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Determining the amount and bioaccessibility of methylglyoxal and glyoxal in functional snack foods with herbal teas: effect of different herbal teas on α-Dicarbonyls

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Abstract

The global challenge against cardiovascular diseases, some tumours, diabetes, and diabetes-related disorders have accelerated. These conditions are often due to several dysfunctions in the metabolic pathway, which are influenced by diet. One reason for this is that excess consumption of processed foods may be accompanied by conversion of their components into harmful macromolecules such methylglyoxal (MGO) and glyoxal (GO) in the body. These hazardous compounds can be restricted during metabolism by plant-based natural sources or some medications. In this paper, anti-diabetic beverages such as green tea, bergamot-flavored black tea, and olive-leaf tea were used as plant-based sources, and functional snacks were developed using these ingredients. According to the results, the teas limited the formation of glycation products, with the greatest effects from bergamot-flavored black tea, followed by green tea and olive-leaf tea, respectively. The rates of MGO reduction were 83.80 ± 4.19, 97.84 ± 4.4, and 96.51 ± 4.37 μg/100 g, while the rates of GO reduction were 65.18 ± 2.95, 93.7 ± 4.2, and 33.1 ± 1.50 μg/100 g, respectively.

Keywords: glyoxal; methylglyoxal; green tea; bergamot-flavored black tea; olive-leaf tea.

Practical Application: Effect of different herbal teas on α-dicarbonyls.

1 Introduction

According to recently published data from the International Diabetes Federation, the number of people with diabetes worldwide has reached 451 million (Li et al., 2020). The World Health Organization (WHO) predicts that almost 693 million people will be diagnosed with diabetes by 2045 and, accordingly, declared diabetes an epidemic (World Health Organization, 2021; Dabur et al., 2018). Diabetes mellitus (DM) is a serious metabolic disorder with microvascular and macrovascular complications that have a major impact on the health and life expectancy of affected individuals (Burçak, 2008; Anwar et al., 2021). These complications cause many diseases, such as neuropathy (neural damage), retinopathy (eye disease), nephropathy (kidney disease), atherosclerosis, Alzheimer's disease (AD), Parkinson's disease (PD), rheumatoid arthritis, and cataracts (Patel et al., 2020). One of the main reasons for the occurrence of complications is the presence of reactive oxygen species (ROS), reactive carbonyl species (RCS), and reactive nitrogen species (RNS), which occur with long-term hyperglycemia (Macit & Akbulut, 2015). Especially, methylglyoxal (MGO) and glyoxal (GO) from α-dicarbonyls (α-DC) form as a result of carbonyl stress, caused by both Maillard reactions (MRs) and advanced glycation end products (AGEs) (Lim & Shin, 2020; Sobhy et al., 2020). It is well known that advanced glycation plays an important role in the progression of diabetic complications (Polizzi et al., 2012). In diabetic patients, glycation reactions are observed in the form of glycosylated hemoglobin in the body (Peng et al., 2011). Damage by MGO to low-density lipoprotein through glycation causes a fourfold increase of atherogenesis in diabetics (Rabbani et al., 2011).

MGO and GO are formed especially as a result of the polyol pathway, autoxidation of fructose (Wolff pathway), autoxidation of Heyns components (Hodge pathway), and oxidation of Schiff base fragments (Namiki pathway) (Semchyshyn, 2013). There are many reasons for these reactions. Firstly, due to the changing lifestyle and modern diets, products that have been exposed to processes such as heating, cooling, and storage are frequently consumed. Therefore, the amount of GO and MGO risk in terms of health (Yılmaz et al., 2018). In addition, numerous environmental factors, such as cigarette smoke, diets with high levels of refined and simple carbohydrates, high-calorie diets, high-temperature-processed food, and sedentary lifestyle has led to the formation of glycation products (Perrone et al., 2020).

The formed MGO and GO react with the free amino groups of lysine and arginine and with the thiol groups of cysteine, forming AGEs. AGEs, lipid peroxidation products, amino acids modified by reactive oxygen species (ROS) along with chlorine and nitrogen, and racemized amino acids are the detectable forms of chemical damage induced by glycation (Anwar et al., 2021).

Some therapeutic approaches have been developed to prevent the formation of MGO and GO, which involve both synthetic compounds and natural products (Peng et al., 2011). The synthetic compounds include metformin, aspirin, ibuprofen, indomethacin, D-penicillamine, and deferoxamine (Macit

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& Akbulut, 2015). Natural products include, as an example, polyphenolic compounds and some radical scavengers such as aminoguanidine, alagebrium, pyridoxamine, and the arginine-containing peptides L-carnosine and carnosinol (Schalkwijk & Stehouwer, 2020). Some polyphenolic compounds regulate blood glucose metabolism. In addition, their antioxidant activity inhibits intermediate dicarbonyl compounds as well as glycation and AGE formation. Hence, these compounds prevent many health complications and are used to manage diabetes complications (Perrone et al., 2020). Furthermore, several of the herbal compounds studied could regulate post-prandial blood glucose (Tolmie et al., 2021). Green tea, rooibos tea, and ginseng tea herbal compounds are known to prevent diabetes complications (Bellï & Yaman, 2020). Aside from consuming natural sources to prevent MRs, these compounds may control the value of water activity (a_w), including under prolonged time and low temperature (Saldamlı, 2017). Furthermore, with physical training such Tai Chi, there is a significant association between increased duration of physical activity and lowered glycation (Maessen et al., 2017). The purpose of the study was to create functional foods with low amounts of GO and MGO using processed products with some herbal teas, such as green, bergamot-flavored black, and olive-leaf tea.

