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Physiochemical Characterization of Food Grade Titanium Dioxide (TiO_2 E171)

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ABSTRACT

Food grade titanium dioxide (E171) is a white additive widely consumed in many of the daily life products such as salad dressings, yogurt, candies, water flavorings, and coffee cream powders. The physiochemical properties of TiO_2 E171 such as particle size and surface chemistry determine it toxicity and bioactivity. There are many evidences that particles of TiO_2 E171 with smaller size can penetrate the cell membrane and accumulate in colon, liver, spleen, testis and brain casing a diverse hazardous effect. In this work, X ray diffraction (XRD), High Resolution Electron Microscope (HRTEM) and Fourier transformation Infra-red (FTIR) spectroscopy were used to investigate the physiochemical properties of TiO_2 E171. The obtained results revealed that TiO_2 E171 is in the rutile phase with tetragonal crystal structure with lattice parameters were a=b= 4.594 nm, 4.5879 nm, 4.5369 nm and average particle size 102.76 ± 27.68 nm. HRTEM images showed a non-uniform spherical shape with average particle size 136.76 ± 44.5 nm.

Keywords: Food additives, TiO_2 E171, structure, XRD, FTIR

Introduction

A food additive is any substance added to food at any stage to improve its keeping quality, taste, color, texture, alkalinity or acidity, or consistency or to serve any other technological function in relation to food. There are thousands of food additives used as antioxidants, flavorings and coloring agents, preservatives, sweeteners, thickeners, and many others [1].

Food additives are grouped into two according to their source; the natural and the synthetic. The natural found naturally, such as extracts from plants, animals and minerals. The synthetic is either synthetic identical copies of substances found naturally or produced synthetically and not found naturally [2].

According to European Community (EC) legislation food additives are defined as 'any substance not normally consumed as a food in itself, food additives could be natural or synthetic and assigned as E numbers, also food additives to be authorized should satisfying three conditions [3], [4]:

(i) There is a technological demand for their use

(ii) Consumers are not misled

(iii) Additives are not hazardous to consumers' health

The side effects of food additives may be immediate headaches, change in energy level, and alterations in mental concentration, behavior, or immune response or may be Long term effects increase risk of cancer, cardiovascular disease and other degenerative conditions [5].

Titanium dioxide (TiO_2) is widely used as white coloring agent with many applications. It exists in crystalline and amorphous forms, crystalline in either the rutile or anatase or brookite form or mixture of this [6]. Due to its unique physicochemical properties such as brightness , high refractive index, resistance to discoloration. TiO_2 (E171) is used in the food industry as coloring agent with number E171 to improve the color of food products such as candies, chewing gums, white sauces, and icing. It is also added to fat products such as skimmed milk, pastries, and ice creams [7]. The US Food and Drug Administration allows weight of TiO_2 (E171) does not exceed 1% of overall food weight. average adult's ingestion of TiO_2 0.2–1 mg/kg daily, while an average child's ingestion1–3 mg/kg [8]. However, recent evidence found TiO_2 (E171) in the liver, kidneys, spleen, and lung tissues and showed that TiO_2 particles could be transferred to other tissues after reuptake by digestive tract [9]. It is also found significant hepatic toxicity that could be induced by sub-chronic oral exposure to TiO_2, which was more obvious and severe in female rats and caused through indirect pathways [4], [10]. Other studies observed an accumulation of TiO_2 in the liver and morphological and physiological alterations in liver and kidney [9], [11]. Moreover, studies showed exposure to TiO_2 (E171) promotes colonic tumorigenesis and induces change in gut microbiota composition [12], [13]. TiO_2 is classified as potentially carcinogenic for humans via inhalation. The International Agency for Research on Cancer (IARC) excluded the link between occupational exposures to

TiO_2 particles and risk for lung cancer in humans but categorized TiO_2 as group 2B carcinogenic compound experimentally [14], [15]. In the current study we focus on the physiochemical properties of food grade TiO_2 (E171).

