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Effect of Pulsed Electric Field on Drying Rate and Physical Characteristics of Potato Slices

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Abstract- The present investigation was undertaken to study the impact of PEF on dehydration of potato slices. The potato slices from cv. Kufri Chandramukhi were subjected to 10 min dipping pre treatments in water, 0.25% KMS 2.0% NaCl and 0.50% $CaCl_2$. After dipping, the slices were subjected to 0, 2, 4 and 6 kV levels of PEF for 15 s. Drying rates, rehydration ratio and co-efficient of rehydration were higher in PEF treated samples, maximum being observed for KMS-2 kV PEF pre treatment. It was observed that various chemicals and PEF pre treatments had no effect on the recovery, moisture content and texture of the dehydrated potato slices. The browning was lower in potato slices pre treated with PEF 2 kV, which did not further decrease significantly with increasing levels of PEF.

Keywords: dehydration, pre treatments, pulse electric field, drying rate, rehydration ratio

I. INTRODUCTION

Potato (*Solanum tuberosum*) is an important commercial tuber crop. The distinctive characteristic of potato is the presence of high quality starch, protein, vitamins and minerals which accounts for its use as vegetable and food. It ranks fourth as the major food crop of the world [1]. India possesses wide agro-climatic conditions and area suitable for adequate and round the year supply of processing quality potatoes The global as well as Indian production is steadily increasing due to improved cultivars, production technology and expansion of area but inadequacies in its post-harvest handling, storage, transportation and marketing often pose a serious problem especially during the glut season resulting in heavy post-harvest losses and remunerative prices to growers.

In India the demand for the processed potato products is increasing rapidly due to increased urbanization, rising per capita income and preference to fast foods. Chips are the most popular processed product of potatoes. The efficiency of processed products depends on quality of final product, which is determined by the raw materials, and therefore potato is key factor in potato processing [2]. The suitability of a variety for processing depends on chemical composition such as dry matter, total phenols, reducing and total sugars etc. besides shape, size and colour of tubers. Varieties Kufri Kuber and Kufri Jawahar have been reported to be suitable for making chips [2]

Conventional dehydration of potato, as for other fruits and vegetables, affect its physical and biochemical status, leading to shrinkage, change of colour, texture and taste [3]. Improvement in the dehydration techniques can reduce the intensity of these changes. Blanching, osmo-dehydration, sulphiting, use of chemicals as pre-treatments etc., are some of the conventional approaches to reduce the qualitative changes during drying [4], [5].

To enhance the rate of dehydration, heat is applied, which may result in browning, case hardening, scorched flavour,

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

denaturation of protein, loss of solubility upon rehydration, textural changes and some nutrient losses like heat labile vitamins. The present approach of food processing industry for producing dehydrated food though has centred on enhancing drying rate, but importance is also given on reducing the energy consumption and minimizing thermal degradation of food constituents [6]. Pulse Electric Field is fast emerging as one of the more promising non-thermal processing pre- treatment to improve quality during dehydration. The application of PEF appears to be more promising due to its potential for continuous application, short-time treatment and low-energy requirements. For food quality attributes, PEF is considered superior to traditional heat treatment of food because it greatly reduces the detrimental changes of the sensory and physical properties of food [7]. It also maintains flavour, colour taste and nutritional value of foods while destroying microorganisms. Thus, it has potential to replace conventional thermal pasteurization and blanching treatments [8]. Promising results reported in the literature have suggested potential application of PEF as a pre-treatment in dehydration operations. The technology can be used to enhance drying rates and to reduce consumption of energy. Pre-treatment with pulse electric field has potential of reducing energy consumption and minimizing thermal degradation. With these perspectives in mind the present investigation was planned to study the drying characteristics and physical properties of pulsed electric field treated potato slices.

