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JUICE NANOTECHNOLOGY: A MINI REVIEW

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green synthesis, nanojuice, nanomilling, nanofiltration, nanopackaging, regulation

ABSTRACT
In the past two decades, nano-science is widely used in different applications and the increased interest in the utilization of nanoparticles in food processing is clear. Such applications include processing, packaging, development of functional food, safety, foodborne pathogens detection, and shelf-life extension. In this article, the essential facts and the latest uses of nano-science in fruit and vegetable juices were described. The green synthesis of nanoparticles with antioxidant, antibacterial and antifungal characteristics is of great interest in food preservation. These nanoparticles such as metals, oxidized metals and its bioactivity in juice were reviewed. The current procedures to prepare nanojuice including nanofiltration and the most recent nanomilling were presented. Beside the preparation, special emphasis has also been given to the chemical as well as the biological (microbial and enzymatic) quality of the produced nanojuice. The role of nanotechnology in the development of the smart and the active food packaging systems for the improvement of food shelf- life and quality was also discussed. Since the physical and chemical characteristics of nanoparticles are completely different from those of macro-size. Therefore, special and urgent attention by responsible authorities should be given and effective policies should be applied for food products to ensure product quality, customer health and safety as well as the environmental protection.

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НАНОТЕХНОЛОГИЯ СОКА: МИНИ-ОБЗОР

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КЛЮЧЕВЫЕ СЛОВА:
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АННОТАЦИЯ
В последние два десятилетия нанонаука широко используется в различных областях и очевиден повышенный интерес к применению наночастиц при переработке пищевых продуктов. Такие области включают переработку, упаковку, разработку функциональных продуктов, безопасность, обнаружение пищевых патогенов и продление сроков хранения. В данной статье описаны важнейшие факты и современное применение нанонауки для фруктовых и овощных соков. Большой интерес вызывает зеленый синтез наночастиц с антиоксидантными, антибактериальными и противогрибковыми свойствами для увеличения сроков хранения пищевых продуктов. Сделан обзор наночастиц, таких как металлы, некоторых видов их оксидов и окислов, и их биологическая активность в соке. Приведены современные процедуры для производства нано-соков, включая нано-фильтрацию и самое современное нано-измельчение. Помимо производства, особый акцент в обзоре сделан на химических, а также биологических (микробиологических и ферментативных) качественных характеристиках произведенных нано-соков. Также обсуждена роль нано-технологии в развитии систем «разумной» и активной упаковки для увеличения сроков хранения и улучшения качества пищевых продуктов. Показано, что физические и химические характеристики наночастиц полностью отличаются от характеристик частиц макроразмера. Сделан вывод о том, что производителям пищевой продукции при использовании новых технологий должно уделяться особое внимание обеспечению ее качества для сохранения доверия потребителей. При этом контролирующими и регулирующими организациями должна проводится эффективная политика по обеспечению безопасности пищевой продукции, сохранности здоровья потребителей и защиты окружающей среды.

1. Introduction

Nanotechnology is a field of science that concerned with controlling the material on the scale of atoms and molecules. Such small particles ranged from 1 to 100 nm in diameter with a high surface-to-volume ratio, which essentially allows them to be more active and dispersed than their larger one. They provide a lot of food implementations i. e., processing, packing, storing, handling, bioactivity as well as food safety [1]. Nanoparticles (NP) are usually produced by crushing molecules into nano-scale particles (top-down) or rearranging it (bottom-up) to produce nano-sized particles with new properties [2]. Low fat, sugar and salt diets could be produced using nanotechniques [3].

Any food cultivated, produced, processed or packed using nanotechniques as well as with added NP, is called nanofood [4, 5]. Nanojuice (NJ) aims to increase nutritional value and avoid the failure of juice quality. NJ possesses unique characteristics such as crossing the body's natural barriers, entering into cells or the bloodstream and even through the cell wall surrounding the brain. As a result NJ constituents i. e., antioxidants, antimicrobials, natural pigments, biomolecules and other bioactive compounds will be more nutritious and active inside the body.

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NP improved taste, flavor, consistency, stability and texture of food products. Also, enhanced bioactivity of nano nutraceuticals was achieved [6,7,8]. Phyto-NP showed higher antioxidant activity than macromolecules. This may be due to the high surface area of NP that resulted in increasing chemical activity [9]. NJ minerals (i. e., Fe, Ca, K, Cu, Zn…etc.) could be better absorbed by the body to tackle deficiency. Due to the limited knowledge concerning NJ, therefore, this article aims to provide the basic facts regarding the recent uses of nanotechniques in juice processing and packing as well as safety, health concerns and regulation.

