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Dietary Fiber as a Potential Chemopreventive Agent: Evidence from Multiple Cancer Studies

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Abstract
Dietary fiber has been identified as a key preventive factor against a variety of cancers, notably those affecting the digestive and reproductive systems. This study combines findings from epidemiological studies, systematic reviews, and meta-analyses to assess fiber's chemopreventive potential across a variety of cancer types. Strong evidence suggests that high fiber intake reduces the incidence of colorectal, breast, pancreatic, esophageal, and gastric cancers, with potential advantages for ovarian, prostate, liver, and bladder cancers. Fiber helps prevent cancer by improving bowel transit, reducing carcinogen exposure, modulating gut microbiota, producing anti-inflammatory short-chain fatty acids, and regulating hormones. The review emphasizes the relevance of entire food sources, such as fruits, vegetables, legumes, and whole grains, in terms of fiber intake. Despite consistent findings, more high-quality research is needed to explain fiber's impact in less well-studied cancers and to improve dietary guidelines. Overall, increasing dietary fiber consumption is a low-cost, widely available technique for cancer prevention and public health promotion.
Keywords: *Dietary fiber, cancer, short-chain fatty acids, colorectal cancer.*

I. INTRODUCTION

The World Health Organization (WHO) reported in 2019 that cancer was the primary or second-leading cause of death in 112 nations and the third or fourth-leading cause of death in 23 countries (WHO, 2023). Cancer has an impact that goes beyond only making families unhappy; it also hinders socioeconomic growth. According to the most recent IARC data from 2020, colorectal, prostate, stomach, and esophageal cancers were among the top 10 with the highest death rates, while breast cancer led the list of incidences (Wild et al., 2020). According to Hu et al. (2023), effective prevention is therefore thought to be the most successful and economical method of controlling cancer given the high expense of cancer treatment and the low cure rate.

Dietary fiber and whole grains provide a unique combination of bioactive components such as resistant starches, vitamins, minerals, phytochemicals, and antioxidants. As a result, research into their possible health advantages has gotten a lot of attention during the last few decades. Epidemiological and clinical studies show that dietary fiber and whole grain consumption are inversely related to obesity (Tucker & Thomas, 2009), type 2 diabetes (Meyer et al., 2000), cancer (Park et al., 2009), and cardiovascular disease (CVD). (Streppel et al., 2008).

Dietary fiber is believed to be a key component of a healthy diet as recommended by several nutritional guidelines. Dietary fiber is defined as edible plant parts or similar carbohydrates that are difficult for the human small intestine to digest and absorb. It can be classified as either soluble or insoluble fiber based on how soluble or insoluble it is in water (Veronese et al., 2018). Insoluble dietary fiber is mostly found in cereals and whole grain products, whereas soluble dietary fiber is mostly found in fruits and vegetables. The required daily intake of dietary fiber is frequently not met, even though it can be found in many everyday meals. According to Hu et al. (2023), adults in European nations consume dietary fiber at levels below the recommended daily consumption of 18–24 g for men and 16–20 g for women. Approximately 25 to 35 grams of dietary fiber per day, of which 6 grams are soluble fiber, is thought to be an adequate amount for the majority of people (Lattimer & Haub et al., 2010).

The Food and Drug Administration (FDA) has accepted health claims for dietary fiber. According to the FDA (2008a), consuming more dietary fiber from fruits, vegetables, and whole grains, in addition to reducing fat consumption (<30% of calories), may lower the risk of certain cancers. Recent research supports the inverse association between dietary fiber and the development of various malignancies, including colorectal, small intestine, oral, laryngeal, and breast cancer (Park et al., 2009; Nomura et al., 2007; Schatzkin et al., 2008). Although the majority of investigations agree with these findings, the underlying mechanisms remain unclear. However, several different courses of action have been offered. First, dietary fiber (DF) resists digestion in the small intestine, allowing it to enter the large intestine and be fermented into short chain fatty acids with anti-carcinogenic characteristics (Young et al., 2005). Second, because DF increases fecal volume and viscosity, possible carcinogens spend less time in contact with mucosal cells. Third, DF enhances the interaction between bile acids and carcinogens. Fourth, greater dietary fiber consumption leads to higher antioxidant levels. Fifth, DF

may increase estrogen excretion in feces by inhibiting estrogen absorption in the intestines (Adlercreutz et al., 1987).

Recently, systematic reviews and meta-analyses were published, yielding mixed results. Some studies suggest that dietary fiber can reduce mortality in cancer patients, whereas others found no benefit. This review intends to make recommendations for the use of dietary fiber in cancer care.

Dietary Fiber Role in Prevention of Cancer

There is a strong correlation between dietary factors and the rise in tumor incidence. Though the results have been inconclusive, numerous researchers have conducted extensive studies in recent years to examine if dietary fiber intake can improve prognosis and prevent cancers. Here, we compiled and analyzed the pertinent publications from our literature search in popular academic databases. It is abundantly evident from the literature that dietary fiber can provide protection against colorectal, breast, ovarian, pancreatic, and bladder cancers. Although the evidence is still quite little, there is also evidence that dietary fiber intake can protect against lymphoma and malignancies of the liver, lung, stomach, kidney, and esophagus. There is still uncertainty regarding the impact on prostate and endometrial cancers (Xie et al., 2020).

