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Encapsulation of Beetroot Extract using Spray Drying

K. Poornima[1], R. Sinthiya[2]
[1,2]Department of Food Processing and Preservation Technology, Avinashilingam University for Women, Coimbatore.

Abstract: The present work was carried out to produce a dry powder of red colour from beetroot, for natural colouring of some food products using encapsulation technique. Betalains are water-soluble, nitrogen-containing pigments which seeks awareness towards food industry. They are present in most plants belonging to the order Caryophyllales, where they execute the function of anthocyanins, and are divided into two groups: red colour betacyanins and yellow colour betaxanthins. They are bioactive molecules that comprise of health-promoting properties. In this work, the characteristic betalain and its stability is highly promoted by its encapsulation in a combination of maltodextrin and gum arabics matrix. A suitable spray-drying procedure for encapsulation is described, and a bright red powder is obtained. The strength is analyzed under different conditions and different physical and chemical analysis were done to analyze the properties of the powder.
Keywords: encapsulation,betalains,maltodextrin,gum Arabic,spraydrying.

I. INTRODUCTION

Beet root (*Beta vulgaris*) is botanically classified as an herbaceous biennial from *Chenopodiaceae* family and has several varieties with bulb colours ranging from yellow to red. It is originally from temperate regions of Europe and North Africa (Gokhale and Lele, 2014). Betalains are water-soluble nitrogenous pigments, which comprise two main groups, red coloured betacyanins and yellow betaxanthins and they have major role like free radical scavengers that prevent active oxygen-induced and free radical-mediated oxidation of biological molecules (Pedreno and Escribano,2001). Gibbs *et al.*, 1999 defined encapsulation is a process in which tiny particles or droplets are surrounded by a coating, or embedded in a homogeneous or heterogeneous matrix, to form small capsules and build a barrier between the component in the particle and the environment. The core may be composed of just one or several ingredients and the wall may be single or double-layered. Taking into account food industry characteristics, microencapsulation should be defined as a technique by which liquid droplets, solid particle, or gas compounds are entrapped into thin films of a food grade microencapsulating agent (Gharasallaoui *et al.*, 2007). Spray drying is the most common technology used in food industry due to low cost and available equipment. Compared to freeze-drying, the cost of spray-drying method is 30-50 times lower (Desorbry *et al*., 1997). Gouin, 2004 reported that microencapsulation by spray-drying has been successfully used in food industry for several decades and this process is one of the oldest encapsulation methods used since the 1930s (Shahidi and Han, 1993). The objective of this work is to evaluate the potential of difference ratio of core (beetroot extract) and wall material (combination of maltodextrin and gum arabic) with difference inlet drying temperature (120, 140 and 160°C). The properties to be analyzed are encapsulation yield, encapsulation efficiency, moisture content and betanin content.

II. MATERIALS AND METHODS

A. *Materials*

The beetroot was bought from the local market in Kattankulathur, Chennai which was cultivated in Theni district. It was stored in the refrigerated condition in order to prevent the changes due to environmental conditions. The wall materials such as maltodextrin and gumarabic were purchased from Hi-Media and it was stored in air tight container until use.

B. *Aqueous Extraction of Betanin*

The beetroots were washed and sanitized with 50 mg/kg of sodium hypochlorite solution for 3 min. Then it is peeled, sliced and steam blanched for 3 min and air cooled to ambient condition. The aqueous (beetroot slices: water, 1:0.5) were added and ground by using a high speed mixer at 3000 rpm for 2 min. The ground material was manually pressed and filtered with a muslin cloth and betanin was extracted at ambient condition to get beetroot extract as shown in Fig 2.1.

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Selection of beetroot

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Washing

↓

Sanitizing (Sodium hypochlorite)

↓

Peeling

↓

Cutting into Cubes

↓

Steam blanching (3 min)

↓

Cooling

↓

Pulping

↓

Manual Pressing

↓

Filtration
(Extraction of betanin using aqueous extraction)

Fig. 2.1. Process flow chart for aqueous extraction of betanin from beetroot

C. Preparation of Feed Emulsion

Emulsions were prepared in three ratios of 1:2, 1:4, 1:6 (core material: combination of wall materials). 100 ml of beetroot extract was taken and mixed with 200 ml of combination of maltodextrin and gum arabic to prepare 1:2 emulsions. For the preparation of combination of wall materials 50 g of maltodextrin and gum arabic was dissolved separately in 60 ml of distilled water at 60ºC which was made up to 100 ml. The prepared wall material concentration was filtered using muslin cloth and mixed together (maltodextrin and gumarabic). Similarly 1:4, 1:6 ratios of core and wall material concentration was prepared. This immiscible mixture is emulsified using high speed mixer at 3000 rpm until the extraction dispersed completely. Then it is emulsified by adding 2 drops of Tween 80.

