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Determination of chromium content in various foodstuffs

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Abstract. Research has been conducted to identify the content of chromium in foodstuffs, including broccoli, celery, snake grass, green mustard greens, tomatoes, carrots, beans, green beans, cauliflower, chicory, cassava, potatoes, black rice, white rice, brown rice, black sticky rice, yeast (bakery yeast) and yeast extract commercial. The determination of chromium was carried out using voltammetry method, whichthe results were processed using OriginProprogram. The data were then analyzeddescriptively. The results showed that the foodstuffs containing the highest $Cr^{3+}$is cauliflower that is 280 x 10^{-4}%, but the Cr^{6+} content is83 x 10^{-4}%.The foodstuffs containing Cr^{6+} in small quantities are cassava, nuts and commercial yeast, which is about 8 x 10^{-4}% to 9 x 10^{-4}%, but Cr^{3+}content is also not very high that is about 18 x 10^{-4}% to 21 x 10^{-4}%.

Keywords: Chromium content, Foodstuffs, Chromium in foodstuffs, chromium determination

1. INTRODUCTION

Chromium is one of the seven most abundant elements in the Earth's crust and at low concentrations is an essential element for living organisms naturally. Chromium is present in various forms of compounds. In addition to being Cr metal, the chromium is found as Cr^{2+}, Cr^{3+} (trivalent chromium), and Cr^{6+} or chromium hexavalent. Cr^{3+} is known to be non-toxic, while Cr^{6+} is toxic to the human body. Cr chemicals are persistent, bio-accumulative, toxic and not readily degradable in the environment, thus accumulating in the human body through the food chain. Cr from for example the soil environment is entering the food chain through the plant.According to the World Health Organization, Cr^{6+} concentrations in soil should not be more than 0.05 mg/L or 50 ppb [1]. Cr^{6+} compounds also have genotoxic, mutagenic, and carcinogenic properties [2]. The toxicity brought by this metal can harm vital organs such as liver, kidneys, cause lung cancer, acute poisoning, chronic, irritation to the respiratory system, and irritation to the human skin [3].

Various natural ingredients including foodstuffs are known to contain chromium, both Cr^{3+} and Cr^{6+} ions. Several studies have revealed that consumption of chromium can decrease type 2 diabetes mellitus (DM). Chromium is an essential mineral that the body needs for carbohydrate and fat metabolism [4]. Diabetes mellitus type 2 (T2DM) is the most common form of diabetes found worldwide [5] [6] [7]. This is characterized by abnormalities in pancreatic insulin secretion or actions that cause hyperglycemia due to impaired metabolism of carbohydrates, fats and lipids [5][7]. T2DM prevalence worldwide is increasing and more than 366 million people are expected to be affected by 2030[5][7]. T2DM is continuing to be a public health concern, and many people are using alternative medicine using chromium.Chromium is a common supplement used by many T2DM patients for the purpose of improving glucose regulation and in 2002 sales of chromium supplements were estimated at $85 million [8].

According to the National Institute of Health: Dietary Supplement Office, adequate intake of Cr for men and women is 35 and 25 µg/day, receptively [5][9][10]. Chromium chloride is a natural

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trivalent chromium variety found in common foodstuffs sources such as: whole grains, broccoli, mushrooms and green beans. In contrast, Cr picolinateis the synthetic family of Cr chloride. Additional forms of Cr supplements can also come from Cr's yeast and brewer's yeast.Chromium is an important micronutrient associated with the regulation of many processes in the human body including glucose homeostasis.Chromium helps regulate glucose homeostasis by activating insulin receptors through chromodulin oligopeptide thus increasing insulin signal transduction and sensitivity. Cr deficiency can lead to glucose intolerance, high circulating insulin, hyperglycemia at the time of fasting, and even disruption of growth [5][11].