Colorectal cancer

One of the main causes of cancer-related mortality in developed countries is colorectal cancer (CRC). Dietary fiber deficiency is prevalent in Western diets and is associated with a higher risk of colorectal cancer. Fiber consumption and the incidence of colorectal cancer are inversely correlated, according to epidemiological research. Fiber may be rich in antioxidants (such as resveratrol and polyphenols), change the metabolism of bile acids (which can encourage carcinogenesis), be fermented by the gut microbiota to produce butyrate (which has anti-proliferative effects), and change the composition of the gut microbiota, all of which can affect the risk of colorectal cancer (CRC) (Celiberto et al., 2023).

Strong evidence that dietary fiber is protective against colon cancer was presented by Gianfredi et al. (2018) in their comprehensive review and meta-analysis. The risk of colon cancer was 26% lower for those who consumed the most fiber than for those who consumed the least. Improved intestinal transit time, less contact between carcinogens and the intestinal lining, and the synthesis of short-chain fatty acids with anti-inflammatory and anti-carcinogenic qualities, such as butyrate, are probably the causes of the protective effect (Gianfredi et al., 2018).

According to a comprehensive review and meta-analysis of 25 prospective studies, the incidence of colorectal cancer is dramatically decreased for every 10g/day increase in dietary fiber, particularly from cereals and whole grains (Aune et al., 2011). To assess the effects of dietary fiber from cereal, vegetable, fruit, and legume sources on the risk of colorectal cancer (CRC) and colorectal adenomas, a dose-response meta-analysis of ten prospective cohort studies was conducted. Cereal fiber was found to have the largest negative correlation with the incidence of colorectal cancer, followed by fruit and vegetable fiber (Oh et al., 2019).

Higher consumption of total dietary fiber, particularly from cereals and whole grains, is consistently linked to a lower risk of colorectal cancer, even if not all forms of fiber are similarly beneficial. Cereal fiber has the strongest evidence, and its mechanisms include better intestinal transit, anti-inflammatory benefits, and microbiota modification.

Breast cancer

In 2020, breast cancer (BC) was the second most common cause of cancer worldwide and the first in women, with an age-standardized incidence of 47.8 per 100,000. BC places a significant financial strain on the health care system (Zademohammadi et al., 2024). Some research has looked at the relationship between the risk of breast cancer (BC) and the types and sources of dietary fiber. An 8% decreased risk of breast cancer was linked to a high total fiber intake, according to a Systematic Review and Meta-Analysis of 17 cohort studies, 2 nested case-control studies, and 1 therapeutic intervention. The inverse relationship between soluble and insoluble fibers was stronger for the former. For both premenopausal and postmenopausal women, protective effects were identified (Farvid et al., 2020).

Total fiber, insoluble fiber, and fruit and vegetable fiber intake were found to significantly correlate negatively with breast cancer risk in a case-control research that included 464 breast cancer patients and 498 healthy controls. It is noteworthy that cereal fiber decreased risk in postmenopausal women but raised risk in premenopausal women (Zademohammadi et al., 2024). A review found a positive correlation between gut microbiota modification, dietary fiber, and better health outcomes for breast cancer survivors. The gut microbiota is essential for controlling inflammation, immunology, and estrogen metabolism, all of which are related to the development and recurrence of breast cancer. As a substrate for microbial fermentation, fiber yields short-chain fatty acids (SCFAs) with anti-inflammatory and anti-carcinogenic qualities, such as butyrate. In breast cancer

survivors, higher fiber consumption is linked to better immunological function, metabolic health, and decreased systemic inflammation (Samami et al., 2025).

The incidence of breast cancer is inversely correlated with dietary fiber intake, especially at higher intake levels (≥25g/day), according to a meta-analysis of prospective studies. A 5% decrease in the incidence of breast cancer was linked to every 10g/day increase in total fiber consumption. According to the research, eating more fiber could be a good way to prevent breast cancer (Aune et al., 2012). There is a strong negative correlation between dietary fiber consumption and the risk of breast cancer, especially in postmenopausal women, according to a systematic review and meta-analysis of 24 epidemiological studies (including prospective and case-control). An increased consumption of dietary fiber was linked to a 12% decreased risk of breast cancer. A 4% decrease in risk was seen with every 10g/day increase in fiber intake, according to dose-response analysis. Postmenopausal women also showed a stronger protective effect. The results support the notion that dietary fiber may be protective in methods to prevent breast cancer (Chen et al., 2016).