D. Spray Drying

The prepared emulsion was pumped to the spray drier (Make: S.M.Scientech, Kolkata) through 0.7 mm diameter nozzle. The dryer parameters of the spray dryer were inlet air temperatures 120, 140 and 160°C, outlet air temperature 95±2 °C, compressed air flow pressure at 350kPa, feed rate 17 rpm and air flow rate 2600 rpm was used to produce encapsulated beetroot extract powder. The obtained encapsulated powder was packed in aluminium foil pouches and sealed using the hand sealer. It was stored in a desiccators containing calcium chloride at ambient condition until for future use as shown in Fig 2.2.

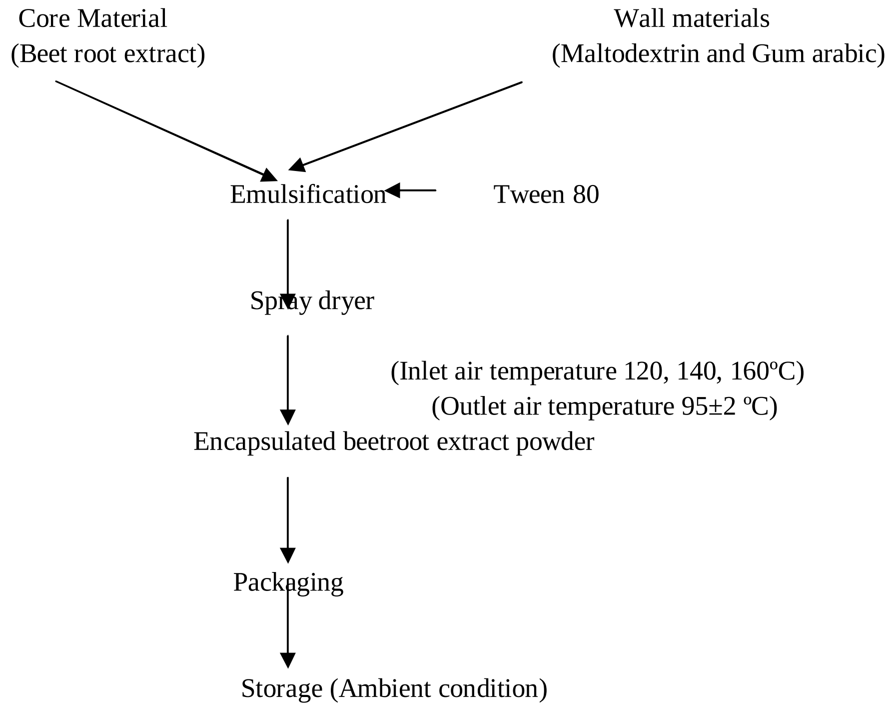

Fig. 3.2. Process flow chart for production of encapsulated beetroot extract

III. QUALITY ANALYSIS

A. Encapsulation Efficiency

The encapsulation efficiency (ME) was calculated according to the equation no (1) (McNamee *et al*., 2001):

$$\%\text{Encapsulation efficiency} = \frac{\text{Total betanin} - \text{Surface betanin}}{\text{Total betanin}} \times 100 \text{ ------------------- (1)}$$

B. Encapsulation Yield

The encapsulation yield (EY) was calculated according to the equation no (2) (Itaciara *et al.* 2007):

$$\%\text{ Encapsulation efficiency} = \frac{MSA}{MSB} \times 100 \text{ -------------------------------- (2)}$$

where

MSA = total mass of microcapsules obtained after encapsulation and

MSB = total mass of solids before encapsulation

C. Moisture Content

5 g of triplicate encapsulated beetroot extract powder is kept in a ventilated hot air oven (Make: Hitech Equipments, Chennai.) at 105±2°C for 3 h. The moisture content was calculated according to the equation no (3) (AOAC, 2000)

$$\text{Moisture content \%(db)} = \frac{\text{Initial weight - Final weight}}{\text{Final Weight}} \times 100 \text{ ------------------- (3)}$$