II. MATERIALS & METHODS

Freshly harvested, uncured potatoes of cv. Kufri Chandramukhi were procured from local market. The potatoes were sorted on the basis of uniformity of shape and size. All the chemicals used in various analyses were of analytical grade. Potatoes were peeled and cut into slices of thickness ~1.75 mm using potato slicer. The slices were collected in a tray and subjected to various treatments. The slices were then dipped in water, 0.25% potassium meta-bisulphite (KMS), 2.0% sodium chloride (NaCl) and 0.50% calcium chloride ($CaCl_2$) for 10 min. After dipping in for requisite time, the slices were removed from solution and the excess of moisture was drained. The slices were divided into 4 lots and subjected to different frequencies of pulsed electric field- 0 kV (no pulse treatment), 2 kV, 4 kV and 6 kV for 15 sec. After pre-treatments, the treated potato slices were dried in hot air oven (tray drier) at 60°C to final moisture ~7%. Drying rate was recorded after an interval of two hours till moisture content on percent weight basis became constant. Rate of drying was expressed as moisture removed in g/h/100g dry weight.

$$\text{Drying rate (g / h/ 100g DW)} = \frac{\text{Amount of water removed (g) x 100}}{\text{Time (h) x dry weight of sample (g)}}$$

Drying curves were drawn by plotting drying rate versus time (h).

Rehydration ratios, Co-efficient of rehydration, Recovery (%), Non-Enzymatic Browning were also evaluated using the standard methods of analysis [9].

Texture of the fresh and dehydrated potato slices was also determined in this study. The texture of raw potato was measured by using fruit –pressure tester (Ogawa Saiki Co. Ltd., Japan) fitted with a cylindrical plunger 4mm diameter, fruit firmness was measured at two sides each on opposite side. Firmness of three fruits was measured and expressed in kg/cm^2. The texture of dehydrated potato slices was measured by using texture analyzer (TA – XT plus, Stable Micro system, U.K.) using spherical probe -SMS P/ 0.25. Texture of six slices per treatment was measured and expressed as kg.

III. Results and Discussion

A. Effect of pre-treatments on drying rate

The results revealed that there were significant differences in drying rates among different pre-treatments. The drying rate of potato slices under various pre-treatments are presented in Table I and graphically presented in Figure1. It was found that the drying rates of PEF increase significantly with increasing levels of PEF. Among the various chemical treatments, whether with or without PEF, higher drying rates were observed for KMS pre-treated potato slices, followed by $CaCl_2$ and NaCl. In all the pre-treatments, the drying rates were faster during first two hours of drying, while it decreased at later stages of drying. Thus, it can be said that the excess surface moisture gets removed during initial few hours of drying. During later drying periods, due to lower moisture content and case hardening of slices, the drying rates got reduced. The drying rates of PEF treated samples were higher than without PEF treated samples, probably because PEF may have induced tissue damage, which caused faster moisture removal and improved the drying rates. Since sufficient tissue damage may have been induced with PEF 2 KV, no further

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

increase in drying rates were observed with increased levels of PEF pre-treatments. These results are in agreement with that of [10], who reported that PEF treatment resulted in improved drying rates of potato slices as compared to that of control samples. Similarly, [11] also reported enhanced drying rates in PEF (0.75 to 1.5 kV/ cm) treated potato cubes and apple slices. In concurrence with the above results [12] reported that sulphitation at temperature ≥ 60°C resulted increased drying rates of dehydrated potato cubes.

In the present investigation, the drying rates of blanched samples were lower than that of all PEF treated samples. This might be due to starch gelatinization (during blanching), which affected cell structure and increased internal resistance to moisture movement, thus resulting in lower drying rates. The drying rates of the potato cubes blanched in boiling 2% brine solution (3 min.) improved with increased temperature of cabinet drier (50-90 ^{0}C). The drying at 50^{0}C took 7 h to reach desired moisture content, whereas at 90^{0}C, potato cubes got dried in almost 3 h to desired moisture content [13].

