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Review Article

Oxygenated Water and Nano Engineered Water Benefits in Drinking Use and Food Processing: A Mini-Review

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Abstract

Increased interest in the utilization of oxygenated water in human prophylaxis and therapy is clear. Dissolved oxygen is an indicator of water quality. In this article, factors affecting dissolving oxygen in water including temperature, salinity, pH, organics and atmospheric pressure were explained. Various benefits in the case of drinking water that contained extra dissolved oxygen were reviewed. These benefits such as improving oxygen availability of the body and the consumer's health were presented. The recent oxygenation procedures to generate functional water rich in oxygen were described. Engineered water nanostructures or nano designed water (NDW) which used in inactivation of food pathogens, cleaning and disinfecting either raw or minimally processed fruits and vegetables and food preparation surfaces instead of other disinfecting methods were also considered. Using NDW in disinfecting air inside food plants was also included.

Key words: Drinkable oxygen, nano-engineered water, hydrosomes, food, quality

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INTRODUCTION

All mankind and organisms are dependent upon oxygen to live and maintain the metabolic processes that produce energy for activity, growth and reproduction. The majority of oxygen uptake is through the lungs and some can be absorbed via the intestine to increase oxygen in the bloodstream¹. Therefore, oxygen content either in the air or dissolved in water is vitally concerned. Many people continue to drink oxygenated water for enhancing their health², for example, oxygenated water inhibits adipogenesis³, also, effects on liver function or at recovery after exercise^{4,5} improves memory and athletic performance⁶.

Since the early 1990s, the consumption of oxygenated water in the world particularly in Europe and the United States⁷ is going through a gradual increase in comparison with the increasing of consumer's awareness of the positive effects of such water. This phenomenon runs in parallel with the expansion of human prophylaxis and therapy and the demand by the public for water with specific standard quality. Many researchers have been carried out investigations to study various aspects of the oxygenation of water and their positive effects. Therefore, the objectives of this review was to provide readers with an overview of the various benefits of oxygenated water and nano-engineered water either in drinking or food processing, factors affecting dissolving oxygen in water, industrial sources of oxygen, current procedures and opportunities of using nano-engineered water in food processing.

Super oxygenated water: Oxygen enters water bodies primarily by direct absorption from the atmosphere and to a lesser extent by the action of photosynthetic organisms and aquatic plants and removed from water by respiration and decomposition of biological oxygen-demanding organics^{8,9}. There are only two possible ways to carry oxygen in the blood: Oxygen is either chemically bound to haemoglobin (98%) or physically dissolved in the (2%) plasma¹⁰.

Dissolved oxygen (DO) is an indicator of water quality. Dissolved oxygen in water can be measured either in concentration (mg/l or ppm) or percent saturation. Normal tap water contains approximately 5-7 mg oxygen per litre and fresh fountain water contains 10-12 mg. Oxygenation of tap water can increase the concentration of physically dissolved oxygen up to 120 mg L⁻¹ (Table 1). Super oxygenated water or equipment for the oxygenation of tap water is put on the market by various companies¹¹. From three decades ago,

several producers (in EC and USA) have generated drinking water rich in DO ranging from 30 to 120 mg O₂/L H₂O⁷.

Oxygenated water benefits: Several authors have been reported the benefits of using oxygenated water, in the case of human health, drinking water that contained extra dissolved oxygen leads to improve oxygen availability of the body and the consumer's health¹¹, which may improve the healing process for diabetic patients² and could increase vitality and improve immune functions¹⁵. Kaqun water is functional water produced using electrolysis, to be used for drinking, cooking and bathing, its pH value and oxygen level are different from normal potable water¹². Table 2 shows that functional water increases the physical performance of the human body as reported by Szalkai¹². Also, oxygenated water is used for animal breeding¹⁶. Furthermore, iron and manganese ions present in extra concentrations in raw water especially groundwater¹⁷ sources cause water browning and blackening. Groundwater in some Egyptian rural areas contains high concentrations of Fe and Mn¹⁸. So, during the water purification steps, the water treatment plants use oxygenation in an aerator to oxidize soluble Fe and Mn to insoluble forms (deironing and demagnetizing)¹⁹ and consequently, Egyptian tap water (Nile treated water) contained 0.39 mg L⁻¹ Fe and 0.03 mg L⁻¹ Mn²⁰.