D. Betanin Content

Betanin content of encapsulated beetroot extract powder was quantified according to Wybraniec and Mizrahi (2002). Encapsulated beetroot powder was weighed and diluted with deionised water. Diluted sample was filtered before performing spectrophotometric measurement (Make: Sigma scientific instruments, Chennai, Model: SL 217). Quantification of betanin was carried out by the following equation no (4):

$$BC\,(mg/100g) = \frac{A \times DF \times MW \times V \times 100}{\varepsilon \times L \times W} \text{ -------------------------- } (4)$$

where BC is betanin content, A is the absorption value at 538 nm, DF is the dilution factor, MW is the molecular weight of betanin (550 g/mol), V is the pigment solution volume (millilitres), Ɛ is the molar extinction coefficients of betanin (60,000 L/mol cm), L is the path length of the cuvette (1 cm) and W is the weight of encapsulated beetroot powder, g.

IV. RESULTS AND DISCUSSION

A. *Effect of Temperatures on Encapsulation Efficiency*

The encapsulation efficiency is related to the physio-chemical characteristic of both the core and wall material. Encapsulation efficiencies refer to the potential of the wall material to encapsulate or hold the core material inside the microcapsule. Encapsulation efficiencies are also related to the shelf life of the pigment content in the powder (Idham *et al*., 2012). The encapsulation efficiency of the spray dried encapsulated beetroot extract powder at varying temperature was found to be in the range of 96.79 to 99.60 for different ratio of wall to core material concentration 1:2, 1:4 and 1:6 as shown in Fig.3.1.Encapsulation efficiency increased with increasing inlet air temperatures for 1:2 and 1:4 core to wall material concentration at 120°C, 140°C, 160°C. It also depends on the surface betanin content if decreases in surface betanin content more it encapsulation efficiency. Surface betanin content is more in 1:2 (120°C) so that encapsulation efficiency is less. Similar result is reported by Anandaraman and Reineccius, 1986 for the encapsulated orange peel oil. Nunes and Mercadante, 2007 reported that the lycopene encapsulation using spray dryer (Lab plant SD-04, UK) with gum arabic and sucrose (8:2) with inlet and outlet temperatures of 170±2 and 113±2ºC respectively the microencapsulation efficiency ranged from 94 to 96%. The maximum efficiency of 86% was obtained for bixin encapsulated with gum arabic/sucrose (95:5),whereas with maltodextrin 20 DE this value was 54%, increasing to 75% with addition of an emulsifier to maltodextrin (Barbosa *et al*., 2005). In conclusion, since the efficiency found in the present work was higher than those obtained in the literature, combination of gum arabic and maltodextrin as wall material could be considered an excellent choice for the encapsulation of beetroot extract using spray drying technology.

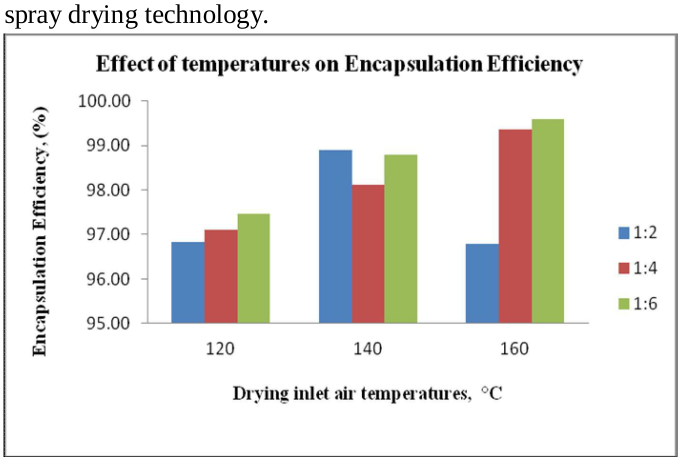

Fig. 3.1. Effect of temperatures on Encapsulation efficiency

B. *Effect of Temperatures on Encapsulation Yield*

Encapsulation yield varies in inlet air temperature at different emulsions. For emulsion 1:2 the encapsulation yield for the encapsulated beetroot powder increasing and decreased at 120°C, 140°C and 160°C respectively. But for 1:4 and 1:6 core and wall material concentration the encapsulation efficiency increased with increasing temperature as shown in Fig.3.2. Increasing temperatures led to higher process yield, which can be attributed to the greater efficiency of heat and mass transfer processes occurring when higher inlet air temperatures are used. The increase on feed viscosity can cause more solids to paste in the main chamber wall, thus reducing the process yield. In addition, the higher the solids content in the mixture, the higher the amount of solids available to be in contact with the chamber wall and to paste in it. Thus, the lower the process yields. This is in agreement

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with the results published by Cai and Corke (2000), working with spray drying of Amaranthus betacyanins pigments. The drying process yield strongly depends on the equipment confriguration (Nunes and Mercadante, 2007).