Chromium can be obtained from foodstuffs and is available in very small quantities (1-2 micrograms or less). Chromium in the foodstuffs has a form of chromium (III) (indicating the amount of oxidation). Trivalent chromium or chromium (III) or Cr^{3+} is the most stable chromium and most secure, including one of the least toxic. Cr^{3+} is relatively harmless and has a role in the body's metabolism, while Cr^{6+} has a potential of 100-1000 times more toxic than Cr^{3+} because it has a high oxidation potential.

The following is a list of foods rich in chromium: broccoli (18.55 mcg/1 cup), barley (8.16 mcg/0.33 cup), oats (5.38 mcg/0.25 cup), beans (2.04 mcg/1 cup), tomatoes (1.26 mcg/1 cup).Chromium has proven its involvement in the mechanism of treatment of type 2 diabetes in several ways, including by increasing glucose tolerance. Chromium supplements increase glucose tolerance in humans with type 2 of diabetes [12]. Cr supplementation with brewery yeast may provide a marginal benefit in lowering blood glucose levels in patients with T2DM compared with placebo but no effect on glycated hemoglobin [5].

It is generally accepted that chromium is an essential element for humans. Chromium deficiency has been described in both humans and animals, but a clear quantitative definition of the daily requirement of chromium in human nutrition has not been arrived at estimates that the daily minimum population mean intake likely to meet normal requirements for chromium mightbeapproximately33μg/person [1]. Results of panels related to the Food Supplement and Nutrition Source, Cr^{3+} added to food and food aimed at the general population (including dietary supplements), concluded that after oral administration, trivalent chromium is poorly absorbed. The result of in vitro bacterial mutagenic test consistently is negative. The panel concluded that in very large quantities, certain trivalent chromium compounds have been shown to be cytotoxic and cause chromosomal damage. The panel also evaluated long-term toxicity and carcinogenicity data for Cr^{3+}. Based on the facts, it is known: 1) a maximum intake level of up to 250 µg/day for additional intake, 2) that in vitro, at high levels of concentration, Cr^{3+} can cause DNA damage, 3) that DNA damage is not reflected in the in vivo genotoxicity test, 4) that Cr^{3+} is not carcinogenic, 5) that it is safe for a daily intake of 250 µg/day, equivalent to 4.1 µg/kg body weight/day for people 60 kg [13]. Although chromium is an essential trace element for humans because it helps us to use glucose. However, it is poisonous in excess.

Daily chromium intake according to US dietary guidelines is 50-200 mg for adults, 30-35 mg for adult males and 20-25 mg for adult women [14][1].. About 2% of Cr^{3+} or trivalent chromium can be absorbed and the rest is excreted in the stool.Amino acids, vitamin C and niacin can increase the absorption of chromium by channels of the intestine. These minerals further accumulate in the liver, bone, and spleen. Trivalent chromium is found in a variety of foodstuffs including wheat products, processed meats, cereals, coffee, beans, green beans, broccoli, spices, and some brands of wine and beer. Most fruits and vegetables and dairy products contain only low amounts.

2. METHODOLOGY

2.1 Preparation of materials

Foodstuffs identified about their chromium content are broccoli, celery, snake grass, green mustard, lettuce, tomatoes, carrots, beans, green beans, cauliflower, chicory, cassava, and potatoes, black sticky rice, white rice, brown rice, black rice, yeast (bakery yeast) and yeast commercial extract. The foodstuffs cut into small pieces, then weighed each 5 grams. The next step of each

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foodstuff is heated in a furnace at a temperature of 700°C for 7 hours to obtain ash. The obtained ash is dissolved in 1 ml of the concentrated HNO_3 and 1 ml of the concentrated HCl. Each solution is ready to determine its chromium content.

2.2 Determination of chromium content

Determination of chromium content is done by using voltammetry method. Instrument used is Voltammeter.The chromium to be determined is Cr^{3+} and Cr^{6+}. The first step taken on the determination of this chromium content is to make a standard solution. The standard solution used was prepared by dissolving $K_2Cr_2O_7$ and $CrCl_3.6H_2O$ in variations of 5, 10, 20, 40 and 80 ppm. Measurements were made using Silica Carbon Electrode with scan rate of 50mV/sec [15]. Measurement of standard solution using voltammeter produces voltammogram, which then processed using Origin-Pro program and made standard curve between concentration versus current, so obtained linear regression equation y = a + bx. Then measured each sample solution or foodstuff, the result is incorporated into the equation.