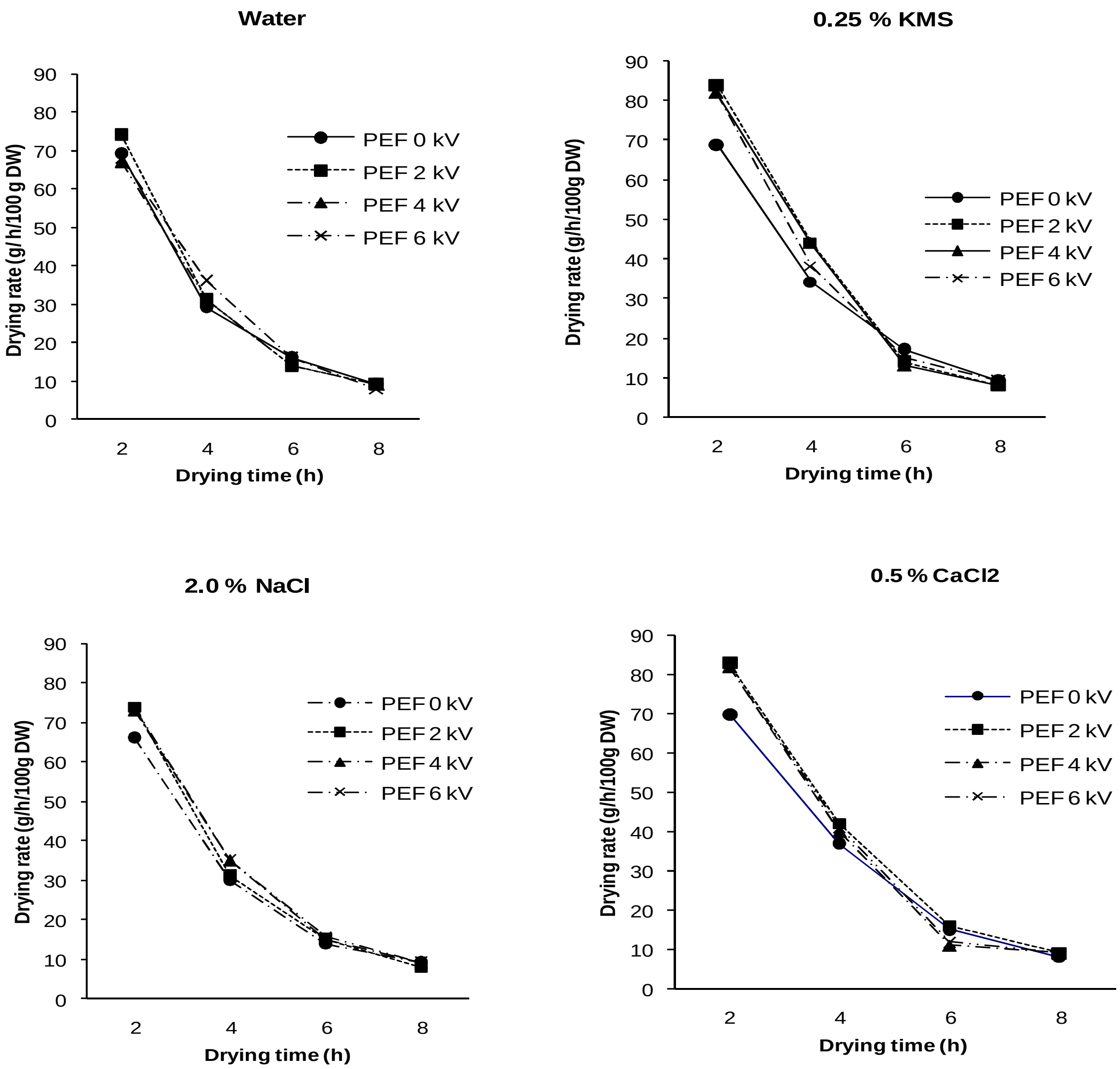

Fig 1: Drying rates of potato slices pre-treated with various chemicals and levels of PEF

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TABLE I.

EFFECT OF VARIOUS PRE-TREATMENTS ON DRYING RATES (g/h/100 g DW) OF POTATO SLICES

Treatments	**Dehydration time (h)**			
	2	**4**	**6**	**8**
PEF – 0 KV				
Water	69	29	16	9
KMS	69	34	17	9
NaCl	66	30	14	9
$CaCl_2$	70	37	15	9
PEF – 2 KV				
Water	74	31	14	9
KMS	84	44	14	8
NaCl	74	31	15	8
$CaCl_2$	83	47	16	9
PEF – 4 KV				
Water	67	31	14	9
KMS	82	46	13	8
NaCl	73	35	11	9
$CaCl_2$	81	40	11	9
PEF – 6 KV				
Water	68	36	16	8
KMS	86	38	16	9
NaCl	74	38	18	9
$CaCl_2$	81	43	21	9

INTERNATIONAL JOURNAL FOR RESEARCH IN APPLIED SCIENCE AND ENGINEERING TECHNOLOGY (IJRASET)

Blanched	51	22	14	8
C.D. at 5 %	1	1	1	NS

B. Effect of pre-treatments on physical characteristics of dehydrated potato slices

Recovery (%)