To conclude, reactive dicarbonyls such as MGO and GO both produce glycation products in foods and cause numerous diseases, as stated in the text above. The main purpose of this study was to reveal disruptions in metabolic pathways that occur with these diseases. Another goal was to help with the development of a method for detecting these toxic molecules as there is currently no gold-standard method to detect MGO and GO (Çimen, 2008; Perrone et al., 2020).

2 Materials and methods

2.1 Samples and reagents

All samples, under different brands, were purchased from local markets in Istanbul, Turkey. Details of samples are given in the Results and Discussion section. Snack samples containing oatmeal and sugar-containing processed foods were prepared 1 year before laboratory use and stored at -18ºC. All chemical reagents were purchased from Sigma-Aldrich Co. Ltd. (Dorset, UK), unless otherwise stated.

2.2 Extraction and HPLC analysis for MGO and GO oxalaldehydes

In this study, the extraction method for MGO and GO in improved functional snack food samples was carried out according to our modified Mahar's method. All functional snack samples were homogenized with a coffee grinder. Next, 5 g of each sample was taken into a 50 mL falcon tube, and 5 mL of methanol was added. Each sample was extracted with an Ultra-Turrax homogenizer for 2 min and centrifuged for 5 min at 8000 rpm. From each supernatant, 0.5 mL was taken and transferred into a 10 mL glass tube, and 1 mL sodium acetate buffer (0.1 M, pH 3) was added. Afterwards, 0.5 mL of the derivatization solution 4nitro-1,2-phenylene-diamine (NPD) in 1% methanol was added. All prepared samples were incubated for 20 min at 70ºC. In the final step, the samples were filtered using a 0.45 mm cellulose acetate filter and injected into the HPLC.

2.3 Extraction of fructose and sucrose samples in functional snack food samples

The sugar extraction method described by Richmond et al. was used with some modifications (Richmond et al., 1981). First, all samples were homogenized with a blender. Next, 5 g of each sample was weighed into a 50 mL plastic Falcon tube. Then, 20 mL deionized water was added, and the sample was extracted using the Ultra-Turrax homogenizer for 2 min. The final volume was adjusted to 50 mL with deionized water. The mixture was centrifuged at 8000 rpm for 5 min. The samples were filtered with a 0.45 µm cellulose acetate filter and injected into the HPLC.

2.4 HPLC determination of GO and MGO

The HPLC conditions described by Mahar et al. were used with some modifications (Mahar et al., 2010). The HPLC system was composed of a Shimadzu LC 20AT pump with a Shimadzu SPD-20A UV/VIS detector (Shimadzu Corporation, Kyoto, Japan). The mobile phase consisted of methanol/water/acetonitrile (42:56:2, v/v/v). The wavelength was 255 nm. GO and MGO were separated with an Inersil ODS-3 (250 × 4.6 mm, 5 µm) column with a flow rate of 1 mL/min. The column oven temperature was 30°C.

2.5 HPLC determination of sugars

The HPLC conditions described by Richmond et al. were used to determine sugar content (Richmond et al., 1981). The HPLC system consisted of a LC 20AT pump with a Shimadzu RI-20A refractive detector (Shimadzu Corporation, Kyoto, Japan). The mobile phase was composed of acetonitrile/water (80:20, v/v). Fructose, glucose, and sucrose were separated with an Agilent NH_2 (250 × 4.6 mm, 5 µm) column (Santa Clara, CA, USA) with a flow rate of 2 mL/min. The column oven temperature was 30°C.

2.6 Bioaccessibility of functional snack food samples

The bioaccessibility of MGO and GO in functional snack foods samples was assessed using an *in vitro* simulated digestive system (Yaman & Mızrak, 2019) (Figure 1).

3 Results and discussion

The chromatogram of sugars obtained in the analysis of snack food sample 2 can be seen in Figure 2. Fructose, glucose, sucrose, and lactose were separated using the modified method. In this study, the Agilent NH_2 (250 × 4.6 mm, 5 µm) column was used.