3. RESULT AND DISCUSSION

Figures-1 and -2 show the standard curves of Cr^{3+} and Cr^{6+} in variations of concentrations of 5, 10, 20, 40, and 80 ppm. The regression equation obtained from the standard measurement of Cr^{3+} is Y = 3.370798x + 0.004378 and the regression equation obtained from the standard measurement of Cr^{6+} is Y = 3.139306x + 0.008648.

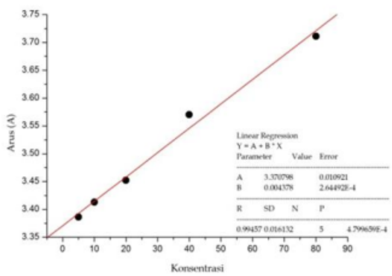

Figure-1 Standard Curve of Cr^{3+}

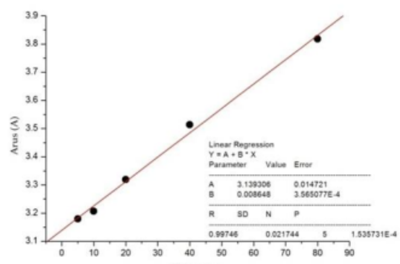

Figure-2 Standard Curve ofCr^{6+}

By entering the data from the current strength obtained from each sample or foodstuff tested using voltammeter into the equation Y = 3.370798x + 0.004378 for the determination of Cr^{3+} and Y = 3.139306x + 0.008648 for the determination of Cr^{6+} then the data obtained as shown in Table-1 and -2.

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Table 1 Content of Cr^{3+} Determined from Various Foodstuffs.

Groups	Name of foodstuffs		**Cr^{3+} (10^{-4}%)**
Vegetable group	Broccoli	Brassica oleraceavaritalica	116
	Celery	Apiumgraveolens L	96
	Snake grass	*Clinacanthusnutanslindau*	82
	green mustard	Brassica rapavarparachinensis	96
	lettuce	Lactuca sativa	136
	Cauliflower	Brassica oleraceavarBotrytis	280
	Chinese cabbage	Brassica juncea	176
Group of fruit	Tomatoes	Licopersicumesculentum	141
	Carrots	Daucuscarota	110
	Long beans	Vignasinensis	20
	Chili	Capsicum frutescens	70
Group of rice /cereals	black rice	Oryza sativa L	20
	Black sticky rice	Oryza sativa varglutinosa	21
	Brown rice	Oryzapunctata	19
	Green beans	Oryza sativa	18
	White rice	Phaseolusaureus	20
	Red beans	Vignaangularis	18
Group of tubers	Potatoes	Solanumtuberosum L	83
	Cassava	Manihotutilissima	41
Group of yeast	Yeast (bakery's yeast)	Saccharomyces cerevisiae	16
	Yeast extract commercial sample	Saccharomyces cerevisiae	18

Table 2 Content of Cr^{6+} Determined from Various Foodstuffs.

Groups	Name of foodstuffs		**Cr^{6+} (10^{-4} %)**
Vegetable group	Broccoli	Brassica oleraceavaritalica	54
	Celery	Apiumgraveolens L	45
	Snake grass	*Clinacanthusnutanslindau*	39
	green mustard	Brassica rapavarparachinensis	45
	lettuce	Lactuca sativa	64
	Cauliflower	Brassica oleraceavarBotrytis	83
	Chinese cabbage	Brassica juncea	39
Group of fruit	Tomatoes	Licopersicumesculentum	66
	Carrots	Daucuscarota	132
	Long beans	Vignasinensis	52
	Chili	Capsicum frutescens	33
Group of rice /cereals	black rice	Oryza sativa L	9
	Black sticky rice	Oryza sativa varglutinosa	10
	Brown rice	Oryzapunctata	9
	Green beans	Oryza sativa	9