The data pertaining to recovery of dehydrated potato slices are presented in Table II. It is evident from the table that PEF treatments had no effect on the recovery of the dehydrated potato slices. In the same way chemical treatments, whether with or without PEF, had no significant differences in the recovery percentage. The recovery was, however, maximum (17.1%) in case of blanched samples than other treatments. The non-significant differences in recovery percentage could be due to non-significant differences in moisture content prior to dehydration in potato slices subjected to various pre-treatments. The higher recovery in blanched samples could be due to initial lower moisture content. The moisture content of potato slices after pre-treatments but prior to dehydration was, however, not determined in the present investigation. Studies by [13] reported that recovery for dehydrated potato cubes was 9.65% and 8.78% for cvs. Kufri Jawahar and Kufri Jyoti, respectively. Similarly, [14] reported about 16.35% recovery of the chips prepared from cv. Kufri Chandramukhi.

Rehydration ratio and co-efficient of rehydration

The data in table II revealed that various pre-treatments significantly affected the rehydration ratio and co-efficient of rehydration of dehydrated potato slices. It was found that both rehydration ratio and co-efficient of rehydration were higher for PEF treated samples, which increased with increasing levels of PEF. The results of the present investigation are in concurrence with the findings of [15] who reported that combination of PEF and osmotic dehydration gave higher rehydration capacity in dehydrated apple slices.

Amongst the various chemical treatments, whether with or without PEF, higher rehydration ratio and co-efficient of rehydration were observed for KMS pre-treated potato slices, followed by $CaCl_2$ and NaCl. The higher rehydration ratios observed for PEF pretreated samples could be due to the reason that PEF caused cell permeabilization of the slices resulting in more porous structure and thus resulting in more absorption of water during rehydration. Similarly, [16] observed that PEF treatment decreased bulk density, decreased volume shrinkage and increased porosity of air-dried apple tissue. In the present investigation, higher rehydration ratios and coefficient of rehydration of 0.25% KMS treated slices could be due to the reason that KMS resulted faster dehydration and thus the dehydrated product rehydrated better as it was more porous. Similarly, [12] reported that sulphitation affected the rate of rehydration of the dehydrated potato cubes.

TABLE II.

EFFECT OF VARIOUS PRE-TREATMENTS ON RECOVERY PERCENTAGE, REHYDRATION RATIO AND COEFFICIENT OF REHYDRATION OF POTATO SLICES

Treatments	**Recovery (%)**	**Rehydration ratio**	**Coefficient of rehydration**

PEF – 0 KV			
Water	15.7	2.95	0.50
KMS	15.8	3.87	0.65
NaCl	15.7	3.48	0.59
$CaCl_2$	15.4	3.94	0.67
PEF – 2 KV			
Water	15.8	3.16	0.54
KMS	16.0	4.65	0.79
NaCl	15.8	3.74	0.64
$CaCl_2$	15.6	4.10	0.70
PEF – 4 KV			
Water	15.8	3.57	0.61
KMS	16.0	4.54	0.77
NaCl	15.9	4.01	0.68
$CaCl_2$	15.7	4.03	0.69
PEF – 6 KV			
Water	15.6	4.01	0.69
KMS	15.9	4.34	0.74
NaCl	15.7	4.03	0.60
$CaCl_2$	15.5	4.08	0.67
Blanched	17.1	2.50	0.46
C.D. at 5 %	0.3	0.05	0.01

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The rehydration ratio of blanched samples was found to be lower than other treatments. This might be due to the reason that blanching led to leaching of soluble solids, softening of tissues and cell disintegration, thus resulting in decreased rehydration ratio of the dehydrated slices.

