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Literature Review

Vinegar: functional aspects

Vinagres: aspectos funcionais[1]

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Abstract

Vinegar is a widely used condiment, consumed by all social classes and has great potential for health benefits, which justifies the concern for their beneficial activity. The country is still a beginner in vinegar research, concerning the verification of its health benefits, as the raw materials used and the production process. The article aims to gather and discuss studies that show the vinegar beneficial effects for human health. In studies conducted in Europe and Asia, it was observed that consumption of vinegar can be beneficial, as it showed antitumor effect, reduced the blood glucose level, effects on the immune system, anti-hypertensive effect, among others. Those responsible for the medicinal effects are acetic acid (at least 4% in vinegars, under Brazilian law), but also other compounds resulting from the metabolism of microorganisms during the stages of fermentation and/or aging. Despite these results, “in vivo” research as are still deficient concerning the recommended daily doses that prove the medicinal efficacy of vinegar are unknown. However, in view of the favorable results, the functional potential of these vinegars should not be ignored, then, more studies are necessary in order to demonstrate their functional properties.

Additional keywords: antioxidant action; human health benefits; vinegar consumption.

Resumo

O vinagre é um condimento amplamente utilizado, consumido por todas as classes sociais e com grande potencial para benefícios à saúde, o que justifica a preocupação com sua atividade benéfica. O País ainda é principiante em pesquisas com vinagre, tanto na verificação de seu potencial para a saúde, quanto nas matérias-primas utilizadas e no processo de produção. O artigo tem como objetivo reunir e discutir estudos que comprovam a ação benéfica do vinagre para a saúde humana. Em estudos realizados na Europa e na Ásia, observou-se que o consumo do vinagre pode trazer benefícios, pois apresentou efeito antitumoral, redução do nível de glicose no sangue, efeitos no sistema imunitário, efeito anti-hipertensivo, dentre outros. Os responsáveis pelos efeitos medicinais são o ácido acético (com teor mínimo de 4% nos vinagres, segundo a legislação brasileira), e outros compostos resultantes do metabolismo dos microrganismos durante as etapas de fermentação e/ou envelhecimento. Apesar destes resultados, ainda são deficientes pesquisas *in vivo* e, portanto, as doses diárias recomendadas que comprovem a eficácia medicinal do vinagre são desconhecidas. Desta forma, tendo em vista os resultados favoráveis, não se pode ignorar o potencial funcional deste fermentado acético, sendo necessários estudos que evidenciem suas propriedades funcionais.

Palavras-chave adicionais: ação antioxidante; benefícios para a saúde humana; consumo de vinagre.

Introduction

According to the technical regulation for the setting of identity and quality standards for vinegars, by vinegar or acetic acid fermented it is understood the product derived from the acetylation of the alcoholic fermentation of mash of fruits, cereals or other vegetables, honey, mixed vegetables, or, still, from a hydroalcoholic mixture, with the possibility of adding vegetables, plant parts, aromatic plant extracts, juices, natural flavors or seasonings. The maximum value of 1.00% (v/v) ethanol at 20 °C and at least 4.00% of volatile acidity (Brasil, 2012) must be found.

The vinegar is a solution of diluted acetic acid resulting from a double fermentation, alcoholic and acetic, of any candied fermentable substrate (Solieri & Giudici, 2008). It is widely used in a traditional food in Brazil and easily accessible, but yet little is known about its functional properties. This is one of the consequences of the tiny number of researches conducted on this subject. Europe and Asia are already ahead with studies in this area, and have interesting results that prove the large number of functional compounds present in vinegars from these regions (Budak et al., 2014).

The consumption in Brazil is still low compared with the first world countries, considering that each Brazilian consumes on average 0.8 liters of vinegar per year, while in Europe and the United States this average is 1.8 liters per year per capita (Anav, 2013).

The vinegar has various purposes, being used since ancient times in the human diet as food flavoring and preservative, as well as on the basis of single medicines for humans and animals (Solieri & Giudici, 2009). This fermented product has been used also in some countries as a drink for medicinal purposes (Rainieri & Zambonelli, 2009).

For the food industry, the range of functionality of the vinegar is wide, due to its ability to reduce the pH of foods, inhibiting the growth of bacteria. It also prevents the growth of fungi, disinfects the equipments and neutralizes unpleasant odor of some foods (Vithlani & Patel, 2010).