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	White rice	Phaseolusaureus	9
	Red beans	Vignaangularis	9
Group of tubers	Potatoes	Solanumtuberosum L	19
	Cassava	Manihotutilissima	8
Group of yeast	Yeast (bakery's yeast)	Saccharomyces cerevisiae	8
	Yeast extract commercial sample	Saccharomyces cerevisiae	9

Based on the data in Tables-1, and Table-2, it appears that for the vegetable group Cr^{3+} content ranges from 82 x 10^{-4}% to 280 x 10^{-4}%. Cauliflower has the highest Cr^{3+} content, which is 280 x 10^{-4}%.While snake grass, has the smallest content, which is 82 x 10^{-4}%. Snake grass is a local crop that is believed to be useful for treating diabetes mellitus. Groups of fruits contain Cr^{3+} ranging from 20 x 10^{-4}% to 141 x 10^{-4}%. Tomato fruit has the highest Cr^{3+} content, which is 141 x 10^{-4}%. While the long bean, has the smallest content, which is 20 x 10^{-4}%. The black rice has the highest Cr^{3+} content, which is 21 x 10^{-4}%. While green beans and red beans, has the smallest content, which is 18 x 10^{-4}%. Tuber groups contain Cr^{3+} ranging from 41 x 10^{-4}% to 83 x 10^{-4}%. Potatoes have the highest Cr^{3+} content, which is 83 x 10^{-4}%. While cassava has the smallest content, which amount to 41x 10^{-4}%.The yeast group has Cr^{3+} content ranging from 16 x 10^{-4}% to 18 x 10^{-4}%.The commercial yeast extract which is thought to be made of brewery yeast has the highest Cr^{3+} content, which is 18 x 10^{-4}%. While yeast (bakery yeast/yeast bread), has the smallest content, which is 18 x 10^{-4}%. Based on the findings in this study, it can be concluded that the vegetable group has the highest Cr^{3+} levels among the foodstuffs tested, especially cauliflower.

Based on the data in Table -2, it can be seen that for the vegetable group Cr^{6+} content ranges from 39 x 10^{-4}% to 83 x 10^{-4}%. Cauliflower has the highest Cr^{6+}content, which is 83 x 10^{-4}% while the chicory and snake grass have the smallest content, which is 39 x 10^{-4}%. The fruit group contained Cr^{6+} ranging from 33 x 10^{-4}% to 132 x 10^{-4}%.Carrot fruit has the highest Cr^{6+} content, which is 132 x 10^{-4}% while chili has the smallest content, which is equal to 33 x 10^{-4}%. The rice/cereals group contained Cr^{6+} ranging from 9 x 10^{-4}% to 10 x 10^{-4}%. Black rice has the highest Cr^{6+} content, which is 10 x 10^{-4}% whereas white rice, brown rice, black sticky rice, green beans and red beans contain 9 x 10^{-4}%. Tuber groups contain Cr^{6+} ranging from 8 x 10^{-4}% to 19 x 10^{-4}%. Potatoes have the highest Cr^{6+} content, which is 8 x 10^{-4}% while cassava has a content of 19 x 10^{-4}%. The yeast group has a Cr^{6+} content ranging from 8 x 10^{-4}% to 9 x 10^{-4}%. Commercial yeast extract has the highest Cr^{6+} content, which is 9 x 10^{-4}% while yeast (bakery yeast/baker yeast) is 8 x 10^{-4}%. Based on the findings in this study, it can be concluded that carrots have the highest Cr^{6+} content among the foodstuffs tested.

4. CONCLUSION

The results showed that foodstuffs containing the highest Cr^{3+} were cauliflower having 280 x 10^{-4}%, but Cr^{6+} was 83 x 10^{-4} %. Foodstuffs that have a small Cr^{6+} content are cassava, nuts and commercial yeast, which range from 8 x 10^{-4}% to 9 x 10^{-4} % but Cr^{3+} content is not very high, ranging from 18 x 10^{-4}% to 20 x 10^{-4}%.

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