacarosa en glucosa y fructosa que, por la vía portal llegarán al hígado. Finalmente, salen al torrente sanguíneo en forma de glucosa y en algún caso, además, como lipoproteínas de muy baja densidad (VLDL).

El cerebro precisa casi exclusivamente un suministro constante de glucosa desde el torrente sanguíneo. El cerebro adulto utiliza aproximadamente 140 g de glucosa al día, cantidad que puede representar hasta el 50% del total de los carbohidratos que se consumen.

El consumo de una comida o bebida con sacarosa se ha asociado con una mejora de la agilidad mental, la memoria, el tiempo de reacción, la atención y la capacidad para resolver problemas matemáticos, así como con una reducción de la sensación de cansancio, tanto en individuos sanos como en enfermos de Alzheimer.

La adecuada nutrición del cerebro mantiene la integridad estructural y funcional de las neuronas. Se ha demostrado que en las enfermedades mentales mayores, como la esquizofrenia, depresión y demencia de Alzheimer, hay deficiencias nutricionales a nivel celular.

En el momento actual, los estudios realizados ponen de manifiesto la necesidad de profundizar en el conocimiento de los procesos implicados en el deterioro de las funciones cognitivas y en los mecanismos, a través de los cuales, los componentes nutritivos de la dieta, y particularmente la sacarosa, pueden modularlos.

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Palabras clave: *Sacarosa. Funciones cognitivas. Conocimiento. Memoria.*

Introduction

Digestible carbohydrates, both slow absorption, mainly starch, as well as fast absorption, monosaccharides and disaccharides (glucose, fructose and galactose; and lactose, maltose and sucrose respectively) are present in natural form. Furthermore, the food industry adds some of these carbohydrates to food during processing and elaboration, as they carry out important roles. Simple carbohydrates have an energy value of (4 kcal/g) and a sweetening power. They offer very important organoleptic properties, improving the product's consistency and texture, or giving it colour and flavour after thermal treatment. Finally, it has been and continues to be used as a preservation method.

In the case of table sugar or sucrose, it has been said that it is different to that found in foods which contain it, which is a clear error, sucrose is a chemically pure substance which has only been separated from other components which exist in the plant from which it has been extracted, sugar or beet, and is, therefore, identical to that which exists in natural form in fruit.

From a nutritional point of view, the only drawback that can be attributed to sucrose is that, as it is a chemically pure product it only provides energy and no other nutrients[1].

The idea of some "experts" that sucrose can provoke some form of addiction in the same way as illegal drugs and, therefore, should be included in the list of addictive substances[2], is an opinion that has little scientific proof. The experimental evidence does not support the claim that sugar and other highly palatable foods produce addiction[3]. It is important to qualify that sucrose forms part of foods that produce pleasure but not dependence[4].

Other effects that have been attributed to sucrose have been that they produce hyperactivity and aggression in children. However, different writers and a report by FAO/OM Sydicate that as well as not provoking such effects, they can, in fact have a sedentary effect[5]. Finally, Benton (2007)[6], in his review of the effects of diet on behaviour, stated that sucrose had no negative effects on behaviour.

Table I
Classification of dementias in function of their aetiology

Aetiology	*Type of changes*
Of degenerative origin	Alzheimer Lewy diffuse bodies dementia Frontotemporal dementia Pick's disease Huntington's disease Dementia associated with Parkinson's Progressive supranuclear paralysis
Vascular dementia	Multi-infarct dementia Small blood vessels (lacunar, micro infarcts, leukoencephalopathy (Binswanger disease) Strategic infarcts Haemorrhages Hypoxia, hypoperfusion
Of infectious origin	Neurosyphilis Associated to AIDS Creutzfeldt disease Lymeo disease Herpes virus encephalitis
Of a metabolic or nutritional origin	Hiccups or hyperthyroidism Hiccups and hyperparathyroidism, adrenal pituitary Kidney failure Hepatic failure Wilson's disease Vitamin B12 deficit Folic acid deficit Pellagra
Of a toxic origin	Associated with alcohol: alcohol dementia, Korsakoff and Marchiafava-Bignani disease Other toxic substances: aluminium, arsenic, bismuth, lead, etc.
Of a neoplastic origin	Primary and metastatic brain tumours Limbic encephalitis Carcinomatous meningitis

