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Effect of thermal treatment on drying characteristics of spinach leaves

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Abstract
Spinach being a good source of micronutrients constitutes functional ingredients for new products with good nutritional values. The control and conventionally thermal processed (at 95 ºC for 1 min) spinach leaves were dried in fluidized bed dryer. The drying characteristics were studied for 30, 40, 50, 60 and 70 ºC. Drying parameters like drying time, moisture content at different temperature and thermal treatment was evaluated. The drying time was found to be higher for control condition spinach samples than thermally processed spinach leaves.

Keywords: Spinach leaves, thermal treatment, fluidized bed drying, drying time

Introduction
Spinach, scientifically known as *Spinacia oleracea* L., is a green leafy vegetable that grows as an annual throughout the chilly season (Vazquez *et al*., 2013) [1]. It is a functional food since it contains protein, fibre, and minerals. Spinach is beneficial for anaemia, dyspepsia, and constipation (Kumar *et al*., 2013) [2]. Dehydrated leafy vegetables have the potential to become a very important product due to enormously inexpensive, speedy prep arable meal and high in numerous vital vitamins which might be vital for human health. Dried leafy vegetables have excellent capability to be use throughout the year. The dried substance can be used when fresh vegetable is unavailable in market. Dehydrated veggies are easy to use, have a longer shelf life than fresh vegetables, increase menu diversity and requires less labour, space and has less waste than fresh vegetables (Chauhan and Sharma, 1993) [3]. On drying leafy vegetables and using them in the future will open up new vistas in food technology. Rich in antioxidants, protein and being fiber-rich foods are flavored by customers to maintain human health and avoid ailments like cardiovascular disease, weight gain, diabetes etc. (Kumar *et al*., 2015) [4]. Spinach derived phytochemicals and bio actives are capable of scavenging reactive oxygen species thus, preventing macromolecular oxidative damage, it modulates expression of genes involved in metabolism, inflammation and antioxidant defense and also curb food intake by including secretion of satiety hormones (Roberts and Moreau, 2016). Spinach extract can be used as natural antibiotic and preservative in food and pharmaceuticals industries (Issazadeh *et al*. 2017) [6].

Materials and Methods
The experiments were carried out in Department of Processing and Food Engineering, MPUAT, Udaipur. Spinach leaves were collected from Institutional Farm of Maharana Pratap Agricultural and Technology, Udaipur, Rajasthan.

Thermal processing
Conventional thermal processing of spinach leaves at 95 ºC for 1 min was done.

Drying Method
Fluidized bed drying
The drying was carried out at air velocity of 2 m/s. The temperature of drying was carried out at 30 ºC, 40 ºC, 50 ºC, 60 ºC and 70 ºC. The experimental data were analyzed.

Moisture content
The initial moisture content of spinach leaves was obtained using oven dry method. The reduction in moisture content in spinach leaves were recorded at regular intervals till the end of drying process.

Results and Discussion

The initial moisture content of spinach leaves was obtained using oven dry method was 91.07 per cent (wb). The initial moisture content, final moisture content, time required to dry spinach leaves with per cent reduction in drying time for various temperatures are shown in Table 1. The variation of moisture content of spinach leaves with drying time in fluidized bed dryer are depicted in fig. 1 and 2 respectively. From the figures, it can be observed that, the moisture content of spinach leaves decreased exponentially with drying time in both the conditions. The drying followed a typical trend of behavior for food material as reported by Prasad and Ankita 2017 and Jain *et al.* 2011 [7, 8]. The drying rate increased with increase in drying temperature. This resulted into substantial decrease of drying time. The initial moisture content of spinach leaves ranged from 1019.82 to 985.78 per cent (db) for control and thermal processed conditions respectively. Similarly the final moisture content of spinach leaves was in range of 4 to 11 per cent (db).