In this study, we used a variety of snack items containing oatmeal as well as sugary processed products. We developed novel functional ready-to-eat foods. The quantities of fructose, glucose, sucrose, and lactose are shown in Table 1. Commercial oatmeal is one of the materials used, with the declared contents (per 100 g) of 53 g carbohydrate, 14 g protein, 7.5 g fat, 1.3 g

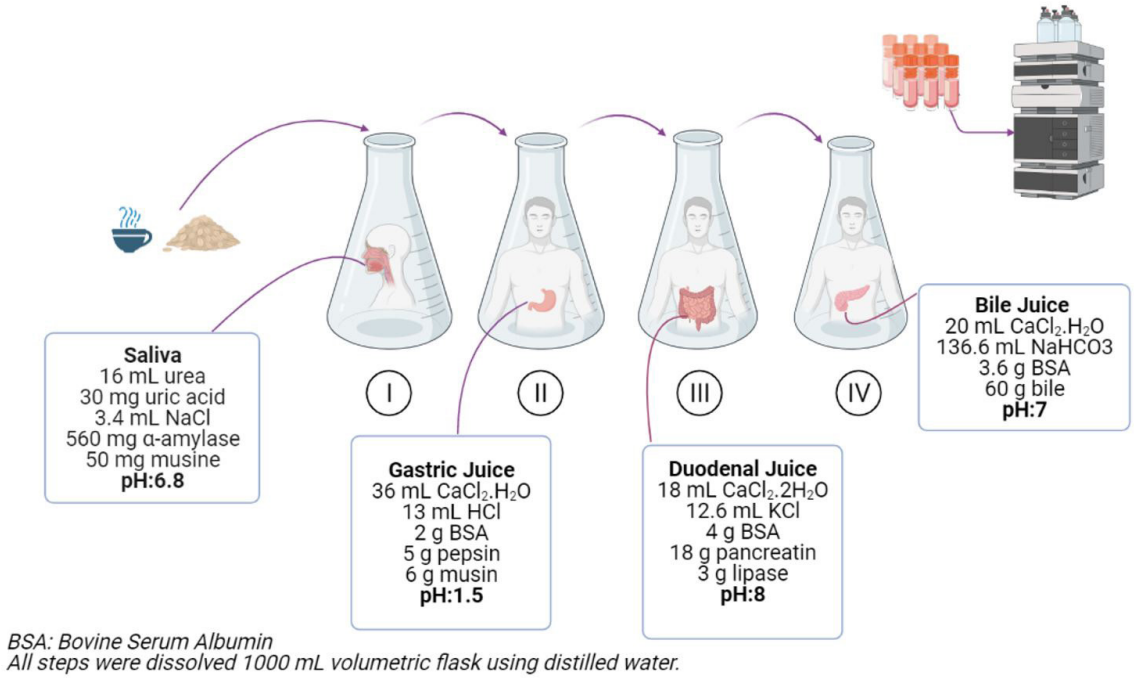

Figure 1. Determination of bioaccessibility of each sample. Simulated mouth digestion, stomach digestion, small intestine, and pancreas, respectively.

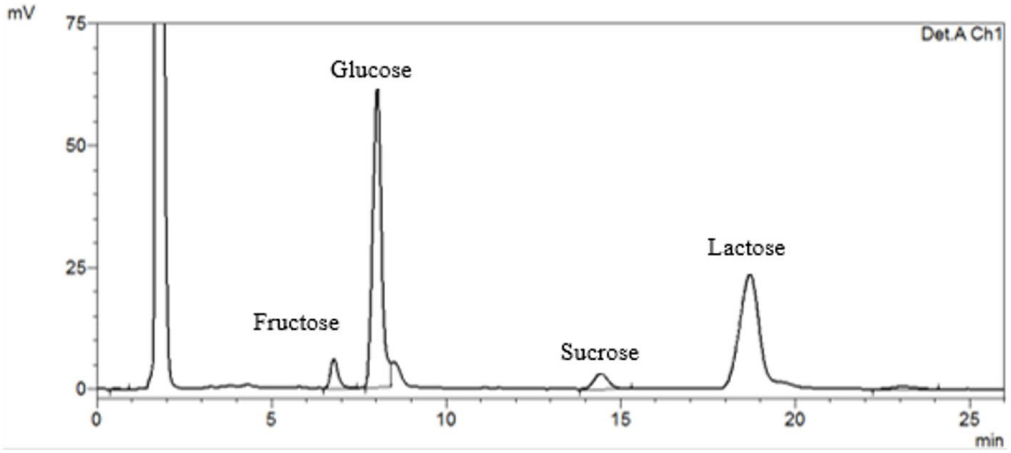

Figure 2. HPLC chromatogram of sugars in snack food sample 2.

Table 1. Fructose, glucose, sucrose and lactose amount of all snack food samples (g/100g)

Samples	Fructose	Glucose	Sucrose	Lactose
SF 1	1123.24 ± 50.82	1001.65 ± 45.32	6482.32 ± 293.28	nd
SF 2	1128.23 ± 51.04	16633.4 ± 752.55	983.71 ± 44.51	982.713 ± 44.6
SF 3	13319.5 ± 602.62	14975.9 ± 677.56	17.94 ± 0.81	57.81 ± 2.62
SF 4	2682.03 ± 121.34	3614.91 ± 163.55	11441.7 ± 517.66	nd
SF 5	16782.9 ± 759.31	18764.2 ± 848.96	680.72 ± 30.80	34.88 ± 1.58
SF 6	4398.29 ± 198.99	3923.87 ± 177.53	19571.5 ± 885.48	nd
SF 7	17605.1 ± 796.51	18587.83 ± 840.98	nd	nd
SF 8	16130.1 ± 729.78	17657.94 ± 798.90	nd	nd
SF 9	4470.05 ± 202.24	7848.75 ± 355.10	8616.18 ± 389.82	nd
SF 10	8308.21 ± 375.89	7217.86 ± 326.56	70.76 ± 3.20	nd