Materials and methods

Materials Chemical and Reagent

The following chemicals were used in this study, all these chemicals were used without additional purification Food grade purchased from Nerol Company (Cairo-Egypt) .

Physicochemical characterization

Characterization

(XRD) measurement were performed on Bruker D8 Advance using Cu-Kα radiation with radiation 40 mA, 40 kV from Position [2 θ°] 4.01 to 89.99by step 0.02 with Scan Step Time [s] 0.6000 ,the crystallite size was calculated using the Scherer equation. Mean average size and shape of primary particles were determined by Transmission Electron Microscope(TEM) JEM- 2100 (JEOL , Japan), operating at 200 kV and Images were captured at 30,000 X magnification. The functional groups were measured using FTIR-4100 type A in the 349.053 -7800.65 cm^{-1} range, with a resolution of 4 cm^{-1} at room temperature.

Results and discussion

Modified TiO_2 Characterization

X-ray diffraction (XRD)

Figure (1) represents XRD pattern of food grade TiO_2 (E171), all the assigned peaks were in a good agreement with the JCPDS no (87-0920) for rutile TiO_2 [16]. The rutile phase with tetragonal crystal structure were detected. The calculated lattice parameters were a=b= 4.594 nm, 4.5879 nm, 4.5369 nm.

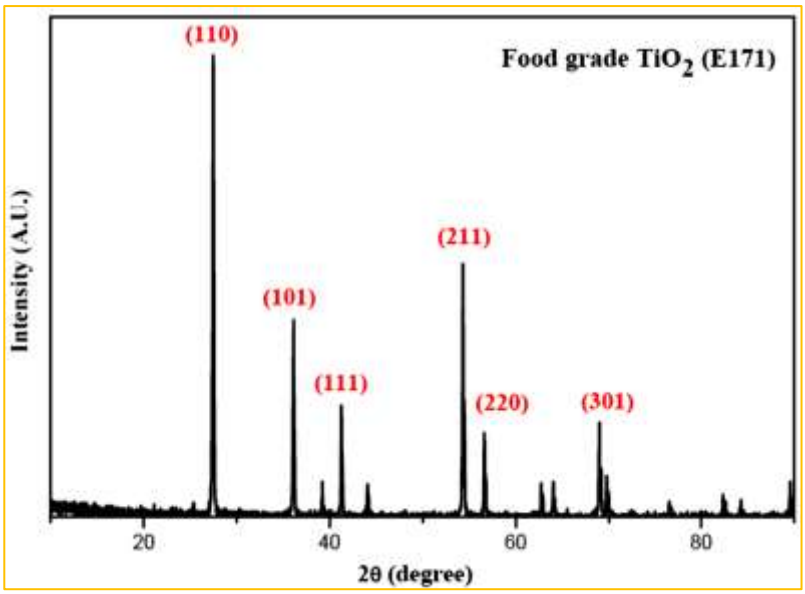

Fig 1. XRD of Food grade TiO_2 E171.

The average crystalline size of TiO_2 E171 was calculated by Scherer's equation to be 102.76 ± 27.68 nm.

High resolution transmission microscope (HRTEM)

It's observed in HRTEM images that TiO_2 (E171) have a non-uniform spherical shape with average particle size 136 ± 44.5 nm, figure (2).

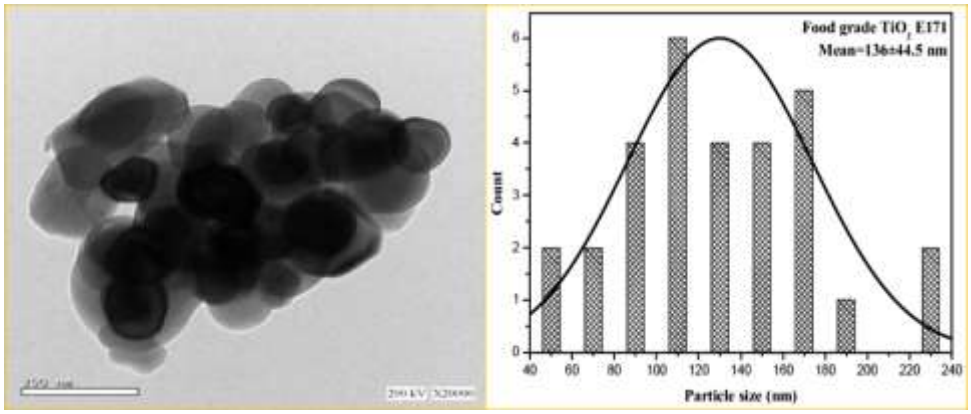

Fig 2. Transmission electron microscopy image and the particle size distribution of Food grade TiO_2 E171.