The multiple features of vinegar are not deriving from the modern world, as there are approximately 5 thousand years that vinegar is produced and marketed. The Babylonians traded vinegar flavored with fruit, honey and malt until the sixth century. Records in the Old Testament indicated the use of vinegar as a medicine for treatment of wounds (Budak et al., 2014).

The Chinese also already knew it, as they use vinegar for more than 3000 years; in addition to flavoring and preservative, it has been used for medicinal purposes in traditional Chinese medicine (Fan et al., 2011).

The microorganisms responsible for vinegar acetic fermentation produce, besides the acetic acid, various metabolic compounds that modify the flavor of the product. Some vinegars, such as rice, balsamic and fruit, in general are known to contain antioxidants, antitumor compounds and other bioactive metabolites that can be responsible for its beneficial health effects (Murooka et al., 2009; Giudici et al., 2009; Vanin et al., 2012).

Foods or drinks that have beneficial properties to the human body can be classified as functional foods. These foods are defined as any substance, or constituent of a food, that provides health benefits, and have adequate nutritional effects. It can only be considered functional if its beneficial action is shown to one or more target functions in the body, being important both for the well-being and health as well asreducing the risk of a disease (Siró et al., 2008; Ordoudi et al., 2014).

According to resolution establishing the basic guidelines for analysis and verification of functional properties and/or of health alleged in labeling of foods, functional property claim is that the one which shows the metabolic or physiological role that the nutrient or non-nutrient plays in the growth, development, maintenance and other normal functions of the human body (Brasil, 1999).

Since vinegar has been the subject of researches that characterize it as a functional food, mainly due to its antioxidant action, this article aims to gather and discuss studies showing the beneficial action of vinegar to human health.

Functional properties of vinegar

The phenolics and antioxidants present in vegetables and beverages depend on the feedstock used and on the processing and aging, because the fermentation, for example, may change the chemical nature and effectiveness of its phenolic constituents (Shahidi et al., 2008; Cerezo et al., 2010). Fruit vinegars are considered superior in sensory and nutritional qualities, when compared to other types of vinegar (Marques et al., 2010.)

The duration of the fermentation process of the Brazilian vinegar is much smaller and can take a few hours, and aging is not a usual practice, what characterizes a product (vinegar) with lower functional characteristics (Budak et al., 2014).

Many studies argue for the functional properties of rice vinegar, the *kurosu*, traditional Japanese vinegar, one of the most common traditional vinegars in Japan, with a high concentration of amino acids and organic acids compared with other vinegars. *Kurozu* is used in Japan as a healthy drink to relieve hypertension, prevent cancer and improve the symptoms of allergies. Many of these effects have been shown in scientific studies (Shimoji et al., 2002; Fukuyama et al., 2007; Hashimoto et al., 2013; Miyoshi et al., 2014.).

White rice vinegar may have antiglycemic function (Salbe et al., 2009; Gu et al., 2012), brown rice vinegar (*kurosu*) has benefits across the immune system (Hashimoto et al., 2013) and antitumor effect, for example (Fukuyama et al., 2007).

Gu et al. (2012) found that the consumption of Chinese white rice vinegar helped in controlling blood glucose; Fan et al. (2011) obtained similar results, verifying inhibitory activity of α-glucosidase, which can be useful for diabetics. Other studies have demonstrated benefits across the immune system (Hashimoto et al., 2013) and anti-hypertensive effect (Kondo et al., 2001).

Part of *kurosu* functional properties may be explained by the production process, which is done using slow or static process (Murooka et al., 2009). This process is not used industrially, and the Brazilian production uses, mostly, the submerged process (Budak et al., 2014). The process of fermentation lasts 6 months, followed by a year, at least, of aging. During this process, the majority of micro-organisms associated with fermentation loses its activity, and it is expected the presence of microbial components responsible for some of the functional properties of the vinegar (Hashimoto et al., 2013).

Besides the rice vinegar, the vinegar of other raw materials are also featured in functional properties, such as sherry wine vinegar with different fruits (orange, strawberry, grape and lemon) (Bastante et al., 2010); apple vinegar, with potential in the prevention of tumors (Abe et al., 2007), in lowering cholesterol and triglycerides level (Budak et al., 2011); vinegar made from ginseng extracts with antiglycemic and antidiabetic effect (Lim et al., 2009); pomegranate vinegar, being classified as a functional condiment due to phenolic compounds and antioxidant activity with potential in reducing the accumulation of visceral fat (Ordoudi et al., 2014; Park et al., 2014). In Indian jujube vinegar (*Zizyphus mauritiana*) - a little exploited Indian fruit - the authors found a high antioxidant activity of the fermented, and it may be defined as a functional vinegar (Vithlani & Patel, 2010); and, in general, Salbe et al. (2009) assessed the effects of vinegar on the regulation of human glucose and possible mechanisms of action.