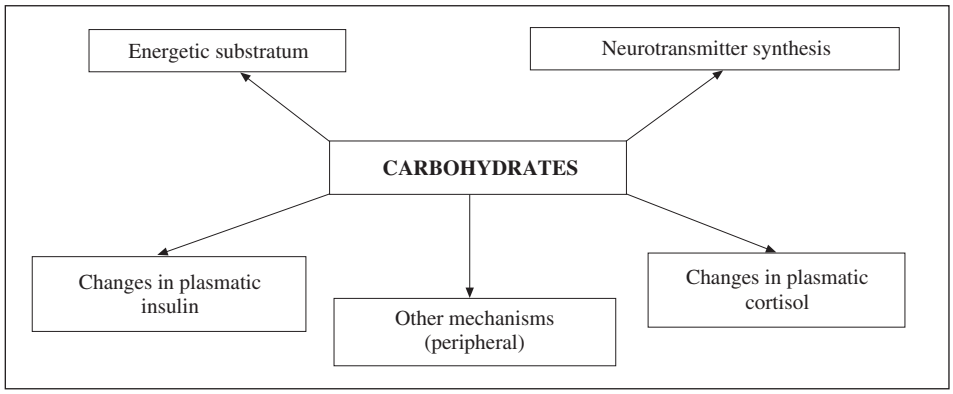

Fig. 1.—Carbohydrates action mechanisms on cognitive functions.

There is a growing worry for the increase in prevalence of changes associated with cognitive function. It is estimated that the number of cases of dementia will double every 20 years in developed countries, and will multiply by three in developing countries in the same time period. In the year 2040, it is calculated there will be more tan 80 million people affected by these neurological illnesses of different origins (Table I)[7].

The close relationship between the nutritional state and the function of the central nervous system evidences the importance of the diet models as a determining factor in the capacity of cognitive functions. So the deficiencies in numerous micronutrients show neurological manifestations, fats, and particularly saturated fats and their "trans" configuration, can negatively influence cognitive function, while carbohydrates, simple and complex could have the opposite effect.

In figure 1 it shows possible action mechanisms through which carbohydrates can act upon cognitive functions[8].

Next we describe according to the DAFO analysis, some of the most impressive aspects and mechanisms, through which sucrose and other simple carbohydrates act upon cognitive functions.

Weaknesses

Sucrose is not found internally, and therefore, it is materially impossible for it to influence directly on cognitive functions, behaviour and knowledge. However, during the digestive process, disaccharides, such as sucrose, are absorbed in the enterocytes of the brush border of the small intestine, where, the corresponding disaccharides, in this case, the sucrose, break up the molecule splitting it into the corresponding monosaccharides, fructose and glucose, which reach the liver. The fructose will be converted into glucose if the person is hypoglycaemic, something not very likely if they have ingested sucrose, or triglycerides if hypoglycaemic or euglycaemic. The glucose will come from the liver, which, through systematic circulation, will reach the different tissue. It is worth referring, once again, to the inadequacy of prescribing fructose to a diabetic as it is clear it does not increase blood sugar: fructose cannot be converted into glucose during hyperglycaemia, and continues on its way to being transformed into triglycerides (Fig. 2), and these leave the kidney in the form of very low density lipoproteins (VLDL), producing dyslipidaemia, which constitutes one of the side effects of diabetes.

The cells are dependent on and they all obtain their energy from glucose. Furthermore, some of them, in particular neurons, the only substrata that can obtain it is from this monosaccharide, a situation that it shares with red blood cells. This means to say that nerve cells need glucose to adequately carry out their functions; it is true though that, in extreme conditions they can obtain energy from other substrate such as lactate.

Direct diagnostics through imaging methods used to value the relationship between the ingestion of nutrients and cognitive functions are at the moment expensive and difficult to interpret. Furthermore, the evaluation of said relationship through indirect methods; based on the application of different tests, offer an interpretation of the result with notable limitations. At the same time, the easy application and interpretation biomarkers are insufficient and are low cost for this type of study[9].

Currently, there is no effective therapy that reverses the symptoms caused by cognitive deterioration. Alternatively, the evidence of the effect of carbohydrates on cognitive functions is scarce and inconclusive.

