

RESEARCH ARTICLE

The Effects of Diallyl Disulfide on Certain Oxidative Stress and Biochemical Parameters in an Azoxymethane-induced Colon Cancer Model

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Abstract

The aim of the present study is to investigate the effects of diallyl disulfide (DADS), an active compound of garlic, on certain serum biochemical and oxidative stress parameters in colon cancer induced by azoxymethane (AOM) in rats. The rats were divided into 5 groups: Control, AOM, DADS, AOM+DADS and corn oil. AOM-treated groups received 15 mg/kg sc AOM injections (twice at one-week intervals), while DADS-treated groups received 50 mg/kg DADS via gavage 5 days a week at the end of the 15th week. The corn oil group received 1 ml/kg corn oil via gavage 5 days a week (for 3 weeks) at the end of the 15th week of the study. Total protein and albumin ($p<0.05$) levels were higher in the DADS group than in the AOM group. ALP activity decreased in the DADS and AOM+DADS groups; whereas, ALT activity increased in the AOM group ($p<0.05$). Additionally, cholesterol and HDL levels lowered in the AOM and AOM+DADS groups ($p<0.05$). ROS concentration was significantly higher in the AOM group compared to the other groups ($p<0.05$), while GPx levels were low. Serum magnesium concentration was lower in the AOM+DADS group compared to the control group ($p<0.05$) and this decrease was accompanied by urea levels in both the AOM+DADS and DADS groups ($p<0.05$). Compared to the control group, iron levels were high in the DADS group, while chloride levels were high in the DADS, AOM+DADS and corn oil groups ($p<0.05$). In conclusion, the decreases in serum cholesterol and HDL levels, particularly in the AOM group, supported the notion that these parameters could be important cancer biomarkers in cancer cases. Furthermore, the changes in chloride and iron levels across groups were striking and it was concluded that many biochemical parameters could be identified as new biomarkers in colon cancer through investigation of the therapeutic efficacy of DADS.

Keywords: Azoxymethane, Biochemical parameters, Colon cancer, Diallyl disulfide, Rat

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INTRODUCTION

Cancer is defined as a disease caused by the uncontrolled proliferation of normal cells in the body (Uçak and Kızıltan 2021). Hippocrates was the first in history to state that cancer is a systemic disease affecting the entire body, not just a specific organ and cancer treatment should be based on evaluating the whole organism, not just destroying the tumor (Gunes 2022).

The fact that colon cancer takes approximately 10-15 years to develop has led to various studies and research into cancer-preventive agents in order to prevent this deadly disease and enable early diagnosis. Although preliminary studies have determined that many protective agents have a positive effect in preventing the

disease, the need to identify the optimal preventative is clear. Thus, the azoxymethane (AOM) model for experimentally inducing colon cancer is a valuable model used to screen potentially useful compounds (Chen and Huang 2009). AOM, an active by-product of 1,2-dimethylhydrazine, induces cancer formation in colon-specific colorectal cells (Boateng et al 2006). As it effectively represents colon cancer types, it is widely used to examine the mechanisms underlying human sporadic colon cancer and has become frequently used in the experimental induction of colon cancer, particularly in rodents (Suvarikli Alan and Bulut 2023).

In recent years, there has been an increased interest in components and biological molecules found in



natural foods in drugs produced for the purpose of implementing new treatment methods (Clardy and Walsh 2004). Currently used and effective methods such as chemotherapeutic drugs, radiotherapy and surgical procedures are becoming less preferred every day due to reasons such as their excessive side effects and their negative impact on the patient's psychological process (Özgöçmen 2017). The use of alternative treatment methods has increased due to natural ingredients have few side effects and since it is thought that the biological molecules they contain can prevent cancer (Yu et al 2014, Lin et al 2019).