Antioxidant action

Antioxidants can be defined as stable molecules which can donate electrons to the free radicals and thus neutralize them, reducing thereby their ability harmful to the human body (Halliwell, 1995). They can help to protect the body against damage caused by reactive oxygen species (Halliwell et al., 1995).

Free radicals are defined, in general, such as organic and inorganic molecules and atoms containing one or more unpaired electrons, with independent existence (Halliwell, 1994). They can attack important macromolecules causing oxidative damage to cells and disruption of homeostasis. The target of the free radicals includes all types of molecules of our body, but the most affected molecules are lipids, nucleic acids and proteins, and therefore they are involved in the development of some degenerative diseases (Rao et al., 2011).

The source by which free radicals are formed in our body can be endogenous or exogenous. Endogenous sources originate from biological processes that usually occur in the body, and exogenous sources include smoking, air pollution, organic solvents, anesthetics, pesticides and radiation (Machlin & Bendich, 1987; Soares, 2002).

Antioxidants are one of the compounds with biological activity present in vinegars, which has great ability to scavenge free radicals (Xu et al., 2007).

In a study developed with pomegranate vinegar, it was compared the content of total and individual polyphenols, anthocyanins and the antioxidant activity of vinegar and fresh pomegranate juice. It was found that the alcoholic fermentation was ten times lower in anthocyanins than the vinegar, which in turn had the same concentration as the fresh juice. It was concluded that this vinegar has potential as functional condiment based on its composition in phenolic compounds and moderate antioxidant activity (Ordoudi et al., 2014).

In India, the authors produced a jujube vinegar (Zizyphus mauritiana) (traditional country fruit) and rated physical (titratable acidity, pH, total sugars) and biochemical (phenolic content and antioxidant activity) parameters of the product. They found that the phenolic content and antioxidant activity (using the DPPH and ABTS methods) increased to vinegar compared with fresh fruit juice. Thus, they concluded that vinegar has a considerable amount of antioxidants and antioxidant activity, and may be defined as a functional vinegar (Vithlani& Patel, 2010).

Regarding the production of vinegar from cereal, studies in Japan showed that the vinegar made from brown rice (*kurosu*) has a high antioxidant activity, especially for its phenolic content (Shahidi et al., 2008). The rice bran, constituent of brown rice, also has antioxidant potential and beneficial effects for health due to the presence of phytic acid. The bran, a by-product of the rice industry, is produced on a large scale, being constituted by pericarp, aleurone, and seed, with a phytic acid content of about 5.88 ± 0.09% (Canan et al., 2011).

The antioxidant activity of phytic acid is being studied in several areas, for example, in food preservation (Stodolak et al., 2007; Canan et al., 2012), oxidation of metals (Gupta et al., 2013), and in human health, with anticancer activity (Norazalina et al., 2010; Norhaizan et al., 2011), in the treatment of diabetes (Lee et al., 2006), renal calculus (Saw et al., 2007), and Parkinson's disease (Xu et al., 2008).

In Brazil, a study conducted to evaluate the antioxidant activity, in vitro, and determine the polyphenol content of different types of vinegars sold in the south of the country, found that the vinegar samples (23 in total) showed a great variation in the parameters studied. The evaluated vinegars were of red wine, white wine, red agrin, white agrin, balsamic, alcohol, apple, rice and orange. The highlight for the antioxidant activity was for balsamic vinegar (Vanin et al., 2012).

Antitumor effect

Research involving the antitumor effect are linked mostly to *kurozu* vinegar. According to Hashimoto et al. (2013), many microbial components have antitumor effect. Therefore, it is believed that microbial components of *kurosu* can help in preventing cancer and relieve allergies.

Shimoji et al. (2002) analyzed the antioxidant activity of k*urosu*, and found that the phenolic compounds present in the product had antitumor activity. The main compounds studied were the dihydroxyferulic acids (DFA), dihydroxysinaptic acids (DSA), ferulic, synaptic, vanillin, and p-hydroxycinnamic acids, and the first two were the main contributors in inhibiting tumors. DFA and DSA are homologous of ferulic acid and sinapic acid, which are known as natural antioxidants occurring in rice, wheat, brown rice, and other grain. The antioxidant activities of DFA and DSA were evaluated by scavenging activity method of DPPH radicals (Yamaguchi et al., 1998).