FTIR spectroscopy

The functional groups belonging to TiO_2 were observed approximately at 458 cm^{-1} corresponds to the Ti - O – Ti vibrational band and around 693 cm^{-1} correspond to TiO_2 Modes[17], [18].

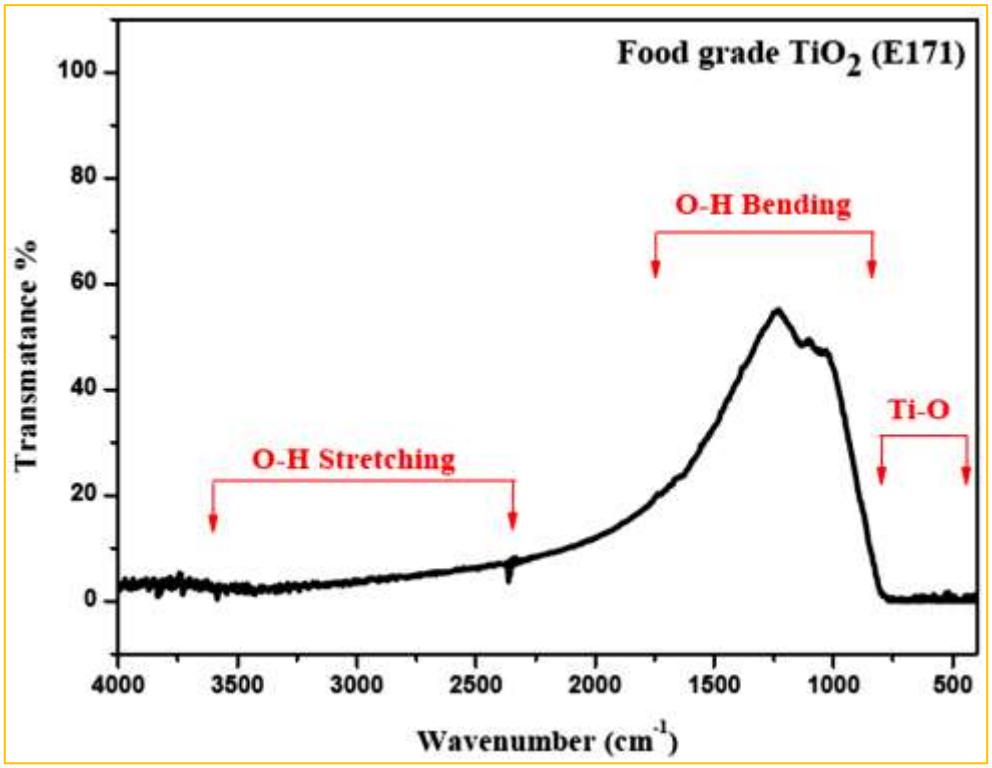

Fig. 3 FTIR spectra of Food grade TiO_2 E171.

Conclusion

This study has made a physiochemical characterization of one of most common food additives TiO_2 E171, to pinpoint the structure and particle size as well as the functional groups. Our results showed that TiO_2 E171 is in the rutile phase with tetragonal crystal structure with lattice parameters were a=b= 4.594 nm, 4.5879 nm, 4.5369 nm. The average particle size 102.76 ± 27.68 nm. HRTEM images showed a non-uniform spherical shape with average particle size 136.76 ± 44.5 nm. This smaller particle size may affect their diffusion on human cells leading to cytotoxicity, we recommend a critical focusing on studying the safety of food additives in future food science research.

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