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Drying of alga as a source of bioenergy feedstock and food supplement – A review

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ABSTRACT

Alga has interesting physical and chemical compositions that attracted attention of researchers to explore it as a food supplement, besides as a source of feedstock for biofuels. However, substantial existence of moisture, ranging from 3.28 to 5.67 kg/kg dry basis, in the material poses a challenge for its drying. The objective of this study is to review, how different drying methods affected the physical and chemical properties of alga. The studies showed the appearance of shrinkage phenomena and formation of cracks and crusts during convective drying. Firmness, swelling, water holding and oil holding capacities were also affected by the process. All of these physical changes are highly dependent and vary with the applied drying conditions, in particular the temperature of the drying air. This study also investigated the deterioration rate of the most important chemical components of alga which are lipids, proteins and vitamins. The studies showed that drying at temperatures above 60 °C can cause deterioration of around 90% of proteins and lipids and more than 50% of the vitamins initially existing in alga. The range between 55 and 60 °C was represented as an optimum drying temperature to recover maximum quantities of lipids, proteins and vitamins. Mainly, freeze, spray and convective drying are reported in the literature for alga. A comparison among these three drying methods showed freeze drying being advantageous with more recovered quantities of lipids and β-carotene in the final dried material. The recovered quantity of protein was found higher in case of convective drying.

Contents

1. Introduction

The world population and its demand in food and energy are continuously on the rise. A recent study [1] predicted the demand of agricultural products until 2050, represented by per capita protein and caloric demand, for different economic groups. The economic groups were differentiated based on the Gross Domestic Product (GDP) parameter; rich regions with high GDP (Group A of Fig. 1) and poor regions with low GDP (Group G of Fig. 1). In some regions, an increase of more than 100% is expected for both capita of caloric and protein requirements, which puts huge pressure on food production and its ensured supply to avoid malnutrition and famine hitches for some poor regions of the world (Fig. 1). From energy consumption perspective, the actual statistics and estimation predicts an increase of 49% in the global energy demand in the next 25 years [2]. The global oil consumption is expected to increase from 86 million barrels per day in 2007 to 104 million barrels per day in 2030, which means that by this year (2030) half of the world's total oil reserves would be consumed [2]. Following

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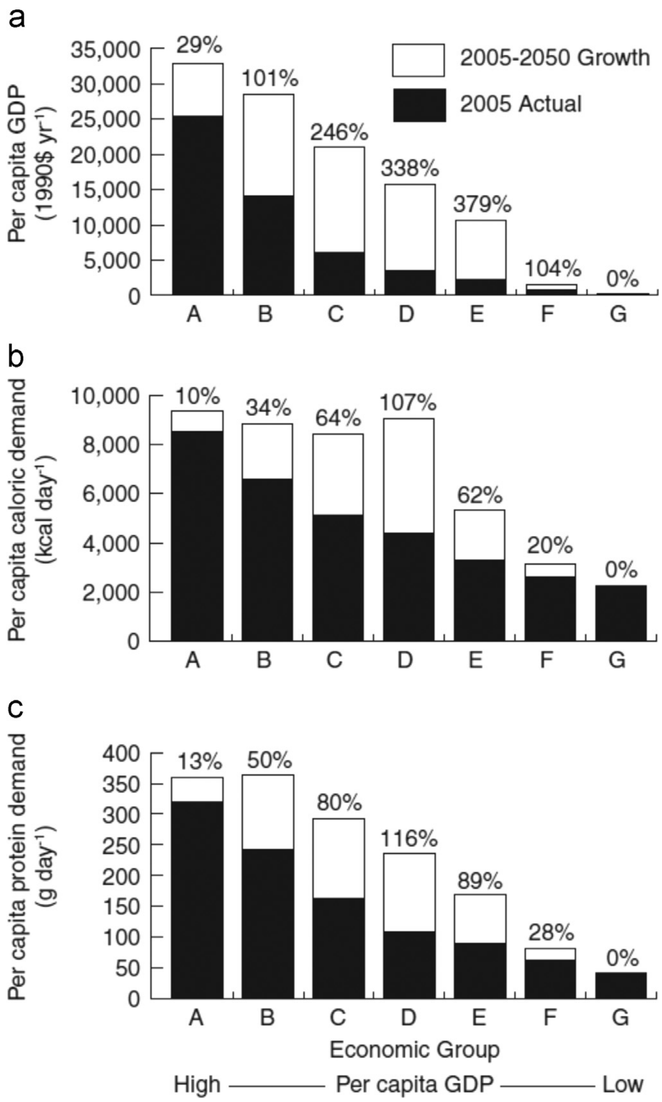

Fig. 1. Statistics about estimated capita GDP, capita caloric demand and capita protein demand [1].

Table 1
Chemical composition of spirulina micro-alga [4].