In another study, in which tests in vitro and in mice skin were performed, it was evidenced the antitumor effect of the vinegar. An extract of *kurosu* vinegar (1ml/100ml acetone) was used and applied to rats for 15 days. A reduction of 36% in the average number of tumors per mouse was presented. It was also found that the *kurosu* (brown rice vinegar) had higher levels of antioxidant activity than rice vinegars, grain vinegars and wine vinegars. The antioxidant and scavenging properties, and interference in the formation of free radicals, were the explanations found for this effect (Nishidai et al., 2000).

The antitumor effect was evaluated in rats comparing *kurozu* and *kurozu moromimatsu* (solid residue from the production of *kurozu* vinegar, after aging). The volume of the tumors in the control group and the group administered with *kurozu* were the same, as for the group on which *kurozu moromimatsu* was used, there was significant reduction in size, indicating beneficial effects of vinegar sediment (Fukuyama et al., 2007).

Antiglycemic effect

Studies that show the antiglycemic effect of vinegar are known for over a century, being demonstrated both in animals and in humans, however the exact mechanism of action is still unknown (Salbe et al., 2009).

The antiglycemic effect of vinegar was reported in 1988 by researchers Ebihara and Nakajima (Ebihara & Nakajima, 1988). These authors studied mice that were fed with a 25% casein-sucrose purified diet for 2 weeks. The animals were divided into two groups of 6 rats, fasted for 24 hours, and then a corn starch solution was administered to 10% (w/v), with or without 2% (v/v) acetic acid to provide 100 mg of starch in 100 g body weight. The rapid rise and decline of glucose concentrations in blood were inhibited in the group treated with acetic acid.

The same authors studied the effect on men, by using a strawberry vinegar and no more acetic acid. A sucrose solution which contained 50 g of sucrose and 60 ml of commercial strawberry vinegar was administered to a group, and 300 ml of a sucrose solution containing 53.6 g of sucrose (control meal) to another. The acetic acid content of this commercial strawberry vinegar (Nakano Vinegar Co. Ltd.) was 5%, and the vinegar contained 6% sugar substance (sucrose + glucose + fructose). One week after the first trial a similar experiment was performed, reversing meals for each group. The results for blood glucose were akin for the two groups, the insulin level, on the other hand, was 20% lower for the group that consumed the vinegar. The authors state that while further studies are necessary to investigate the mechanism of action of the acetic acid, the vinegar can be applied to control the hyperglycemic response after a meal.

One of the latest studies was held by Gu et al. (2012), who investigated the antidiabetic effect of white rice vinegar in diabetic rats induced by streptozotocin (STZ) - diabetogenic substance used to induce diabetes. The study was conducted with two groups of 6 rats, in one of them was administered white rice vinegar (2 ml/kg body weight/day) or with an equal volume of potable water for 1 month. As a result, it was verified the antidiabetic effect in controlling blood glucose, in insulin deficiency, in protecting the hepatocytes and beta cells. Given the importance of beta cells and hepatocytes protection in the development of diabetes and the importance of glycemic control, vinegar can be considered a dietary supplement promising for diabetics.

Fan et al. (2011) studied five different Chinese vinegars, in order to characterize their composition and determine the inhibitory activity of α-glucosidase. On laboratory analysis, it was observed a strong inhibitory activity of α-glucosidase, an enzyme that slows carbohydrate digestion in the intestinal tract, which indicates application to studies on diabetics.

Shishehbor et al. (2008) studied the reduction of lipid profile in rats, on which normal mice and diabetic ones, induced by streptozotocin (STZ), were fed with a diet containing 6% apple vinegar. The apple vinegar administration occurred 8 hours after STZ injection, for 4 weeks. In normal rats, there was significant reduction of low density lipoprotein (LDL) and significant increase in high density lipoprotein (HDL). The apple vinegar also reduced serum triglycerides and increased HDL in diabetic mice, suggesting that the product may be used in the control of complications caused by diabetes.

Ginseng vinegar has been evaluated and, with respect to the data gathered, it has potential for clinical use in the treatment of obesity in patients with diabetes mellitus type 2. The authors have used three groups of rats, one as control and the others administering 300 mg kg^{-1} and 500 mg kg^{-1} vinegar per day (Lim et al., 2009).