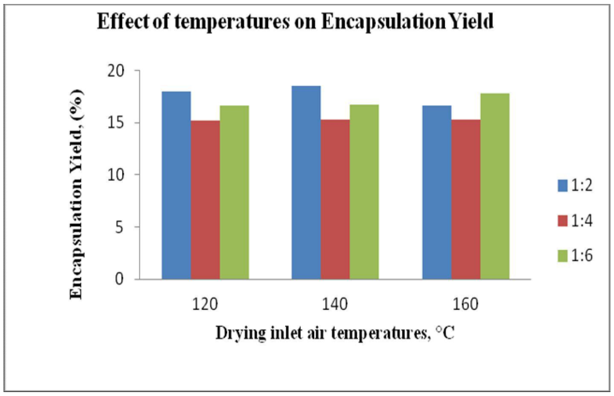

Fig. 3.2. Effect of temperatures on Encapsulation yield

C. *Effect of Temperatures on Moisture Content*

The moisture content of encapsulated spray dried beetroot extract powder varied from 3.4% (db) to 2.8% (db) at 120°C, 2.4% (db) to 1.6% (db) at 140°C and 2.2% (db) to 1% (db) at 160°C for different emulsion 1:2, 1:4 and 1:6 respectively. From this it is observed that the moisture content of the powder will be affected by the inlet air temperature and the wall material concentration. The moisture content of the powder decreased with increasing inlet air temperature. From the Fig.4.3. It was observed that if moisture content of the powder will be lower in 160°C for emulsion 1:6 which is sufficient enough for the long term storage of powder without any microbial deterioration under specific conditions. Inlet air temperature and wall material have effect on moisture content of the finished beetroot extract powder and reduce the moisture content of the encapsulated beetroot extract powder. Bakar *et al*., 2013 reported that higher the inlet temperature and maltodextrin concentration the lower the moisture content of the spray dried papaya peel powder. Moisture content was significantly influenced by inlet air temperature and feed flow rate. At higher inlet air temperatures, there is a greater temperature gradient between the atomized feed and the drying air, resulting in a greater driving force for water evaporation and thus producing powders with lower moisture content. Quek *et al*., 2007, Rattes and Oliveira, 2007 and Grabowski *et al*. 2006 also observed a reduction of powders moisture content with increasing air temperatures, studying the spray drying of watermelon juice, sodium diclofenac and sweet potato puree, respectively. Goula and Adamopoulos, 2005 reported that an increase in air inlet temperature leads to a decrease in moisture content. The greater the temperature difference between the drying medium and the particles, the greater will be the rate of heat transfer into the particles, which provides the driving force for moisture removal. When the drying medium is air, temperature plays a second important role. As water is driven from the particles in the form of water vapor, it must be carried away, or the moisture will create a saturated atmosphere at the particle surface. This will slow down the rate of subsequent water removal. The hotter the air, the more moisture it will hold before becoming saturated. Thus, high temperature air in the vicinity of the drying particles will take up the moisture being driven from the food to a greater extent than with cooler air.

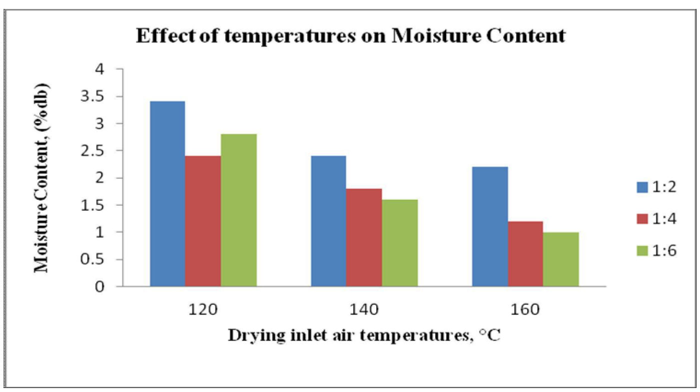

Fig. 3.3. Effect of temperatures on Moisture content

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D. Effect of Temperatures on Betanin Content