Non -enzymatic browning

The data pertaining to non-enzymatic browning (in terms of O.D. at 440 nm) in dehydrated potato slices are presented in Table III. There was increase in browning as potato slices were dehydrated. The browning was lower in potato slices pre-treated with PEF 2 kV, which did not further decrease significantly with increasing levels of PEF. Amongst the various chemical treatments, lower browning was observed for KMS pre-treated potato slices, followed by $CaCl_2$ and NaCl, which, however, were not showing significant differences amongst them. The browning was minimum in slices treated with KMS- PEF 2 kV, whereas, browning was maximum in Water- PEF 0 kV. The minimum browning in KMS pre-treatment could be due to bleaching effect of sulphitation. The decreased browning observed in PEF treated samples in the present investigation are in agreement with the findings of [15], who reported lesser non-enzymatic browning (indicated by lower L values) in PEF treated apple slices. It was postulated by [17] that pulse treatment enhanced the activation energies and thus, resulted in higher degradation of brown coloured compounds to colourless compounds and hence lowers non-enzymatic browning. Similarly, [18] reported lesser non-enzymatic browning in PEF treated as compared to the untreated brinjal slices. This attributed to the fact that PEF treatment led to significant reduction of polyphenol oxidase enzyme activity resulting in lesser browning.

Non-enzymatic browning in blanched samples was found to be lesser than other pre-treatments. This might be due to the reason that blanching caused leaching out of reducing sugars, which otherwise served as substrate for Millard reaction resulting in the production of darker chips. These results are in agreement with the findings of [1], [13] who reported increased non-enzymatic browning in dehydrated potato chips.

TABLE III.

EFFECT OF VARIOUS PRE-TREATMENTS ON NON-ENZYMATIC BROWNING, MOISTURE CONTENT AND TEXTURE OF POTATO SLICES

Treatments	**Browning (OD at 440 nm)**	**Moisture Content (%)**	**Texture (kg)**
PEF – 0 KV			
Water	0.33	6.26	0.13
KMS	0.21	6.33	0.12
NaCl	0.27	6.43	0.13
$CaCl_2$	0.26	6.43	0.15
PEF – 2 KV			
Water	0.28	6.46	0.13

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KMS	0.10	6.53	0.13
NaCl	0.19	6.60	0.13
$CaCl_2$	0.20	6.56	0.14
PEF – 4 KV			
Water	0.25	6.43	0.13
KMS	0.11	6.36	0.12
NaCl	0.20	6.40	0.13
$CaCl_2$	0.21	6.53	0.14
PEF – 6 KV			
Water	0.26	6.76	0.14
KMS	0.12	6.40	0.12
NaCl	0.18	6.36	0.13
$CaCl_2$	0.20	6.60	0.14
Blanched	0.16	6.53	0.17
C.D. at 5 %	0.03	N.S.	0.02

Texture (kg)

Texture of dehydrated potato slices was determined by using texture analyzer in terms of breaking force (in kg). The data pertaining to texture of dehydrated potato slices is presented in Table 3. It was observed that PEF treatments had no significant effect on the texture of dehydrated potato slices. Various chemical treatments also, whether with or without PEF, did not significantly affect the texture of dehydrated potato slices. The texture was, however, significantly higher for blanched samples. The texture of the variously pretreated potato slices, ranged between 0.13-0.17 kg. Non-significant differences in the texture of dehydrated potato slices subjected to various pre-treatments could have been due to the non-significant differences in their moisture content (Table 4). Various studies observed that the breaking force was proportional to moisture content. Therefore, the maximum breaking force of about 4 N was reported for potato chips having 8% moisture content, while 1.8 N was observed for potato chips having 2% moisture content. The results of the present investigation are in agreement with the findings of [11], [19]. They reported that the texture of the potato slices was not affected by PEF treatment.

In the present investigation, the maximum value of the breaking force (0.17 kg) of the slices was in case of the blanched samples indicating maximum hardness, which may be attributed to starch gelatinization leading to hard surface of the slices. The texture of the dehydrated slices subjected to various pre-treatments, however, would have been better exhibited and the pattern could have been different if Kramer-Shear probe of the texture analyser would have been used, which was not available in the present case. The texture of LPSSD (Low-Pressure Superheated Steam Drying) treated and blanched potato chips were determined in terms of breaking force. Maximum breaking force was found to be 5.52 ± 0.21 N for LPSSD treated potato slices while it was found to be 4.843 ± 0.41N in case of blanched (70 ^{0}C for 1 min.) potato slices [20].

CONCLUSION

The above study infer that pre-treatment with pulse electric field has potential of reducing energy consumption and minimizing thermal degradation. Drying rates, coefficient of rehydration and rehydration ratio of PEF treated samples were higher than without PEF treated samples. The drying rates were higher in potato slices pre-treated with PEF 2 kV, which did not further increase significantly with increasing levels of PEF. Amongst the various chemical treatments, whether with or without PEF, higher drying rates and coefficient of rehydration and rehydration ratio were observed for KMS pre-treated potato slices, followed by $CaCl_2$ and NaCl. Thus, from the above results, it can be concluded that the pre-treatment of potato slices with 0.25% KMS solution for 10 min and then exposing to pulsed electric field of 2 kV resulted in better quality of dehydrated product.