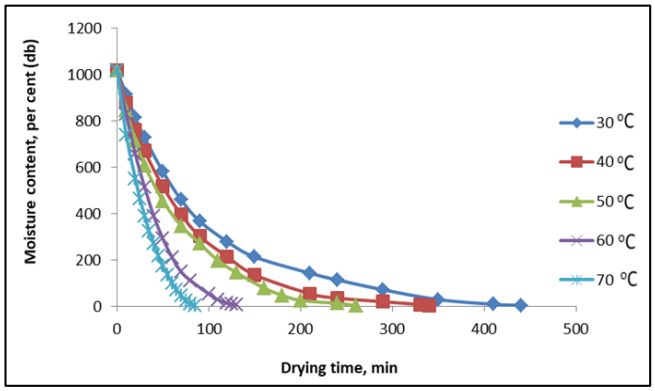

Fig 1: Variation in moisture content at control samples of spinach leaves in fluidize bed drying

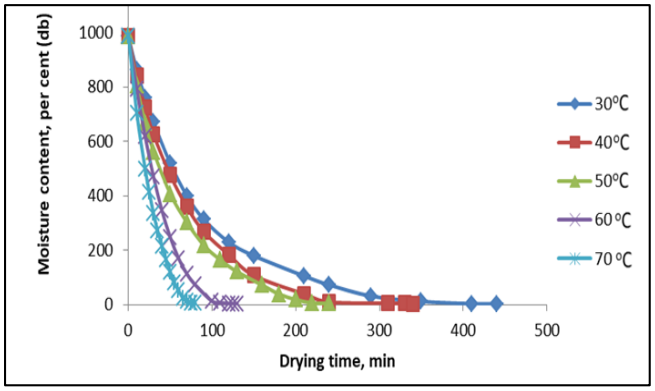

Fig 2: Variation in moisture content for thermal processed spinach leaves in Fluidized bed drying

It is very evident from the table 1 and fig. 1 and 2 that with increase in dry air temperature, time decreased. The time recorded for 30 °C to have final moisture content 7.07 per cent (wb) was 440 min in control condition. Similarly, final moisture content 7.17 per cent (wb) was obtained for 40 °C and the time required was 330 min, for 50 °C to achieve final moisture content 8.13 per cent (wb) time required was 260 min, for 60 °C to achieve final moisture content 7.94 per cent (wb) time required was 130 min and for 70 °C to achieve final moisture content 6.21 per cent (wb) time required was 80 min for control samples. Similarly, for thermally processed samples the time recorded for 30 °C, to have final moisture content 6.59 per cent (wb) was 410 min, for 40 °C and 50 °C to achieve final moisture content of 6.87 and 7.15 per cent (wb) time required were 310 min and 240 min respectively. For 60 °C to achieve final moisture content 7.15 per cent (wb) time required was 110 min and for 70 °C to achieve final moisture content 7.17 per cent (wb) time required was 70 min for thermal processed samples.

Table 1: Time required for drying of thermally processed and control samples of spinach leaves

Treatment	Drying temperature (°C)	Initial Moisture Content (%wb)	Final Moisture Content (%wb)	Drying time (min)	Reduction in time, (per cent)
Control	30 °C	91.07	7.07	440	-
	40 °C		7.17	330	25
	50 °C		7.94	260	21.21
	60 °C		8.13	130	45.83
	70 °C		7.94	80	38.46
Thermal processed	30 °C	90.79	6.21	410	-
	40 °C		6.59	310	24.39
	50 °C		6.87	240	22.58
	60 °C		7.15	110	57.69
	70 °C		7.17	70	36.36

It was observed that thermal processed spinach leaves took less time as compare to control conditions. Reduction in time, per cent for control condition at 30 °C, 40 °C, 50 °C, 60 °C and 70 °C were 25, 21.21, 45.83 and 48.46 per cent respectively. Similarly, for thermally processed it was 24.39, 22.58, 57.69 and 36.36 per cent respectively. It is evident that the drying time increased with decrease in drying air temperature. Hence, it can be inferred that drying air temperature has pronounced effect on the removal of moisture content. Similar result was observed in drying of papaya leaves (Yap *et al.* 2020) [9].

Conclusion

The effect of drying temperatures on moisture content for thermally processed spinach leaves and control spinach samples were observed that the thermally processed spinach samples required less time for drying having higher drying rate. The moisture reduction is rapid in case of thermally processed leaves. It was also observed that as temperature increased the drying time reduced. The result obtained can be used to develop drying equipment.

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