Colon cancer is one of the types of cancer for which alternative treatment options are constantly increasing (Witalison et al 2015). *Allium sativum* (garlic) is used as a medicinal plant in many countries to treat wounds, digestive problems and infections. Garlic is a dietary source with significant effects due to its antioxidant properties, which include sulfur compounds, polyphenols and carotenoids. Garlic has anticancer, antioxidant, anti-inflammatory, antiprotozoal, antimicrobial, immunomodulatory, hypoglycemic and cardiovascular protective effects and its organic sulfur compounds are believed to be responsible for most of its biological activities (Trio et al 2014). These include organosulfur compounds such as diallyl sulfide (DAS), diallyl disulfide (DADS), diallyl thiosulfinate (allicin), diallyl trisulfide (DATS), E/Z- ajoene and S-allyl-cysteine (SAC) (Viswanathan et al 2014). It has been reported that DADS has an inhibitory effect on cancer cell movement and invasiveness and this effect is associated with a decrease in the activity of matrix metalloproteinases (MMPs) (Shin et al 2010, Park et al 2011, Lai et al 2013). Furthermore, raw garlic extract has been reported to exhibit anti-proliferative effects on human cancer cell lines, including liver, colon, prostate and breast cancer cells (Bagul et al 2015).

It has been reported that garlic prevents oxidative damage in normal cells by stimulating the scavenging of ROS (Amagase 2006, Szychowski et al 2018) and its oral administration to mice significantly reduces lipid peroxidation and increases the activity of radical scavenging enzymes such as superoxide dismutase, reduced glutathione and glutathione peroxidase (Balasenthil et al 2000).

Considering its potential significant effects on cancer formation and treatment, this study aimed to investigate the effects of DADS, one of the major active compounds in garlic, on some biochemical and oxidative stress parameters in an experimental colon cancer model induced by azoxymethane (AOM) in rats.

MATERIAL AND METHODS

Male Wistar Albino rats aged between 12 and 16 weeks (220-250 g) obtained from the Selcuk University Experimental Medicine Research and Application Center (SUDAM) were used in the study. During the 18-week study period, the rats were kept in groups of six in cages at 20°C and 40% humidity, with a 12-hour night and 12-hour day cycle. The research project, approved by the Ethics Committee of the Faculty of Veterinary Medicine, Selcuk University, on 30.04.2021 with decision number 2021-34, was supported by the Scientific Research Projects (BAP) Coordination of Selcuk University (Project No: 21202130).

Animal groups and treatments

The rats used in the study were divided into 5 groups as follows, with 12 rats in each group. Rats that died during the study period were removed from the groups and the study was terminated.

1. Control Group (C, n:12): No treatment was performed on this group, which was provided with ad libitum feed and water throughout the study period.
2. Azoxymethane Group (AOM, n:12): Subcutaneous injections of azoxymethane (AOM, Azoxymethane Sigma-Aldrich, A5486, Germany) (15 mg/kg) were administered twice at one-week interval (Er et al 2019).
3. Diallyl disulfide Group (DADS, Diallyl disulfide, Sigma-Aldrich, SMB00378, n:11): DADS dissolved in corn oil was administered via gavage at a dose of 50 mg/kg for 3 weeks (5 days per week) starting after the 15th week of the study.
4. Azoxymethane and Diallyl Disulfide Group (AOM + DADS, n:10): Similar to the AOM group, the group receiving AOM administration was also administered DADS at a dose of 50 mg/kg via gavage for 3 weeks (5 days per week) starting from the 15th week.
5. Corn Oil Group (n:12): To determine the effects of corn oil used as the DADS solvent in the study, corn oil was administered via gavage at a dose of 1 ml/kg for 3 weeks (5 days per week) starting from 15th week.

Blood samples were collected from rats in all groups on the day following the last administration using subcutaneous ketamine (95 mg/kg) + xylazine (5 mg/kg) anesthesia and the rats were then sacrificed using the cervical dislocation method.

At the end of the study, serum samples were analyzed for glucose, triglycerides, total cholesterol, HDL, AST, ALT, ALP, uric acid, creatinine, total protein, albumin, Na, K, Ca, Cl, Mg and Fe levels using commercial kits (Architect Abbott Laboratories, USA) on an autoanalyzer (Architect c8000, USA). Serum SOD (E0168Ra), ROS (E0304Ra), CAT (E0869Ra), GPx (E1242Ra) and GSH (E1101Ra) levels were measured using an ELISA reader (BIOTEK

ELX800) according to the procedures described in commercial ELISA kits (Bioassay Technology Laboratory, Rat, ELISA Kit, China).