SF: Snack Foods; Nd: Not Detected.

sugar, and 13 g fiber. Oats exclusively contain avenanthramides, which contribute to the anti-hyperglycemic response through multiple molecular pathways (Hoda et al., 2019). According to the Turkish Food Composition Database (TURKOMP), the nutritional values of white oatmeal (*Avena sativa*, per 100 g) are 0.09 g glucose, 0.09 g fructose, 0.00 g lactose, 12.24 g total fiber, 0.240 mg vitamin B_6, and 0.391 mg vitamin B_1 (Turkomp, 2021). According to the US Department of Agriculture (USDA) studies, 100 g of baked oatmeal cookie with raisins (Roanoke Rapids brand) contains 7.58 g glucose, 11.1 g fructose, 29.8 g starch, 0.295 mg thiamin, and 2.69 mg vitamin E (alpha-tocopherol) (United States Department of Agriculture, 2021). These products have the advantage of being simply and quickly prepared as daily snacks. When we evaluated our results, the amount of fructose ranged from 1123.24 ± 50.82 g/100 g (SF 1) to 17605.1 ± 796.51 g/100 g (SF 7) among the snack food types. The amount of glucose for all snack food samples ranged from 1001.65 ± 45.32 g/100 g (SF 1) to 18587.83 ± 840.98 g/100 g (SF 7). Sucrose was not found in the analysis of SF 7 and SF 8. The lactose contents are listed in Table 1, with SF 5, SF 3 and SF 2 having 34.88 ± 1.58, 57.81 ± 2.62 and 982.713 ± 44.6 g/100 g, respectively. In this study, to begin with, the amount of sugars were determined in all snack food samples. When we compared the amounts of glucose and fructose, they were not very different, but the sucrose levels have a large range.

Owing to the carbonyl groups of sugars and the amino group of proteins, glycations products are formed in the metabolic pathway (Yusufoğlu et al., 2021). Thus, closely monitoring the level of sugar consumption is pivotal for our health. According to literature studies, biscuits are one of the major dietary sources of α-dicarbonyl compounds, since they contain varying amounts of high-fructose corn syrup (Hamzalıoğlu & Gökmen, 2016). When we compared the types of sugars in this paper, foods containing high amounts of fructose are more reactive than foods containing other types of sugars, in terms of glycation speed.

The capability of MGO to react with the amino acid side chains of proteins is about ten thousandfold higher than that of glucose to form advanced glycation end products (Degen et al., 2013). Among the snack food products, sample 7 has high levels of fructose and glucose; additionally, it is higher by fifteenfold compared to sample 1. This is because sample 7 contains commercial honey.

Figure 3 below shows the HPLC chromatogram of MGO and GO standard. The types of novel functional snack food products and their bioaccessibilities are given in Tables 2 and Table 3.

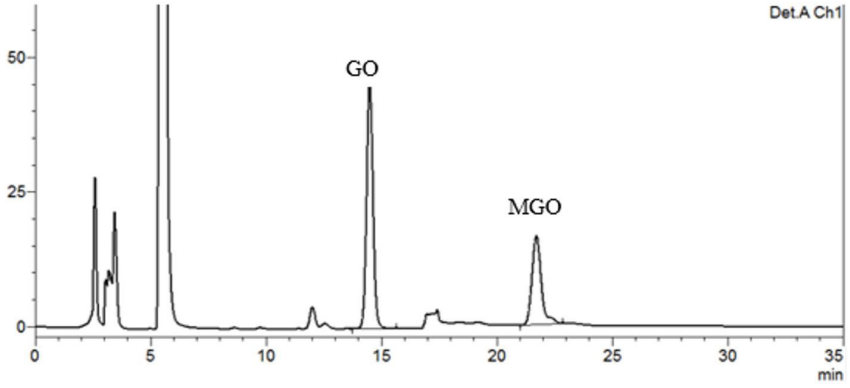

Figure 3. HPLC chromatogram of MGO and GO standard.

Table 2. Different sample types and their amount of α-DC (MGO)