Factors affecting dissolving oxygen in water: Several factors affect O₂ saturation in water, including water temperature, the amount of dissolved salts (salinity) present in the water, organics, pH and atmospheric pressure^{8,21}. So, the amount of oxygen dissolved in saturated water will be greater in cooler waters than in warmer ones. Higher water temperatures result in increased molecular vibrations, essentially reducing the amount of space available between water molecules. The capacity of water to hold DO also decreases as the salinity increases.

Common sources of oxygen

Oxygen cylinders: Oxygen is produced in processing plants by cooling air until it liquefies, then distilling the liquid to separate pure oxygen, which is then passed through a liquid oxygen pump into cylinders^{22,23}.

Oxygen concentrators: Concentrators draw in air from the environment, which usually contains 21% oxygen, 78% nitrogen and 1% other gases and extract the nitrogen to leave

Table 1: Oxygen concentrations in different water samples

Samples	DO mg L ⁻¹ (mL L ⁻¹)	References
Tap water	5-7	Speit <i>et al.</i> ¹¹
Fresh fountain water	10-12	Szalkai ¹²
Oxygenated tap water	120	Fang <i>et al.</i> ⁷
Freshwater	4.2-4.98	Febiyanto ¹³
Seawater	(4.95)	Evans and Claiborne ¹⁴

Table 2: Health effects of functional water¹²

Increasing quantity of the reactive oxygen species (ROS) within the lymphocytes	Improving attention concentration ability
Decreasing the systolic and diastolic blood pressure	Quickly increases tissue oxygen levels
Increasing the brain activity	Reducing stress sensitivity
Increasing the small vessels' expansion	Acting on Prolyl hydroxylase and possibility reduces anaerobic metabolism

almost pure oxygen (O₂ concentration 90-96%). Concentrators provide a safe, less expensive, reliable, cost-efficient source of O₂^{22,23}.

Oxygen enriched water procedures: Super oxygenated water are commercially available either by saturation of water with molecular oxygen under elevated pressure²⁴, water was saturated with oxygen supplemented by O₃, ultrasound²⁵, or electrolysis of halide ion-free water in an electrolytic cell²⁶. Recently, deionized and tap water was saturated with molecular oxygen either before, or after, treatment with low-temperature, low-pressure glow plasma of low frequency were performed by Chwastowski *et al.*²⁷. They concluded that tap water saturated with O₂, then treated with plasma for 30 min, generated water containing 23 mg DO L⁻¹.

Nanoengineered water (Hydrozomes): Nano-designed water (NDW) droplets or hydrozomes, looks like normal water but their molecules are smaller than a normal one (the size of nano-designed water molecule equals about 1/10th of normal water). Due to their smaller size, they may be easily absorbed into the body cells. NDW is generated by electro-spraying of water steam. NDW has exclusive properties. NDW molecule has 25 nm diameter, its effect as an airborne inside building remains for many hours, has free radicals such as OH• and O₂• and potent surface charge (ten electrons /structure) and high antimicrobial activity in inhibiting food pathogenic microorganisms in air and on surfaces. Moreover, sustainable, chemical-free, green technology and environmentally friendly²⁸. ROS can cause cell injury including DNA damage¹¹. Consequently, NDW could be used in green cleaning and disinfecting either raw or minimally processed fruits and vegetables and food preparation surfaces instead of other disinfecting methods. Likewise, NDW could be used in disinfecting air inside food plants.

CONCLUSION

Various benefits in the case of drinking water that contained extra dissolved oxygen have been proven. NDW is the very promising liquid used for inactivating food pathogens, green cleaning and disinfecting either raw or minimally processed fruits and vegetables and food preparation surfaces instead of chemical ones. NDW could be used in disinfecting air inside food plants. However, to assure the continuous efficacy and safety of such NDW, further study is needed.

SIGNIFICANCE STATEMENT

This study discovered the water containing extra oxygen concentration and nano-designed water droplets that can be beneficial for drinking use, food processing, green cleaning and enhancing the body's health. This study will help the researchers to uncover the critical areas of oxygenated and nano-designed water that many researchers were not able to explore. Thus a new theory on super oxygenated water and nano-engineered water benefits may be arrived at.

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