Statistical analysis

Data were analyzed using ANOVA and Tukey's test as post-hoc test (SPSS 25.0). The significance level of the study was determined as $p < 0.05$.

RESULTS

The parameters examined in the groups are presented in the tables below.

In the present study, serum glucose levels were statistically similar in all groups, while only the corn oil group showed a statistically significant ($p < 0.05$) increase compared to the control group. In addition, albumin ($p < 0.05$) and total protein levels were higher in the DADS group than in the AOM group (Table 1).

At the end of the study, serum ALP activity showed statistically significant ($p < 0.05$) decreases in the DADS and AOM+DADS groups compared to the control group; whereas, ALT activity increased significantly ($p < 0.05$) in the AOM group. No differences were found in AST activity between the groups (Table 1).

Lipid parameters, specifically cholesterol and HDL concentrations, showed a statistically significant decrease ($p < 0.05$) in the AOM and AOM+DADS groups compared to the control group. An increase in triglyceride concentration ($p < 0.05$) was observed only in the corn oil group (Table 1).

Serum urea levels were low in the DADS and AOM+DADS groups ($p < 0.05$), while no change was observed between

the groups in uric acid and creatinine levels (Table 1). However, no statistically significant change was detected in CAT, SOD and glutathione levels compared to the control group (Table 3).

Serum magnesium concentration was found to be significantly lower ($p < 0.05$) in the AOM+DADS group compared to the control group. While no difference was observed in sodium, potassium and fluoride concentrations in the other groups compared to the control group, increases in chloride levels were determined in the DADS, AOM+DADS and corn oil groups ($p < 0.05$). Iron concentrations were lower in the AOM group compared to the control group ($p < 0.05$), while the DADS group showed a significant increase ($p < 0.05$). Fe levels were also elevated in the AOM+DADS group compared to the AOM group ($p < 0.05$) (Table 2).

Among the antioxidant defense system parameters, ROS concentration was higher in the AOM group compared to the other groups ($p < 0.05$), while GPx levels were significantly lower ($p < 0.05$) (Table 3).

DISCUSSION

The insidious onset and progression of colon cancer over many years has led to research into cancer-preventing agents in various studies. Thus, identifying the optimal preventative agent has been a priority for scientists. For this purpose, AOM is an agent frequently used experimentally in rodents to induce colon cancer (Boateng et al 2006, Chen and Huang 2009).

It has been reported that serum ALT and ALP levels increased significantly in rats with colon cancer induced by AOM treatment (Tan et al 2015, Ranji et al 2019),

Table 1. Effects of diallyl disulfide on some liver, kidney, and lipid parameters in an azoxymethane-induced colon cancer model.