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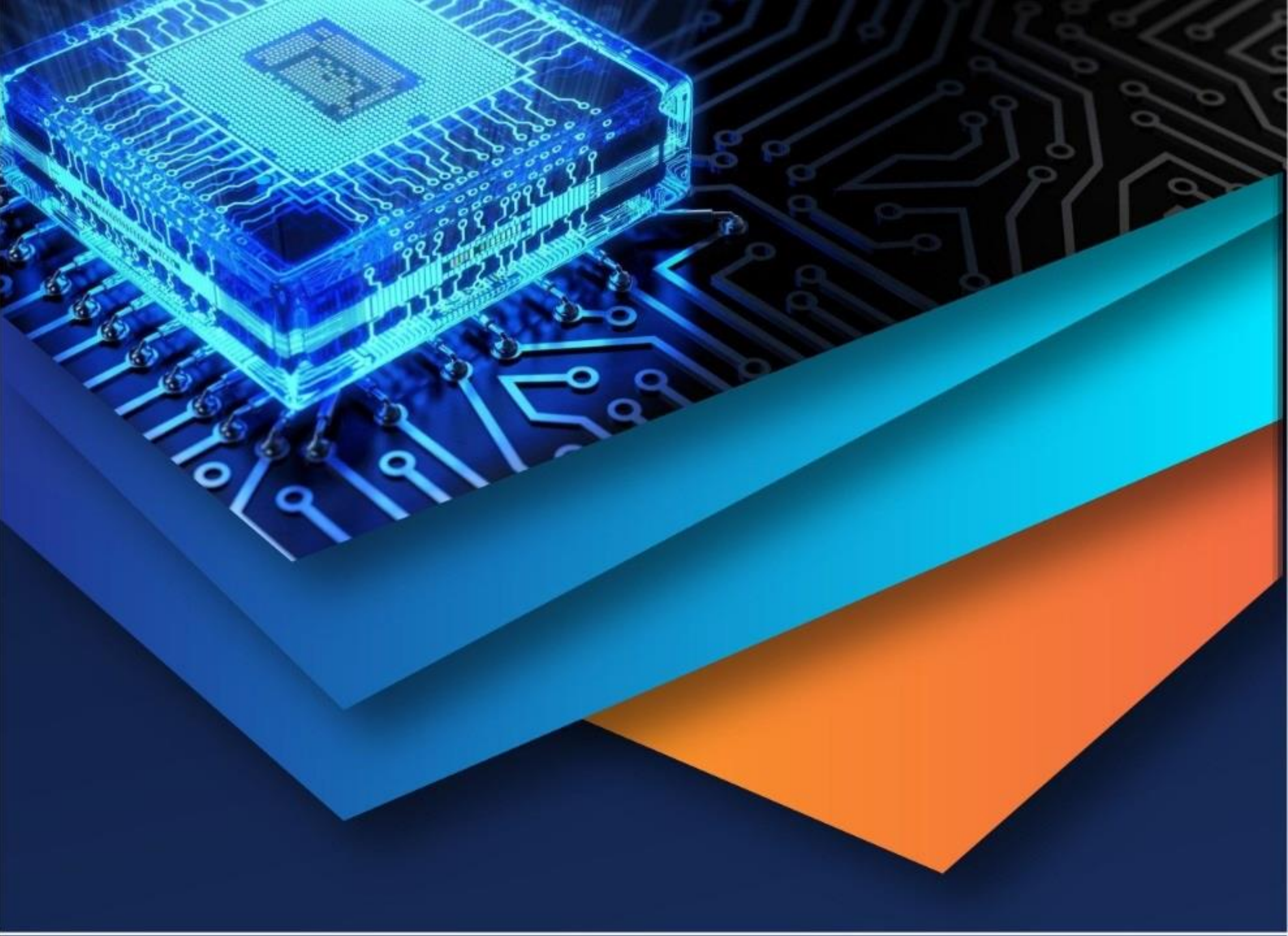

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