Specification	Composition (% w.b.)
Moisture	76.7 ± 0.6
Ash	1.7 ± 0.1
Protein	17.2 ± 1.1
Lipids	2.0 ± 0.1
Carbohydrates	2.4 ± 0.2

this trend of world consumption, scientific efforts are being focused towards finding solutions to meet this challenge while taking into consideration the environmental aspects. The direction is focused to further explore from available natural resources and alga has attracted particular attention as a bio-resource that can also potentially be used in food along with the energy production.

AlgeaBase reports 127,000 of alga species around the world, which include 9000 species of macro-alga, and the others are classified as micro-alga [3]. The study of the chemical composition of alga (Table 1) confirmed the existence of important components that can be valuable. It shows the existence of protein attaining more than 17% of the total mass, which represents 74% of the total dry mass. Dissa et al. [5], Oliveira et al. [4,6] reported that alga has

Table 2a
Amino acid composition in mg g^{-1} protein of Wakame and Nori [7].

Amino acid	Wakame	Nori
Asparic acid	75.60 ± 12.12	66.58 ± 3.63
Serine	33.96 ± 3.04	46.25 ± 2.47
Glutamic acid	120.85 ± 20.26	83.04 ± 6.13
Glycine	65.75 ± 7.8	75.39 ± 6.26
Histidine	17.11 ± 1.17	22.04 ± 1.00
Arginine	88.19 ± 8.49	89.98 ± 8.14
Threonine	29.22 ± 1.24	50.10 ± 3.98
Alanine	97.57 ± 8.20	80.54 ± 7.29
Proline	44.26 ± 3.89	37.97 ± 0.19
Cystine	3.26 ± 0.30	4.58 ± 0.55
Tyrosine	20.99 ± 0.64	29.38 ± 0.92
Valine	58.48 ± 4.77	47.98 ± 3.61
Methionine	1.41 ± 0.21	13.73 ± 0.43
Lysine	39.96 ± 3.40	29.91 ± 1.01
Isoleucine	50.82 ± 4.36	34.44 ± 1.03
Leucine	86.14 ± 7.39	53.23 ± 1.45
Phenylalanine	48.46 ± 3.93	78.15 ± 2.50

Table 2b
Mineral content (mg 100 g^{-1} dry weight) of wakame and nori [7].

Mineral	Wakame	Nori
Calcium	693.2 ± 7.6	359.2 ± 4.1
Phosphorus	1070.0 ± 7.0	720.2 ± 6.1
Iron	7.94 ± 0.80	10.5 ± 0.11
Magnesium	630.2 ± 8.2	233.9 ± 7.2
Zinc	3.86 ± 0.27	3.29 ± 0.24
Iodine	9.6 ± 0.73	0.54 ± 0.05
Sodium	3511.0 ± 26.0	728.2 ± 4.04
Potassium	5679.0 ± 22.3	1602.0 ± 4.03
Manganese	0.69 ± 0.02	2.53 ± 0.05
Copper	0.19 ± 0.01	0.57 ± 0.02

Table 2c
Vitamin content of wakame and nori. Data are expressed in dry weight of sample [7].

Vitamin	Wakame	Nori
Vitamin A (UI kg^{-1})	4729 ± 23.3	23830 ± 17.2
Vitamin B_1 (mg kg^{-1})	0.30 ± 0.03	0.40 ± 0.02
Vitamin B_2 (mg kg^{-1})	0.68 ± 0.03	1.89 ± 0.09
Vitamin B_5 (mg kg^{-1})	2.0 ± 0.11	2.70 ± 0.12
Vitamin B_8 (μg g^{-1})	0.22 ± 0.01	0.10 ± 0.01
Vitamin B_{12} (μg 100 g^{-1})	0.16 ± 0.01	2.90 ± 2.7
Vitamin B_6 (mg kg^{-1})	1.5 ± 0.02	0.9 ± 0.08
Vitamin B_3 (mg kg^{-1})	< 5	< 5
Vitamin B_9 (μg g^{-1})	0.79 ± 0.08	< 0.02
Vitamin C (mg 100 kg^{-1})	3.10 ± 0.11	9.73 ± 0.31
Vitamin E (mg kg^{-1})	6.3 ± 0.12	9.3 ± 0.27

an excellent nutritional value as it contains 60–70% (wb) proteins including 12 amino acids, vitamins (A, B1, B2, B6, B12, E, K), minerals such as iron, calcium, potassium, phosphorus, manganese, copper, zinc and magnesium. Alga contains the phycocyanin which is considered as an anti-oxidant, anti-inflammatory and is widely used in cosmetics. Polysaccharides are also one of the interesting chemical components of alga that can be used to attenuate animal cancers and have anti-tumor and anti-viral effects. Gamma linolenic acid coming from alga is used for the cholesterol reduction effect [5]. Tables 2a–2c show the vitamins, amino acids and minerals composition of wakame and nori macro-alga [7]. Falquet [8] gives the range of some important chemical components of spirulina. This micro-alga is considered as the most important, as almost all the studies done in micro-alga refer to spirulina. Its chemical composition is summarized in Tables 3a–3c [8–10]. The comparison