Parameters	Control (n=12)	AOM (n=12)	DADS (n=11)	AOM+DADS (n=10)	Corn Oil (n=12)
Glucose (mg/dl)	166.25±9.32 ^b	187.33±10.5 ^b	171.18±13.34 ^b	169.70±12.1 ^b	220.41±9.94 ^a
Albumin (g/dl)	3.09±0.05 ^b	3.17±0.04 ^{ab}	3.28±0.04 ^a	3.13±0.07 ^{ab}	3.09±0.05 ^b
Total Protein (g/dl)	6.84±0.14 ^{ab}	6.72±0.11 ^b	7.17±0.09 ^a	6.73±0.18 ^b	6.87±0.12 ^{ab}
ALP (U/L)	136.83±12.95 ^{ab}	163.92±11.27 ^a	78.27±7.26 ^d	103.1±11.34 ^{cd}	128±10.93 ^{bc}
ALT (U/L)	51.42±2.09 ^b	60.67±2.62 ^a	55.18±3.94 ^{ab}	56.5±2.24 ^{ab}	53.75±2.36 ^{ab}
AST (U/L)	177.67±23.53	119.08±8.63	176.45±29.21	137.4±14.55	148.33±25.68
Cholesterol (mg/dl)	85.83±4.44 ^a	72.42±2.27 ^b	88.1±4.33 ^a	72.9±2.5 ^b	89.33±4.48 ^a
Triglyceride (mg/dl)	150±13.72 ^b	154.83±7.83 ^b	118.1±12.34 ^b	113.3±11.58 ^b	200.25±20.52 ^a
HDL (mg/dl)	53.31±2.38 ^a	41.12±1.54 ^c	56.57±2.52 ^a	43.7±2.13 ^{bc}	49.23±3.31 ^{ab}
Urea (mg/dl)	43.08±0.83 ^a	42.75±0.79 ^a	34.18±0.83 ^b	36.3±0.99 ^b	42.17±0.1 ^a
Uric acid (mg/dl)	3.41±0.26	3.1±0.36	3.12±0.42	3.15±0.33	3.88±0.33
Creatinine (mg/dl)	0.56±0.01	0.55±0.01	0.57±0.02	0.54±0.01	0.57±0.01

^{a,b,c} Different letters in the same row indicate statistical significance ($p < 0.05$). ALP: Alkaline phosphatase, AST: Aspartate aminotransferase, ALT: Alanine aminotransferase, HDL: High density lipoprotein.

Table 2. Effects of diallyl disulfide on some mineral levels in an azoxymethane-induced colon cancer model.

Parameters	Control (n=12)	AOM (n=12)	DADS (n=11)	AOM+DADS (n=10)	Corn Oil (n=12)
Calcium (mg/dl)	10.67±0.16	10.53±0.14	10.86±0.20	10.79±0.14	10.79±0.23
Sodium (mmol/l)	142.58±0.67 ^{ab}	141±0.89 ^b	144.64±0.86 ^a	143±1.04 ^{ab}	143.25±0.6 ^{ab}
Potassium(mmol/l)	5.06±0.19	4.88±0.23	5.35±0.26	5.41±0.27	5.25±0.28
Chlorine (mmol/l)	99.92±0.71 ^c	100.92±0.71 ^{bc}	103.55±0.51 ^a	104.4±0.98 ^a	102.75±0.57 ^{ab}
Magnesium (mg/dl)	2.43±0.09 ^a	2.18±0.01 ^{ab}	2.15±0.12 ^{ab}	2.03±0.04 ^b	2.29±0.1 ^{ab}
Iron (ug/dl)	239.5±7.6 ^{bc}	226.58±14.27 ^c	367.73±18.13 ^a	269.2±19.02 ^b	244.42±7.92 ^{bc}

^{a,b,c} Different letters in the same row indicate statistical significance (p < 0.05)

while no difference was found in AST, creatinine and urea levels (Tan et al 2015). Tan et al (2016) reported a similar increase in serum ALT levels, a significant decrease in AST levels and no change in ALP, creatinine and urea levels. Jabbar et al (2024) reported that similar applications in rats resulted in a significant decrease in total protein and albumin levels in colon tissue and an increase in ALT, AST, urea and creatinine levels, while Ahmed et al (2024) determined that ALT, AST, urea and creatinine levels elevated in colon tissue in experimental colon cancer. Studies have also found that similar treatments in rats did not produce a statistically significant difference in ALT, AST, total protein and albumin levels (Hajrezaie et al 2014, Refaat et al 2015). Similarly, Al-Henhena et al (2014) reported no statistically significant difference in total protein, albumin, glucose and creatinine levels in rats with colon cancer.

In the study, similar to both studies (Tan et al 2015, Tan et al 2016), an increase in serum ALT (p<0.05) and ALP levels and a decrease in AST levels were observed in the AOM group. Findings regarding serum urea and creatinine levels were also found to be consistent with the above studies (Hajrezaie et al 2014, Tan et al 2015, Tan et al 2016). The results regarding total protein, albumin (Al-Henhena et al 2014, Hajrezaie et al 2014, Refaat et al 2015) and glucose (Al-Henhena et al 2014) levels support the reported results.