Betanin is an active compound present in beetroot. Higher the retention of the active compound, the quality of encapsulated beetroot extract powder will be superior. Hence it was considered to be important parameter to determine the quality of the encapsulated beetroot powder. In 1:2 core to wall material concentration the betanin content was about 0.20 to 0.11 mg g-1 at different inlet air temperatures. For 1:4 concentrations the betanin content was about to 0.11 to 0.078 mg g-1, whereas for 1:6 the betanin content varies from 0.049 to 0.035 mg g-1. From Fig.3.4, it was clear that the betanin content decreased with increasing in inlet air temperature. The degradation of fruit pigments during the high spray drying temperatures
varies. Quek *et al*., 2007 reported that spray-drying of watermelon juice above 165 °C led to inferior products due to nutrient loss; however, spray drying temperatures higher than 180 °C were not suitable for Amaranthus betacyanins pigments (Cai and Corke, 2000). Betacyanin pigment in pitaya peel powder was considered stable when spray-dried at inlet temperature of 155– 175 °C and outlet temperature of 75–85 °C. In this study Good betacyanin pigment retention in pitaya peel powder partly may be contributed by the usage of low dextrose equivalent (DE) maltodextrin. Rodríguez- Hernández *et al*., 2005 demonstrated that low DE maltodextrin had better nutrient binding properties than the higher DE maltodextrin. Furthermore, low DE maltodextrin caused lower hygroscopicity of the spray-dried powders, as highermolecular- weight maltodextrin contained longer chains and less hydrophilic groups (Cai and Corke, 2000).

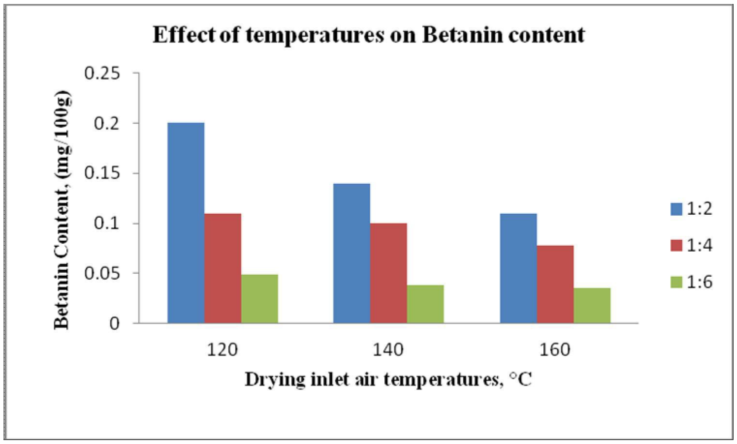

Fig.3.4. Effect of temperatures on Betanin content

V. CONCLUSION

Beetroots contain a unique class of water-soluble, nitrogen-containing pigments called betalains, which are synthesized from the amino acid tyrosine into two structural groups: the red–violet betacyanins and yellow–orange betaxanthins. Several lines of evidence suggest that betalains show a number of biological properties, including antioxidant, anti-inflammatory, anti-carcinogenic, neuro and hepatoprotective activities. Spray drying is a commercial processes which is widely used in large-scale production of encapsulated flavours, colour and volatiles. The encapsulation efficiency is related to the physico-chemical characteristic of both the core and wall material. The encapsulation efficiency of the spray dried encapsulated beetroot extract powder at varying temperature was found to be in the range of 96 to 99 for emulsion 1:2, 1:4 and 1:6. Encapsulation efficiency increased with increasing inlet air temperatures. Increasing in wall material concentration increased the encapsulation efficiency. Encapsulation yield varies in inlet air temperature at different emulsions. For emulsion 1:2, 1:4 and 1:6 the encapsulation yield for the encapsulated beetroot powder was more at 120°C, 140°C and 160°C. It is observed that increasing temperature led to higher process yield, which can be attributed to the greater efficiency of heat and mass transfer processes occurring when higher inlet air temperatures are used. The increase on feed viscosity can cause more solids to paste in the main chamber wall, thus reducing the process yield. The moisture content of encapsulated spray dried beetroot extract powder varied from 3.4% (db) to 2.8% (db) at 120°C, 2.4% (db) to 1.6% (db) at 140°C and 2.2% (db) to 1% (db) at 160°C for different emulsion 1:2,1:4 and 1:6. From this observed value, it is noted that the moisture content of the powder was affected by the drying inlet air temperature. The moisture content of the powder decreased with increasing inlet air temperature. It was observed that if moisture content of the powder was lower in 160°C for emulsion 1:6 which is sufficient enough for the long term storage of powder without any microbial deterioration under specific conditions. Betanin is an active compound present in beetroot. Higher the retention of the active compound, the quality of encapsulated beetroot extract powder will be superior. Hence it was considered to be important parameter to determine the quality of the encapsulated beetroot powder. In 1:2 core to wall material concentration the betanin content was about 0.20 to 0.11 mg/g at different inlet air temperatures. For 1:4 concentrations the betanin content was about to 0.11 to 0.078 mg/g, whereas for 1:6 the betanin content varies from 0.049 to 0.035 mg/g.