Threats

There is a widely held opinion now for decades which suggests table sugar is responsible for a multitude of sins that threaten humans, even going as far as to consider it a poison, and was considered as much in some articles that referred to the four white poisons, and included sugar, salt, flour and milk. This is information that lacks any scientific and critical sense, apart from being completely false. But the reality is that this

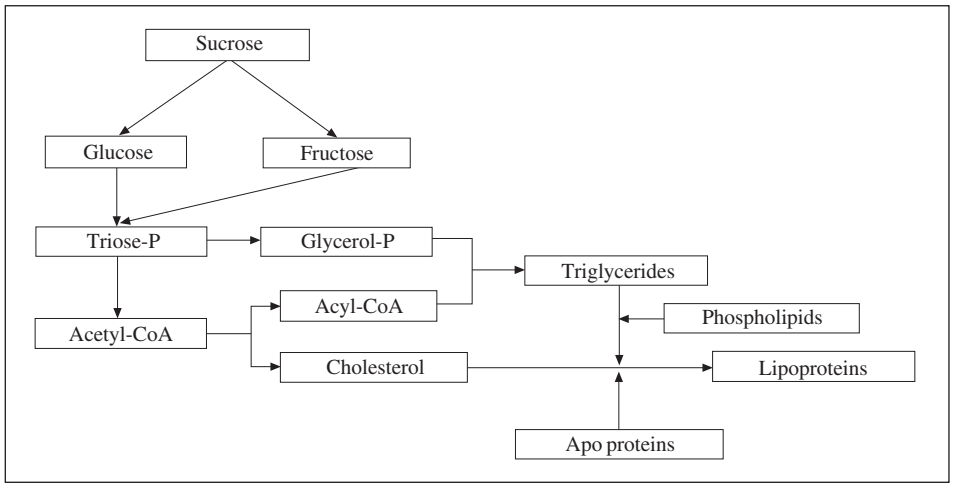

Fig. 2. —Metabolic fate of sucrose during a hypoglycaemic or euglycaemic episode.

idea is widely believed and generates great confusion amongst the general population.

All the energy that comes from ingested foods, solid or liquid, which exceeds an individual's needs, will be converted into triglycerides, which shall accumulate or be turned into fatty tissue deposits, independently of if the energy comes from carbohydrates, lipids or proteins. In a hypoglycaemic situation it is impossible for triglycerides to form, and what would increase in the bloodstream would be fatty acids, which would produce a serious dyslipidaemia with acidosis.

An incorrect control of the blood sugar has a close relationship with the deterioration of cognitive functions in diabetic patients. Furthermore, the presence of insulin and it's receptors in different areas of the brain related with memory and learning (cortex and hippocampal), suggests that changes in concentration of said hormone can produce a deterioration of cognitive functions[10].

The appearance of non evidence based and frequently confusing information related to beneficial aspects of sucrose on cognitive functions, can lead to an excessive consumption of this disaccharide which can be associated with the development of obesity, diabetes and metabolic syndrome, which can increase the risk of cognitive deterioration.

Taking part in physical activity, especially anaerobic, intense and or long duration, provokes fatigue as a consequence of depletion of glycogen in the liver and muscles, which can alter the cognitive state of the individual[11].

It has been suggested that certain components in foods amongst which carbohydrates and lipids are found, as well as the association among them, could be addictive. However, it has been pointed out that the addiction could be a phenotypic characteristic of obesity[12].

As a consequence of progressive ageing of the population and an increase in life expectancy, an increase in the prevalence of neuro-degenerative illnesses is expected.

Studies of neuro-degenerative illnesses require long monitoring periods, making obtaining conclusive results difficult. Alternatively, the scientific bibliography shows inconsistencies and occasionally contradictory results of the effect that the ingestion of sucrose has over the cognitive functions. Furthermore, there is a great lack of knowledge regarding the processes and factors implicated in the recuperation or regeneration of the cognitive functions.

As in other fields, the field of neurosciences has produced a reduction in the resources allocated to research.

Strengths

The adequate nutrition of the brain helps maintain the structural and functional integrity of the neurons. It has been proved that in serious mental illnesses such as schizophrenia, depression and Alzheimer there exist nutritional deficiencies on a cellular level.

The consumption of food or drink with sucrose is associated with an improvement in mental agility, memory, reaction times, attention and the capacity to resolve mathematical problems, as well as a reduction in the sensation of tiredness, both in young and old healthy people and Alzheimer patients,

Other studies have shown that individuals that consume sugary drinks before and during the tests in a driving simulator made fewer errors in comparison with those who had only drank water[13].

The administration of oral sucrose solutions has been proved as a safe and effective treatment to combat sharp pains that cause some clinical procedures, both in healthy and sick children[14].

Sports drinks that contain sugar, minerals and water, avoid dehydration, the depletion of glycogen reserves and slow down the appearance of fatigue, due to the sugar

that, in the first instance delivers glucose directly to the muscle and this lengthens the duration of the exercise[15].

Not only is the ingestion of complex carbohydrates effective in promoting synthesis of muscular glycogen, as was initially believed, simple carbohydrates also produce similar increases in storage of it.