2. Juice nano-processing

Literature revealed the use of filtration or milling techniques to achieve nanoparticles juice (NPJ). Nanofiltration utilizing filters with pores of nano-size was used by many authors for clarification, concentration, stabilization, discoloration and pigments separation of juices (Table 1). Nanofilteration was successfully used in concentrating strawberry juice maintaining of its bioactive phenolic compounds [10] and in improving the quality of pear juices [11]. De-coloration of dark apple and grape juices was carried out by physical separation of melanoidins using nanofiltration membranes and the color characteristics of the only apple juice became closer to the non-browned juice [12]. Procyanidin was separated from grape juice utilizing nanofilters and the main advantages were: rapid separation, energy efficient, and with no oxidization loss [13]. The Korean dongchimi nanojuice (alternative health soft drink) was prepared via fermentation followed by nanofiltration instead of using heat treatment and the nanofiltered juice used as anti-adipogenic agent [14]. Nanomilling was utilized for the first time [15] in the preparation of NP orange juice (NPOJ) (Figure 1). The prepared juice exhibited high sensory scores, lower pectin methylesterase activity and as a result lower juice separation as well as higher microbiological quality (Table 2).

Table1

Juice nanofiltration

Juice type	Action	References
Apple and Pear	higher concentration	[16]
Apple and Grape	melanoidins separation	[12]
Pear	enhance stability and shelf life	[11]
Amla	improve color, clarity and valuable component.	[17]
Grape	procyanidin separation	[13]
Strawberry	efficient concentration with maintenance of phenolic compounds	[10]
Apple	juice with 30% less sugar	[18]

Table 2

pH values, ascorbic acid content, pectin methylesterase activity (PME), psychrotrophs and yeast and mold counts of fresh OJ, pasteurized OJ and NPOJ with freeze dried kiwi (0.3%, w/w) [15]

Parameter	Fresh OJ	Pasteurized OJ (70 °C/5 min)	NPOJ
pH	3.67±0.18	3.70±0.07	3.71±0.12
Ascorbic acid (mg/100g)	44.00±0.80	18.97±0.08	28.50±0.24
PME ($U\ ml^{-1}\ min^{-1}$)	4.49±0.00	0.34±0.30	0.26±0.14
Psychrotrophs (log_{10} CFU ml^{-1})	3.01±0.04	2.08±0.06	1.63±0.18
Yeasts &Molds (log_{10} CFU ml^{-1})	2.70±0.02	1.50±0.08	1.61±0.30

3. Green synthesis of NP

Green synthesis of NPs with antioxidant, antibacterial and antifungal characteristics is of great interest in food preservation [19]. In general, various synthetic methods include physical, chemical and biochemical (green) techniques were used for the production of nano-sized silver particles (AgNPs). The reduction by chemical procedures is widely used since it generates AgNPs on large scale under gentle conditions. However, it exhibited side toxic compounds which may have adverse impact in the medical uses and environment. Therefore, the synthesis of AgNPs by green method has many advantages over those obtained by physical and chemical means as it is eco-friendly, cost effective, and generated under mild conditions [19]. The metal such as silver nitrate was used as the silver precursor, while the fruit juices were used as reducing and stabilizing agents. Green synthesized AgNPs, as an antimicrobial agent, were used in lime, lemon, orange and grape juices against *Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa* and *Bacillus subtilis* [20]. Zirconium nitrate NPs (ZrNPs) were prepared using orange juice and orange peel extract, as green reducing agent and stabilizer [19]. They studied the antimicrobial, anti-inflammatory and antioxidant activities of the synthesized ZrNPs. Recently, nano-sized iron particles (zero valent) encapsulated in carbon were synthesized and used for destroying patulin in apple juice [21]. More recent, fresh apple juice was clarified using nano powders of both silicon dioxide (SiO_2) and titanium dioxide (TiO_2) [22]. Their clarifying abilities were higher than that of bentonite clay. Commercially SiO_2 and TiO_2 are widely utilized as food additives in many food products (E551 and E171, respectively) [23].