Samples	Ingredients of Samples	Initial value MGO (µg/100 g)	After Digestion (µg/100 g)	Bioaccessibility (%)
SF 1	Oat meal, rosehip marmalade	0.60 ± 0.03	4.5 ± 0.2	742.52 ± 33.59
SF 2	Oat meal, apricot marmalade	13.05 ± 0.59	6.0 ± 0.3	45.46 ± 2.06
SF 3	Oat meal, cranberry marmalade	0.60 ± 0.03	3.0 ± 0.1	498.33 ± 22.55
SF 4	Oat meal, plum marmalade	0.53 ± 0.02	9.8 ± 0.4	1842.89 ± 83.38
SF 5	Oat meal, mulberry molasses	3.76 ± 0.17	7.1 ± 0.3	189.29 ± 8.56
SF 6	Oat meal, beet molasses	1.25 ± 0.06	14.3 ± 0.6	1145.77 ± 51.84
SF 7	Oat meal, honey	1.82 ± 0.08	8.0 ± 0.4	434.61 ± 19.66
SF 8	Oat meal, grape molasses	5.83 ± 0.26	6.3 ± 0.3	107.50 ± 4.86
SF 9	Oat meal, carob molasses	8.11 ± 0.37	14.6 ± 0.7	179.87 ± 8.14
SF 10	Oat meal, samphire molasses	6.80 ± 0.31	5.8 ± 0.3	85.64 ± 3.87
HT 1	Green Tea	0.28 ± 0.01	0.5 ± 0.0	192.21 ± 8.70
HT 2	Bergamot-flavored black tea	0.23 ± 0.01	0.9 ± 0.0	390.00 ± 17.64
HT 3	Olive leaf tea	0.18 ± 0.01	0.5 ± 0.0	265.78 ± 12.02

SF: Snack Food; HT: Herbal Tea; MGO: Methylglyoxal.

Table 3. Different sample types and their amount of α-DC (GO)

Samples	Initial value GO (μg/100 g)	After Digestion(μg/100 g)	Bioaccessibility (%)
SF 1	5.55 ± 0.25	12.06 ± 0.44	216.51 ± 9.80
SF 2	7.20 ± 0.33	9.78 ± 0.71	135.42 ± 6.13
SF 3	4.50 ± 0.20	15.79 ± 0.92	349.27 ± 15.80
SF 4	4.31 ± 0.19	20.28 ± 1.30	469.49 ± 21.24
SF 5	2.87 ± 0.13	28.72 ± 1.01	997.36 ± 45.12
SF 6	7.28 ± 0.33	22.24 ± 0.48	304.60 ± 13.78
SF 7	6.83 ± 0.31	10.61 ± 0.42	154.96 ± 7.01
SF 8	3.95 ± 0.18	9.38 ± 0.52	236.83 ± 10.72
SF 9	1.81 ± 0.08	11.56 ± 1.03	635.24 ± 28.74
SF 10	4.69 ± 0.21	22.70 ± 0.88	482.04 ± 21.81
HT 1	10.94 ± 0.50	19.48 ± 1.02	177.46 ± 8.03
HT 2	16.11 ± 0.73	22.50 ± 0.48	139.26 ± 6.30
HT 3	22.40 ± 1.01	10.51 ± 0.48	46.79 ± 2.12

SF: Snack Food; HT: Herbal Tea; GO: Glyoxal.

One of the α-dicarbonyls, MGO is a highly reactive component (Zheng et al., 2019). For all samples, initial values, as well as after digestion and bioaccessibility values, are given as μg/100 g. Initial values of MGO ranged from 0.53 ± 0.02 to 13.05 ± 0.59 μg/100 g (Table 2). After digestion, the amount of MGO values ranged from 3.0 ± 0.1 to 14.3 ± 0.6 μg/100 g. The upper range of MGO is four and a half fold that of the low amount. According to our results, amount of bioaccessibility of MGO is found high in snack sample 4, which contains plum marmalade. Plum marmalade is formed as a result of heat processes applied on plum fruit. Such fruits as cherries, plums, and raspberries are rich in phenolics and show high radical-scavenging activity. These fruits are known to contain high levels of anthocyanins. The cherry, plum, and raspberry cultivars studied showed high levels of total phenolics, anthocyanins and antioxidant capacity (Kim & Padilla-Zakour, 2004).

When MGO amounts in herbal beverages were compared in Table 2, the lowest, olive-leaf tea, was 0.18 ± 0.01 μg/100 g, while the highest, green tea, was 0.28 ± 0.01 μg/100 g. Post-digestion values, on the other hand, ranged from 0.5 ± 0.0 to 0.9 ± 0.0 μg/100 g. Table 2 shows that the GO values of olive-leaf and green tea decrease when they are metabolized.

It is known that biscuits are one of the major dietary sources of α-dicarbonyl compounds, since they contain varying amounts of high-fructose corn syrup (Hamzalıoğlu & Gökmen, 2016). While Hamzalıoğlu and Gökmen reported that MGO concentration was up to 81.4 mg/kg in cookies, other researchers measured 1,2-dicarbonyl compound concentrations of 385 mg/kg in cookies (Degen et al., 2013). Two sugar-containing products, manuka honey and baked cookies, contain 740 mg/kg and 210 mg/kg MGO level respectively, according to Degen et al. Moreover, it has been reported that the amount of MGO in honey does not cause an increase in glycation in healthy people (Israili, 2014).

Initial GO levels in the snack samples ranged from 1.81 ± 0.08 to 7.28 ± 0.33 μg/100 g, as shown in Table 3. After digestion, the amounts ranged from 9.38 ± 0.52 to 28.72 ± 1.01 μg/100 g. When comparing the GO levels of herbal teas, the lowest is 9.38 ± 0.52 μg/100 g, while the highest is 22.40 ± 1.01 μg/100 g for olive-leaf teas. Post-digestion values, on the other hand, range from 19.48 ± 1.02 to 10.51 ± 0.48 μg/100 g. Table 3 shows that the GO value of olive-leaf tea decreases when the tea is consumed. Tables 2 and 3 show similar decreases for olive-leaf teas.