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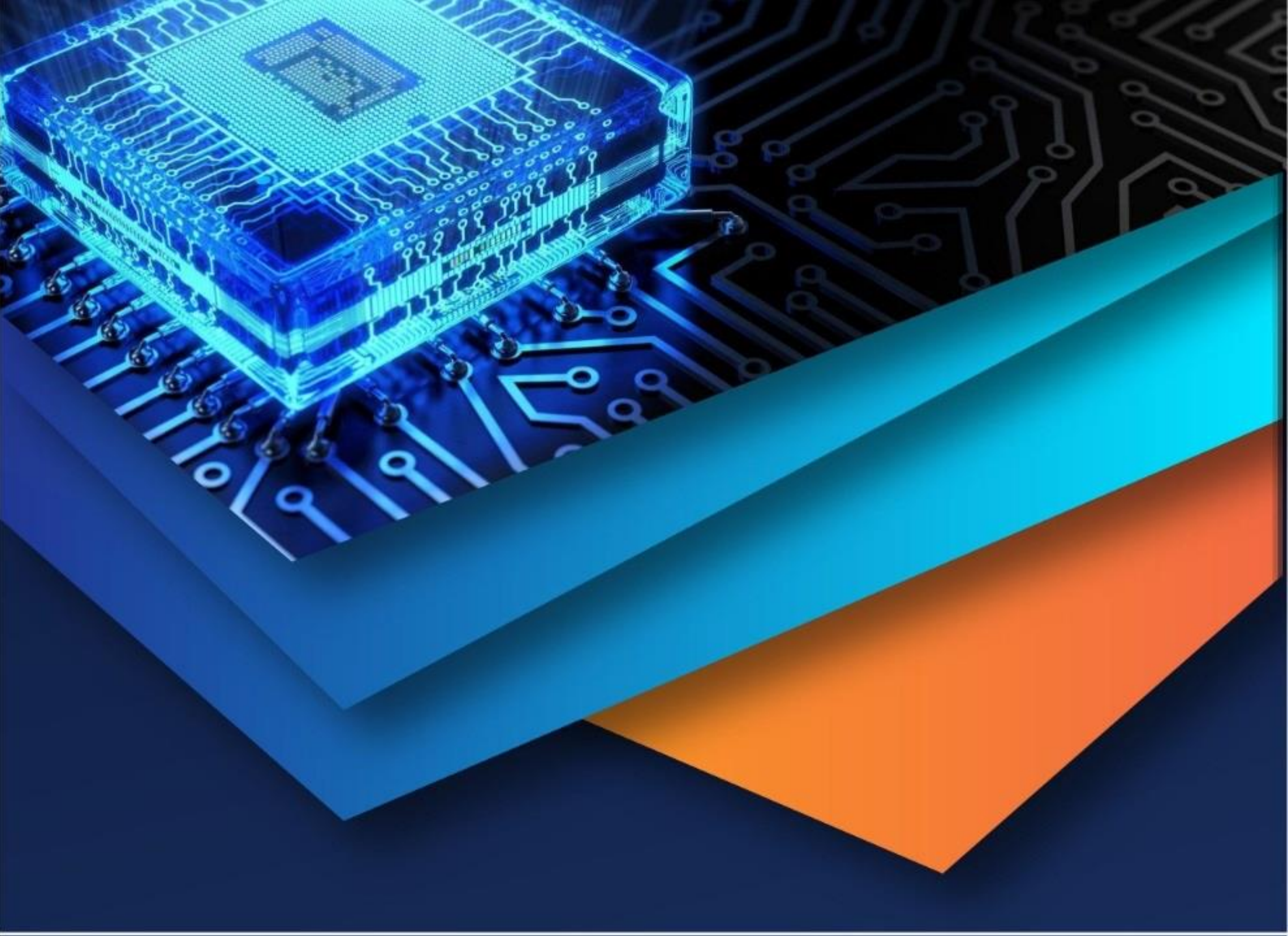

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