It has been reported that serum lipid profiles vary in many

chronic diseases and cases of tissue damage and there is a relationship between low cholesterol and HDL levels and colorectal cancer (Pirro et al 2018, Wang et al 2015, Tao et al 2022). Decreases have been observed in serum total cholesterol and HDL levels in many malignancies, including colon cancer, suggesting that cholesterol may play an active role in cell proliferation and cancer formation and progression (Shekelle et al 1991, Dessi et al 1992, Hassoy et al 2003). Although it is not entirely clear whether low serum total cholesterol levels can be considered a precursor to occult or preclinical cancer (Iwagami et al 2022), Winawer et al (1990) reported that patients' serum cholesterol levels gradually lowered in the years prior to cancer diagnosis and this decrease became more pronounced upon diagnosis. Ranji et al (2019) determined that serum triglyceride levels elevated and HDL levels lowered in mice with colon cancer experimentally induced with AOM. However, Liao et al (2012) reported that AOM administration causing no significant difference in HDL levels in rats caused lowered serum triglyceride and cholesterol levels. Hassoy et al (2003) also determined that serum cholesterol and HDL levels showed a significant decrease in cancer patients, while the decrease in triglyceride levels was not significant. In the present study, serum cholesterol and HDL levels were found to be significantly low in the group with colon cancer induced by AOM, which is compatible with the findings of Hassoy et al (2003). No significant change was observed in triglyceride levels, except for the corn oil

Table 3. Effects of diallyl disulfide on some oxidative stress parameters in an azoxymethane-induced colon cancer model.

Parameters	Control (n=12)	AOM (n=12)	DADS (n=11)	AOM+DADS (n=10)	Corn Oil (n=12)
Catalase ng/ml	27.88±1.16 ^a	27.26±1.41 ^a	27.55±1.15 ^a	24.72±1.49 ^a	26.10±1.44 ^a
SOD ng/ml	2.87±0.29 ^{ab}	2.57±0.28 ^b	3.18±0.31 ^{ab}	2.7±0.21 ^b	3.93±0.59 ^a
Glutathione ng/ml	164.01±13.19 ^a	164.75±15.24 ^a	176.42±12.68 ^a	183.88±14.88 ^a	176.97±14.13 ^a
GPx ng/ml	10.08±1.72 ^{bc}	9.27±1.25 ^c	16.3±1.77 ^a	14.34±1.96 ^{ab}	14.85±1.47 ^{ab}
ROS ng/ml	156.9±18.22 ^b	220.16±29.83 ^a	141.6±15.87 ^b	137.59±18.17 ^b	179.45±16.12 ^{ab}

a,b,c Different letters in the same row indicate statistical significance (p < 0.05) SOD: Superoxide dismutase, GPx: Glutathione peroxidase, ROS: Reactive oxygen species

group, where the increase could be considered normal. Furthermore, the study revealed that the decrease in HDL levels in the AOM group with colon cancer was consistent with the findings of [Ranji et al \(2019\)](#) and the decrease in cholesterol levels was consistent with the findings of [Liao et al \(2012\)](#). Based on these findings, the data obtained support the view that low serum total cholesterol and HDL levels may be a precursor to cancer.