In present days, myriad studies have focused on the correlation between the consumption of plant-based foods and wellness (Spagnuolo et al., 2021). According to the USDA database, approximately 1200 phytochemicals have been reported to reverse or control diabetic conditions. However, some limitations of phytomedicine include the lack of validation of the constituents' proportions and ambiguous mechanisms of action against diabetes (Hoda et al., 2019). Hence, in this context, we researched the effects of such herbal teas as green tea (HT 1), bergamot-flavored black tea (HT 2), and olive-leaf tea (HT3) on the bioaccesibility of α-DC and their reduction or increasing rate in Table 4 and Table 5. These teas are the main beverages widely consumed around the world (Edwards et al., 2015).

Tea leaf infusions are a vital source of phenolic compounds in the human diet (Jeszka-Skowron et al., 2021). Additionally, such natural products have shown different types of molecular mechanisms, such as β-cell regeneration, insulin mimicry, sodium-glucose cotransporters, and oxidative stress (Dabur et al., 2018). The phenolic phytochemicals have been studied for their therapeutic efficacy against various types of diseases, especially cancer, cardiovascular diseases, and some neurodegenerative disorders. On account of phenolic compounds, free radicals disappear from the body, which are possible factors that could trigger diabetes (Hoda et al., 2019).

The main chemical components of green tea (namely, Chinese tea) are polyphenols, gallic acid, epigallocatechin, and epigallocatechin-3-gallate (EGCG). According to clinical studies, the use of green tea promotes weight loss, prevents cancer, and is highly recommended for cardiovascular health. When drinking herbs, tea dosage is the most important; the desirable green tea intake is up to 1200 ml/day (Edwards et al., 2015). As seen in Table 4, green tea (HT 1) reduction rate for MGO ranged from 9.67 ± 0.48 to 83.80 ± 4.19 μg/100 g. These amounts can change in accordance with the type of snack food sample.

Table 4. Treatment of different herbal teas and their effect on MGO

Sample	After Digestion MGO (µg/100g)			MGO increase rate compared rate to initial value %			MGO Reducing Rate %		
	HT 1	HT 2	HT 3	HT1	HT2	HT3	HT1	HT2	HT3
SF 1	1.28 ± 0.06	0.44 ± 0.0	0.71 ± 0.0	213.3 ± 8.7	73.3 ± 3.0	117.9 ± 5.3	71.36 ± 3.57	89.86 ± 4.07	83.84 ± 3.79
SF 2	2.87 ± 0.13	3.55 ± 0.2	1.9 ± 0.1	22.0 ± 0.9	27.1 ± 1.1	18.5 ± 6.3	51.76 ± 2.59	40.40 ± 1.83	67.95 ± 3.07
SF 3	2.70 ± 0.12	0.29 ± 0.0	1.07 ± 0.0	451.7 ± 18.4	48.3 ± 2.0	136.6 ± 78.6	9.67 ± 0.48	90.03 ± 4.07	64.12 ± 2.90
SF 4	5.73 ± 0.26	0.18 ± 0.0	0.31 ± 0.0	1084.9 ± 44.3	34.0 ± 1.4	50.5 ± 15.9	41.33 ± 2.07	97.84 ± 4.43	96.51 ± 4.37
SF 5	1.16 ± 0.05	0.31 ± 0.0	1.56 ± 0.1	30.8 ± 1.3	8.2 ± 0.3	30.7 ± 19.9	83.80 ± 4.19	95.35 ± 4.31	77.95 ± 3.53
SF 6	3.90 ± 0.18	0.27 ± 0.0	2.14 ± 0.1	312.8 ± 12.8	21.6 ± 0.9	123.3 ± 89.0	72.79 ± 3.64	97.79 ± 4.42	84.82 ± 3.84
SF 7	3.51 ± 0.16	0.26 ± 0.0	1.29 ± 0.1	192.3 ± 7.9	14.2 ± 0.6	52.4 ± 33.7	55.89 ± 2.79	96.42 ± 4.36	83.56 ± 3.78
SF 8	4.09 ± 0.18	0.67 ± 0.0	3.72 ± 0.2	70.1 ± 2.9	11.5 ± 0.5	46.9 ± 31.2	35.02 ± 1.75	89.08 ± 4.03	40.91 ± 1.85
SF 9	4.59 ± 0.21	5.63 ± 0.3	5.81 ± 0.3	56.6 ± 2.3	69.2 ± 2.8	70.4 ± 4.3	68.62 ± 3.43	61.47 ± 2.78	60.25 ± 2.73
SF 10	3.26 ± 0.15	1.39 ± 0.1	3.89 ± 0.2	47.9 ± 2.0	20.4 ± 0.8	45.2 ± 22.4	44.20 ± 2.21	76.03 ± 3.44	33.51 ± 1.52

SF: Snack Food; HT: Herbal Tea; MGO: Methylglyoxal.