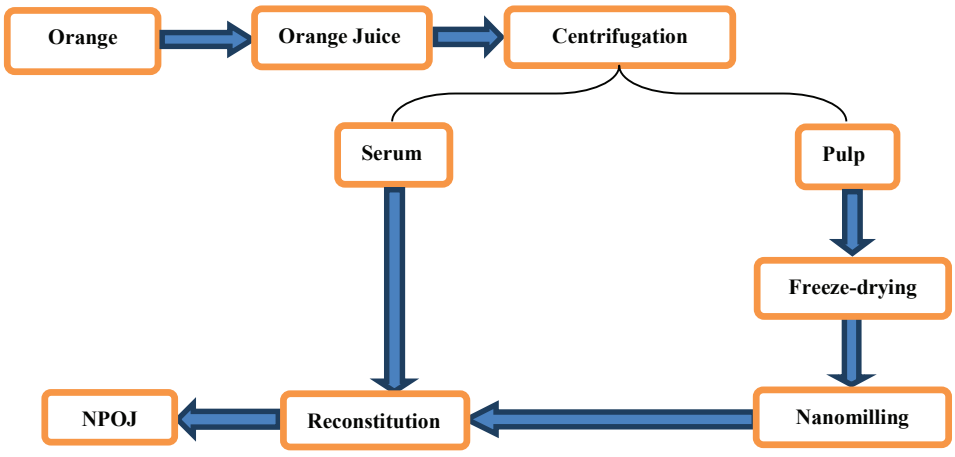

Figure 1. Schematic diagram of the production of NPOJ [15]

4. Juice nano-packaging

Good packing substances should be gas and moisture impermeable in addition to accepted mechanical strength and biodegradability. Nanotechnology has a great role in the development of the smart (contains specific sensor to indicate about the internal condition of the product in form of signals) and the active (contains specific system such as antioxidant or antimicrobial agents to modify the environmental conditions for extending shelf life and improving food safety) food packaging systems. Both types exhibit several benefits over the traditional packaging methods since they can provide better packaging characteristics such as enhanced mechanical strength, barrier characteristics, antimicrobial activity, and ability to specific pathogenic bacteria detection and alerting consumer's attention to product safety [24]. Incorporating NPs of inorganic metals and metal oxides (i. e. Ag, Fe, TiO_2, ZnO, MgO, SiO_2) and carbon within packaging materials, a novel packaging material with potent antimicrobial activity could be performed with more stability in extreme conditions [25]. Several AgNPs based packaging materials with high antimicrobial activities are available in markets [26]. Packages containing nanosilver effectively increased the quality of fresh orange juice [27]. Nanocomposite and nanolaminates also give an extra protection against extreme thermal and mechanical conditions leading to the improvement in food quality [28].

5. Nanojuice safety and regulation

There are several benefits of the applied nanotechniques in food processing. However, safety of the NP should be well considered since the physical and chemical characteristics in nano-size are completely different from those of macro-size. For example issues such as: the partitioning of NPs from packaging materials into food [29], and the bioaccumulation of these small size particles within human body [30] should be carefully evaluated. Each NP type has its own characteristic and therefore, toxicity research should be separately founded [31]. Therefore, responsible authorities should apply effective guidelines and policies for food products to ensure product quality, customer health and safety as well as the environmental protection. In the USA, the US-FDA is involved in the regulation of nanofoods, while the Food Standards Australia and New Zealand (FSANZ), a regulatory body under the Food Standards Code actively participates in the regulation of nanofood additives and ingredients in Australia [26]. Risk assessment of nanotechnology in the European Union is performed by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). The nanofood or food ingredients are completely covered by the European Union Novel Foods Regulation (EC258–97) [32]. Japan and China are the major nano-size materials producing countries. However, they do not have the proper needed legislations [33]. The lack of nanojuice and nanofood legislations in many countries is due to knowledge gap concerning exposure, availability, and toxicity of these materials to human body. Therefore, urgent need of accepted international regulatory system for the regulation of the use of NPs in food processing [26].

6. Conclusion and future perspectives

Currently, nanotechniques play an important role in food industry. It well contributes to the texture, taste, appearance, shelf life and the bioavailability of nutrients of the Food. Although the advances in nanotechnology are clear, however, the current level of research concerning nanojuice is still at research and development stage. Many challenges to improve such technology and to assess its safety are needed to establish customer trust.

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