Anti-hypertensive effect

In the study of Kondo et al. (2001), a significant reduction in blood pressure during the experimental period of rice vinegar administration to spontaneously hypertensive rats (SHR) was observed. The rats were fed with a standard laboratory diet mixed with vinegar or acetic acid solution (about 0.86 mmol of acetic acid/day for 8 weeks).

Another study reports that the ingestion of a drink derived from a red wine vinegar and grape juice (Budo-no-megumi™) mixture, administering 3 ml kg^{-1} (recommended dosage of drink), inhibits the renin-angiotensin system in nonhypertensive rats. The management of the new drink supplied the activity of angiotensin converting enzyme (ACE) in vivo, which may partly explain the hypotensive action. In addition, the acetic fermentation can be useful for the prevention of various cardiovascular diseases, including atherosclerosis, ventricular remodeling after myocardial, infarction, diabetic nephropathy and hypertension (Honsho et al., 2005).

Other benefits

Mimura et al. (2004) conducted a study with *kibizu*, a sugar cane vinegar produced in Amami Oshima, Japan. The fraction extracted with an aqueous solution of 40% methanol showed high scavenging potential of DPPH radical, in addition to growth suppression of human leukemia cells (HL-60). These results led the authors to believe that the active components in sugarcane juice could be converted into more lipophilic compounds by the alcoholic and acetic fermentation, with activity to induce apoptosis in HL-60.

The first study to confirm the beneficial action of apple vinegar was developed by Budak et al. (2011), on which effects on blood lipid levels, liver function and steatosis and body weight in rats were found, however it is emphasized the need for further studies to clarify the mechanisms of vinegar on the metabolism.

In a study by Lee et al. (2013), tomato vinegar was produced and evaluated as to the efficacy of the treatment of lipid accumulation in 3T3-L1 adipocytes and in rats fed a high-fat diet. The rats were fed with a dose of 7 ml/kg/day, for 5 weeks, corresponding to the amount of drink per day in humans. It was concluded that tomato vinegar can be considered beneficial to prevent obesity and reduce visceral fat mass and hepatic steatosis in the obese rats induced by high-fat diet.

It was found that, in long-term, the *kurosu* contains components that stimulate the innate immune system, which are considered to be derived from microorganisms involved in the fermentation process. At a concentration of 1 mg/ml, *kurozu* stimulated the production of cytokines, spleen cells of mice. This indicates that the *kurozu* components are recognized by TLR2, NOD1 and NOD2 (sensors of the innate immune system that recognizes pathogens) in the mouse immune system (Hashimoto et al., 2013).

One of the metabolites (alkali-stable lipid) of acetic acid bacteria have demonstrated improvement of cognitive functions in rats that had brain injury. It was extracted the metabolite of acetic bacteria and administered in mice in the ratio of 165 or 1650 mg/kg per day for 14 days (Fukami et al., 2010).

The activation of protein kinase (AMPK) has been recognized as promising in the treatment of obesity, the acetic acid consumed is absorbed by the the intestine and metabolized in the liver resulting in activation of protein kinase. The study was conducted with pomegranate vinegar, on 78 overweight women, who were randomly assigned to receive either pomegranate vinegar (1.5 g acetic acid per day) or placebo, for 8 weeks. Vinegar decreases visceral adipose tissue (measured by computerized tomography), causing increased phosphorylation of AMPK in comparison with the placebo group (Park et al., 2014).

Conclusions

The number of studies found about the topic discussed is considerably high and current, for although some studies have been done decades ago, researchers continued to conduct scientific research, with interesting results. There is a large concentration of them in the east, investigating ancient traditional vinegars. In Brazil the number of researches is still limited.

Despite the studies conclude that vinegar can provide health benefits, its behavior in the human body is not known for sure. In vivo studies are still deficient, and therefore the recommended daily allowances proving the medicinal vinegar efficacy are unknown.

However, one cannot ignore the findings regarding the proof of the existence of phenolic compounds and the antioxidant property of compounds from fermented acetic studied. In addition, the growing concern of the population with the intake of functional foods and the consumption of vinegar in all social classes should arouse in the scientific team a yearning to seek new findings on the subject, especially in the quantification of a recommended daily intake for to achieve the expected benefits, as well as the development and improvement of fermentation processes.

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