[Waly et al \(2012\)](#), who induced colon cancer in rats by administering AOM at different doses and durations, reported statistically significant increases in GPx, SOD and KAT concentrations in colon tissue, while [Uyar et al \(2022\)](#) reported that AOM administration caused a decrease in colon tissue GSH, GPx and SOD and serum GSH and SOD levels in rats. Similarly, decreases in CAT, SOD, GPx ([Liu et al 2019](#), [Aloliqi 2022](#), [Ahmed et al 2024](#), [Jabbar et al 2024](#)) and glutathione levels ([Al-Numair et al 2011](#)) have been reported by different studies, while it is also possible to find studies ([Al-Henhana et al 2015](#)) observing no difference in SOD levels. Contrary to the reported results, [Karabulut et al \(2014\)](#) reported no difference in glutathione levels in the colon tissue at lower doses. [Al-Henhana et al \(2015\)](#) found that 15 mg/kg AOM administration in female rats did not cause changes in GPx and CAT levels in colon tissue, while some researchers determined a decrease in GSH levels ([Rodríguez-Ramiro et al 2011](#), [Guizani et al 2013](#), [Gurocak et al 2013](#), [Waly et al 2015](#)). [Hajrezaie et al \(2014\)](#) reported that the administration of a total of 30 mg/kg AOM to male Sprague-Dawley rats did not cause a statistically significant difference in CAT, GPx and SOD levels in the AOM group compared to the control group. The study also revealed that the lack of difference in CAT, GPx, SOD and glutathione levels in the AOM group compared to the controls was similar to some of the above studies ([Hajrezaie et al 2014](#), [Karabulut et al 2014](#), [Al-Henhana et al 2015](#)) and it was thought that the lack of change could be related to the dose and duration of the administration.

It has been determined that the organosulfur compounds found in garlic not only inhibit carcinogenic activation but also play an active role in many important cancer development mechanisms ([Yi and Su 2013](#)). Studies conducted with experimental animals have also shown that garlic provides protection against cancer cases induced by various chemical carcinogenic agents ([Arunkumar et al 2007](#)). Epidemiological studies related with DADS, an important component of garlic, have indicated that garlic reduces the incidence of cancer. [Galeone et al \(2006\)](#) determined that there was a negative correlation between consumption frequency of garlic and the development of many types of cancer, including colorectal cancer.

Studies ([Lee et al 2014](#), [Ko et al 2017](#), [Hasan et al 2020](#)) reported no significant difference in liver tissue AST, ALT and ALP levels following oral DADS administration in rats. On the other hand, [Asdaq et al \(2022\)](#) reported that DADS administration at different doses to rats lowered ALP, AST, ALT, triglyceride and total cholesterol levels while elevating HDL levels. While it was reported that gavage administration of DADS to rats did not cause any difference in serum creatinine, urea, uric acid, creatinine and albumin levels ([Shin et al 2016](#), [Hassanein et al 2021](#)), it was determined that intragastric administration of DADS caused a significant decrease in creatinine levels, while no difference was observed in serum urea levels ([Fiore Chiarandini et al 2008](#)). [Pedraza-Chaverri et al \(2003\)](#) also reported that intragastric administration of DADS did not cause a statistically significant difference in serum urea and creatinine concentrations in rats. Contrary to many of the above studies, the present study revealed that there were significant decreases in urea levels in the DADS-treated group and this decrease was also pronounced in the AOM+DADS group. Albumin levels elevated in the DADS group and no changes were observed in uric acid and creatinine levels, similar to the findings of the above studies. Furthermore, in parallel with the results of [Asdaq et al \(2022\)](#), it was determined that ALP levels showed significant decreases, but no change was observed in ALT levels. Although no difference was seen in HDL levels compared to the control group, it was observed that decreasing HDL levels tended to increase with AOM.

Although mineral substances and trace elements are found in small amounts in the organism, they play a vital role in many biochemical enzymatic reactions and are thought to be a potential key factor in various diseases, including cancer ([Bornhorst et al 2018](#)). Furthermore, mineral substances may influence tissue carcinogenesis due to their roles in regulating cell proliferation, differentiation and apoptosis ([Navarro Silvera and Rohan 2007](#)). In recent years, there has been a growing interest in understanding the role of trace elements and metals in the pathogenesis of many types of cancer, including colorectal cancer.