Table 5. Treatment of different herbal teas and their effect on GO

	After Digestion GO (µg/100g)			GO increase rate compared rate to initial value %			Effective Rate %		
	HT 1	HT 2	HT 3	HT1	HT2	HT3	HT1	HT2	HT3
SF 1	14.98 ± 0.68	14.95 ± 0.7	24.92 ± 1.1	269.8 ± 11.0	269.3 ± 11.0	448.8 ± 22.4	123.80 ± 5.60	123.6 ± 5.6	205.9 ± 9.32
SF 2	25.25 ± 1.14	13.95 ± 0.6	23.46 ± 1.1	350.8 ± 14.3	193.9 ± 7.9	326.0 ± 16.3	157.68 ± 7.13	142.2 ± 6.4	239.2 ± 10.82
SF 3	26.70 ± 1.21	10.47 ± 0.5	22.55 ± 1.0	592.7 ± 24.2	232.3 ± 9.5	500.7 ± 25.0	168.57 ± 7.63	33.6 ± 1.5	142.4 ± 6.44
SF 4	7.76 ± 0.35	1.22 ± 0.1	19.16 ± 0.9	180.3 ± 7.4	28.2 ± 1.2	444.9 ± 22.2	61.51 ± 2.78	93.7 ± 4.2	5.5 ± 0.25
SF 5	17.86 ± 0.81	4.23 ± 0.2	16.93 ± 0.8	622.2 ± 25.4	147.2 ± 6.0	589.9 ± 29.5	37.69 ± 1.71	85.0 ± 3.8	140.6 ± 6.36
SF 6	7.69 ± 0.35	8.32 ± 0.4	23.94 ± 1.1	105.8 ± 4.3	114.4 ± 4.7	329.0 ± 16.5	65.18 ± 2.95	62.4 ± 2.8	107.3 ± 4.85
SF 7	25.44 ± 1.15	6.94 ± 0.3	9.82 ± 0.4	372.7 ± 15.2	101.6 ± 4.1	143.8 ± 7.2	238.92 ± 10.81	34.5 ± 1.6	7.5 ± 0.34
SF 8	18.69 ± 0.85	13.26 ± 0.6	17.05 ± 0.8	473.5 ± 19.3	335.9 ± 13.7	432.1 ± 21.6	198.60 ± 8.99	140.9 ± 6.4	181.2 ± 8.20
SF 9	13.95 ± 0.63	23.74 ± 1.1	27.57 ± 1.2	769.2 ± 31.4	1308.8 ± 53.4	1519.8 ± 76.0	120.29 ± 5.44	204.7 ± 9.3	237.7 ± 10.75
SF10	23.92 ± 1.08	17.48 ± 0.8	15.13 ± 0.7	509.6 ± 20.8	372.4 ± 15.2	322.3 ± 16.1	105.01 ± 4.75	22.9 ± 1.0	33.1 ± 1.50

SF: Snack Food; HT: Herbal Tea; GO: Glyoxal.

Freeman and Niemeyer have quantified flavonoid levels in some commercial teas, such as bergamot-flavored black tea and green tea. They showed that bergamot-flavored black tea contains 323.9 ± 28.3 mg/L gallocatechin and 72.0 ± 1.6 mg/L EGCG (Freeman & Niemeyer, 2008).

Bergamot-flavored black tea is rich in phytochemicals, and several studies have hinted towards a strong association between tea drinking and a reduced risk of cancer. Catechins also suppress age-related declines in endurance capacity, causing individuals to feel livelier, long into their later years. Catechins in bergamot-flavored black tea activate energy metabolism and fat oxidation, helping with weight loss efforts (Preedy, 2012). After treatment of bergamot-flavored black tea, the MGO reduction rate ranged from 61.47 ± 2.78 (SF 9) to 97.84 ± 4.43 µg/100 g (SF 4), in Table 4. Meanwhile, GO values ranged from 22.9 ± 1.0 (SF 10) µg/100 g to 204.7 ± 9.3 (SF 9) µg/100 g. When results of this study were evaluated, treatment with bergamot-flavored black tea in different samples resulted in substantially high GO values. As in mentioned above, MGO is one of the highly reactive macromolecules. Therefore, it is crucial to restrict the amount of MGO, which in this study was facilitated.

Lately, people have tried to consume various herbal teas for their bioactive compounds. One of these, olive tree (*Olea europaea* L.) leaves have been widely used in traditional remedies in many countries. As dry matter, the leaves contain 6–9% of oleuropein (El & Karakaya, 2009). Olive tree leaves contain 2.058 mg gallic acid and 858 mg catechin equivalent per 100 g, just like red-grape peel (Makris et al., 2007).

A study has shown the anti-diabetic effect of olive leaf extract in alloxan-induced diabetic rats. During the study, the addition of 3% olive leaf extracts in the diet resulted in substantially reduced amounts of glucose and triglycerides (Mousa et al., 2014). The lowest rate of reduction of GO was 33.6 ± 1.5 µg/100 g, while the highest was 93.7 ± 4.2 µg/100 g, according to the olive-leaf tea results in Table 5.