Recent advances in radio diagnostics, methodology applied to the knowledge of the organisation and function of the brain, have contributed to the design of studies that improve the understanding of the molecular make-up of the conduct[9].

The prevention of the deterioration of the cognitive functions will contribute, without any doubt, to the promotion of autonomy, the mood and the quality of life of the elderly population.

Opportunities

In recent years, nutritional investigations have been centred on the long term evaluation of nutrients on cerebral functions, both in the promotion of neuron development and the prevention of age related cognitive deterioration.

Carbohydrates are important for the adequate functioning of the organism. The adult brain uses approximately 140 g of glucose per day; an amount, which can represent up to 50% of the total carbohydrates that are consumed. The brain requires a constant supply of glucose from the blood flow.

It is generally accepted that the ingestion of sucrose improves the short-term knowledge and memory while favouring concentration[16].

The scientific advances in the knowledge of cognitive deterioration and of neurosciences in general, have without doubt, enabled the design and implementation of nutritional therapies that fight against the degenerative disorders derived from cerebral ageing.

Individuals that have a higher inclusion of the Mediterranean diet present a lower rate of Alzheimer. This coincides with the universally accepted idea that following this kind of diet brings high levels of general health and longer and healthier life[17].

Due to the increase in the prevalence of neurological illnesses, and the high cost of treatment, any therapeutic intervention that slows down the increase of these disorders will have an enormous impact, not only on patients but also in the social and health care arena.

The growing interest of the food and pharmacological industries in the design of new products can have a function in the prevention and treatment of neurological disorders.

Recommendations

Sucrose has been throughout history and continues to be an important source of energy in the human diet. The excessive consumption of disaccharides can replace other food in the diet and produce nutritional deficiencies and, therefore, have undesired consequences, issues that have been addressed in detail in previous chapters.

Sucrose, when included in a measured way in the diet, has important properties, it favours quick release glucose to the brain and muscles, being an essential carbohydrate for the development of cognitive functions and of physical activity. To avoid a rapid rise in blood sugar, which would implicate the formation and liberation of elevated quantities of insulin, the rest of the glucose necessary should be provided by starch. The organism does not differentiate, metabolically speaking, between glucose that comes from starch and that from sucrose.

What is truly important is to avoid hypoglycaemic situations, which would be responsible, amongst other undesired effects for glycosylation of proteins, which has also been addressed in previous chapters.

It is still premature to try and establish, in relation to cognitive functions, recommendations for the ingestion of sucrose for preventative and therapeutic ends. It is important to follow a balanced and varied diet, or as mentioned before, sticking to a Mediterranean diet, both for general health and to achieve a longer and healthier life.

Conclusions

The close relationship between the nutritional status and the function of the central nervous system evidences the importance of diet as one of the determining factors in cognitive function. In recent years the research into nutrition has been centred on the long-term effects of nutrients on cerebral functions. The adequate nutrition of the brain maintains the structural and functional integrity of the neurons. It has been proved that in serious mental illnesses such as schizophrenia, depression, and Alzheimer there exists nutritional deficiencies on a cellular level.

There is a growing concern for the increase in the prevalence of disorders associated with cognitive function. As a consequence of the progressive ageing of the population and the increase in life expectancy, an increase in the incidence of neuro-degenerative illnesses is expected. In fact, it is estimated that in the year 2040 there will be more than 80 million people affected by this type of illness.

Carbohydrates are important for the adequate functioning of the organism, and in particular for the brain, as the neurons, in order to maintain their integrity and functionality, need a constant source of glucose from the bloodstream (140 g/day).

It is generally accepted that the ingestion of sucrose improves, in the short term, knowledge and memory, which on a par favours concentration. Different

studies have shown that the consumption of food or drink that contains sucrose is associated with an increase in mental agility, memory, reaction times, the attention and ability to resolve mathematical problems, as well as a reduction in the sensation of tiredness, both in healthy individuals and Alzheimer patients. However, in scientific literature in consistencies and contradictory results can be found regarding the effects of the ingestion of sucrose on cognitive functions, for which it would be necessary to go deeper into knowing the effects of this disaccharide on the brain.

The prevention of the deterioration of cognitive functions will contribute, without any doubt, to the promotion of autonomy, mood and to the quality of life of the elderly population. Furthermore, due to the increasing prevalence of neurodegenerative illnesses and the high costs of treatment, any therapeutic intervention that slows the increase of these disorders shall have an enormous impact not only on the patients but also in the social and healthcare arena.

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