[Juloski et al \(2020\)](#) reported in their study conducted on humans that Na, K, Mg and Ca levels of intestinal tissue showed significant differences in colorectal cancer tissues and Na levels were lower in tumor tissue compared to controls, while other parameters were higher. The changes observed were largely associated with metabolic changes occurring in the tissue. In addition to all minerals, iron levels in particular have been shown to be an active mineral in the development of colon cancer ([Kishida et al 1994](#), [Wurzelmann et al 1996](#), [Sohrabi et al 2018](#)). Because iron deficiency is extremely harmful to the body, the body's iron balance is strictly controlled ([Uysal](#)

2007). The main component synthesized by the liver that maintains this balance is the hormone hepcidin (Sornjai et al 2020). Hepcidin causes anemia by preventing the release of iron into the plasma and reducing its absorption from the duodenum (Schwartz et al 2021). In their study, Ward et al (2008) reported that the hormone hepcidin was synthesized in colorectal cancer tissue. The study indicated that, apart from serum iron levels, there was no significant change in other minerals in the colon cancer group, while iron levels lowered partially in the AOM group with cancer formation and elevated significantly in the DADS group ($p < 0.05$). Indeed, there are many studies that have determined that serum iron levels decrease in colon cancer patients (Kishida et al 1994, Wurzelmann et al 1996, Sohrabi et al 2018) and low iron levels in colon cancer patients have been associated with the bleeding observed in this type of cancer. In fact, many researchers have suggested that iron levels could be used as a cancer marker. In the present study, serum iron levels in rats with colon cancer were partially lower than in controls, although it was not statistically significant, this finding is consistent with the literature. Furthermore, the elevation in iron levels observed in the DADS and AOM+DADS groups in the present study led to the conclusion that the therapeutic use of DADS may be beneficial.

It has been reported that DADS prevents the decrease in the levels of antioxidant enzymes such as GPx, glutathione reductase and SOD in cases of increased oxidative stress (Pedraza-Chaverrí et al 2003). It has also been determined that DADS inhibits the cell cycle as well as the proliferation of various cancer cells by inducing apoptosis (Tan et al 2008). Ho et al (2012) found statistically significant increases in CAT, GPx and GSH levels in their studies conducted with high- dose DADS administration in rats. Somade et al (2019) reported that DADS administration did not cause a statistically significant difference in GSH levels but observed significant increases in GPx and CAT levels. In the present study, GPx levels, which were significantly decreased in the AOM group, were high in the DADS ($p < 0.05$) and AOM+DADS groups, which is compatible with the above information. Furthermore, the increase in ROS levels in the AOM group and their decrease in the DADS and AOM+DADS groups ($p < 0.05$) in the presented study confirms that garlic prevents oxidative damage in normal cells by stimulating the scavenging of ROS (Amagase 2006, Szychowski et al 2018). This result is important as it reflects that DADS may provide better protection against oxidative damage in colon tissue in rats. Furthermore, the observation of similar increases in SOD levels, although not statistically significant, supported the finding that DADS may be an effective protective agent.

CONCLUSION

The number of experimental studies on the biochemical effects of DADS in colon cancer is quite limited and numerous studies have examined the effects of DADS and AOM independently of each other. The lipid parameters obtained in the present study are particularly important in terms of serum cholesterol and HDL levels. They support the information that low cholesterol levels observed in cancer cases could be an important cancer biomarker when the biochemical effects and causes are investigated further. The decline in serum iron levels, which is notable in colon cancer and similar cancer cases, was found to increase as a result of DADS treatments, suggesting that the effectiveness of DADS in treatment should be investigated. Moreover, despite new and effective treatment methods against colon cancer, it is thought that new strategies are necessary and new biomarkers could be identified by researching many biochemical parameters in different types of cancer.

DECLARATIONS

Competing Interests

The authors declare that they have no conflict of interest regarding the publication of this article.

Availability of Data and Materials

The data that support the findings of this study are available on request from the corresponding author.

Ethical Statement

Selçuk University Experimental Medicine Application and Research Center, Animal Experiments Ethics Committee 30.04.2021, 2021-34 Number Ethics Committee Decision.

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Author Contributions

Motivation /Concept: ZB, SH; Design: ZB, SH; Control/Supervision: SH, ZB; Data Collection and Processing: BT; Analysis and Interpretation: BT, SH; Literature Review: BT, SH; Writing the Article: SH, ZB; Critical Review: ZB

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