When the results of Tables 4 and 5 are combined, bergamot-flavored black tea can be suggested as the tea that maintains good MGO and GO ratios. However, depending on the samples, olive-leaf tea can be said to have a limiting effect (Table 5).

A recent research study has conducted comprehensive analyses of carbohydrates, 1,2-dicarbonyl compounds, and AGEs in industrial bread making. This study shows the AGE contents of 69–149 mg/kg bread or 984–1857 mg/kg protein (Jost et al., 2021). Another study highlighted GO and MGO compounds in french fry samples (7 different samples), showing that french fries contained higher levels of MGO than GO (Çatak, 2020).

In summary, this article was aimed to provide data for both the α-DC of sugar-containing foods and the effect of different anti-diabetic herbal teas on MGO. This aids individuals, healthy or with diabetes, in the self-management of health conditions. When we evaluated the databases for studies on glycation products, different projects were encountered that did not address this gap in the data.

The knowledge of dicarbonyls are crucial for the management of our health. Perhaps information on dicarbonyl content will have to be written on packaged foods in the future, and their quantity will be limited. However, this will require extensive research and the creation of a database. There have been some studies on the subject of developing a database. Maasen et al. studied 223 foods and drinks; Nowotny et al. prepared another detailed study using 800 different food samples, and furthermore, a recent project has been started by the Department of Chemistry and Food Chemistry of the Technical University and Dresden (Maasen et al., 2021; Nowotny et al., 2018). In addition, as a consequence of the findings of this study, we contribute to the databases with multiple examples.

In terms of total dicarbonyl, concentrations were highest in dried fruit and candy bars (>400 mg/kg) and lowest in tea, dairy, light soft drinks, and rice (<10 mg/kg). One of the important results, breakfast cereals were also high in dicarbonyls, with higher amounts in cornflakes and crunchy granola compared to muesli and cooked oats. The reason for this result may be due to two parameters: heat treatment or the amount of sugar. While in manuka honey, the MGO concentration ranged from 0.04 to 736 mg/kg, GO concentration ranged from 0.0 to 37 mg/kg in apple molasses. When we compared some beverages for MGO and GO in this study, in terms of probiotic content, GO 0.01–3.2 mg/L is lower than MGO 0.02–3.2 mg/L (Maasen et al., 2021).

One of the studies have determined the stability of MGO and GO during *in vitro* digestion processes and the impact on gut microbiota. This study confirmed that dicarbonyl compounds in the anaerobic fermentation processes reduced the production of short-chain fatty acids (SCFA). Results have been shown that 90% of MGO and GO are likely to pass through the large intestine. Furthermore, the modern Western diet contains ultra-processed foods rich in dicarbonyl compounds, which could lead to a decrease of bacteria crucial for the microbiome (Brighina et al., 2021).

The American Diabetes Association highly recommends physical activity for people with sedentary occupations, since they are prone to develop excess oxidative stress, which also contributes to the development of Type 2 DM (T2DM) (Hoda et al., 2019). Some clinical studies have shown exercise training to be linked with lower dicarbonyl stress or lower AGE levels in the human body (Goon et al., 2009). A planned diet that includes limited fats and high quantities of green leafy vegetables can reduce such glycations outcomes. Physical activity also plays an important preventative role (Hoda et al., 2019). For prevention and treatment of diabetic complications, exercise is crucial. A study has demonstrated that three weeks of exercise was linked with a reduction of MGO stress (Schalkwijk & Stehouwer, 2020).

4 Conclusion

This study was focused on the inhibition of dicarbonyl compounds by different types of natural anti-diabetic molecules. This research will provide a broad idea about the anti-diabetic compounds and their effects, helping scientists and individuals to choose the appropriate dietary components. In conclusion, this paper presented some phytophenolic herbal teas for therapy against diabetes. Diabetes cannot be cured permanently; however, it may be managed through such various means, such as a regular planned diet containing phenolic components restricted of AGEs, medications, and physical exercise. In addition, many studies have shown that glycemic control reduces the macrovascular and microvascular complications of diabetes. We conclude that natural compounds have therapeutic potential for diseases mediated by oxidative stress, particularly obesity. Further studies on oxalaldehydes are needed to provide a better understanding of the mechanism of these products and their effects on tissues and organs. Plant-based beverages with high polyphenol and flavonoid content were found to be beneficial against GO and MGO in this study. In particular, it has been shown that green tea, bergamot-flavored black tea and olive-leaf tea may be appropriate to add to one's daily diet. In terms of presenting a novel approach, this research proposes a new and fast alternative based on optical features and instrumental analysis. This method contribute to the literature as a method for the diagnosis and treatment of T2DM and many other chronic diseases, by using blood/plasma samples instead of low amounts of food samples in the further studies.

Conflict of interest

The authors declare that they have no competing interests or personal relationships that could have appeared to influence the work reported in this paper.

Author contributions

All authors equally contributed to the structuring of the report, writing, and literature review. All authors have read and agreed to the published version of the manuscript.

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