Ovarian cancer

A meta-analysis of 567,742 participants and 8,200 ovarian cancer cases found that increasing TDF consumption is associated with a lower risk of ovarian cancer. Specifically, those who consumed the greatest dietary fiber had a significant risk reduction compared to those who consumed the least. Furthermore, the dose-response analysis revealed that each extra 5 g/day of dietary fiber intake resulted with a 3% reduction in ovarian cancer risk (Xu et al., 2018).

Prostate cancer

A systematic analysis of five cohort studies and 12 case-control studies, totaling 255,026 individuals and 13,484 cases, looked into the link between dietary fiber consumption and prostate cancer. The study found an inverse connection between high and low TDF intake and the incidence of prostate cancer (Sheng et al., 2015).

Liver cancer

In 2020, liver cancer is the sixth most commonly diagnosed cancer and the third largest cause of cancer-related mortality worldwide. The global incidence and mortality rate of liver cancer have been increasing over the last decade, with more than 900,000 new cases identified and more than 800,000 cancer deaths each year. Furthermore, liver cancer is the most frequent malignancy in 11 geographically varied countries located in Eastern Asia, South-East Asia, and Northern and Western Africa.

Higher consumption of whole grains and dietary fiber significantly decreased the risk of liver cancer (Hazard ratio = 0.69), as well as the mortality rate from chronic liver disease (Hazard ratio = 0.37), according to a study based on the NIH-AARP (National Institutes of Health-American Association of Retired Persons) Diet and Health Study cohort (485,717 participants). Fiber derived from cereals, beans, and vegetables had the strongest protective effects. Reduced incidence of liver cancer and mortality from chronic liver disease is substantially correlated with higher consumption of whole grains and dietary fiber. These results provide credence to the idea that dietary fiber may help protect liver health (Liu et al., 2021).

According to a meta-analysis of 27 observational studies, the incidence of liver cancer was inversely correlated with whole grains (RR = 0.66) and legumes (RR = 0.86). According to dose-response research, for every 50g/day increase in whole grain intake, the risk was lowered by 23%. Legumes and whole grains are strongly linked to a lower risk of liver cancer, whereas the effects of other food groups are either neutral or unclear. According to Liu et al. (2023), the study highlights the significance of plant-based dietary patterns in preventing liver cancer and urges more research in a variety of demographics.

A study compiled the data relating the risk of liver cancer to dietary habits and particular nutrients. Dietary fiber, coffee, seafood, and tea have all been shown to lower the incidence of liver cancer. However, exposure to aflatoxin, excessive alcohol use, and potentially non-yogurt dairy items raised the risk. Red and processed meats, sugary drinks, and refined grains were found to have unclear or mixed evidence. Although there are still gaps, the research currently available suggests that food has a significant role in preventing liver cancer. Particularly in high-risk groups, a focus on plant-based diets, moderate alcohol consumption, and anti-inflammatory substances may help lower risk (Yang et al., 2020).

A meta-analysis of prospective trials demonstrated that a higher consumption of dietary fiber and whole grains was significantly linked to a lower risk of liver cancer in two sizable U.S. cohorts. Fiber promotes the integrity of the intestinal barrier, lowers systemic inflammation, and increases insulin sensitivity. Antioxidants, vitamins, and fermentable fibers found in whole grains support a balanced gut flora. Cereal fiber and whole grain diet showed the largest protective effects, confirming their significance in preventing liver cancer through their anti-inflammatory and metabolic advantages (Watling et al., 2024).

Pancreatic cancer

Pancreatic cancer is one of the worst prognoses of any cancer, with a 5-year survival rate of about 5% and a high case fatality rate. A meta-analysis and systematic review of 18 observational studies (both cohort and case-control) was conducted to determine whether dietary fiber consumption is linked to a lower risk of pancreatic cancer. Consuming more fiber was substantially linked to a decreased risk of pancreatic cancer. In women, the protective impact was particularly robust, reducing risk by as much as 60%. The effects of case-control studies were more noticeable than those of cohort studies. According to the study's findings, eating more dietary fiber, particularly from whole foods, may lower the incidence of pancreatic cancer by improving insulin sensitivity, expanding gut microbiota, and possibly having anti-inflammatory effects (Nucci et al., 2021).

Ibrahim et al. (2023) investigated the relationship between different dietary patterns and nutrients and the risk of pancreatic cancer (PC) by reviewing observational studies, systematic reviews, and meta-analyses published between 1985 and 2022. Inflammation, insulin resistance, and oxidative stress—all major causes of pancreatic cancer—are associated with the western diet, which is heavy in red and processed meats, refined grains, sweets, and saturated fats and low in fruits, vegetables, and fiber. Micronutrients (Vitamins C, E, D, folate, magnesium, and selenium), dietary fiber, antioxidants, and plant-based diets (high in fruits, vegetables, legumes, and whole grains) all contribute to improved metabolic health and a decrease in inflammation. The risk of pancreatic cancer may be considerably reduced by implementing a plant-forward, nutrient-rich diet (Ibrahim et al., 2023).

Esophageal cancer

Dietary fiber intake and the risk of Barrett's esophagus (BE) and esophageal cancer (EC) were evaluated by a meta-analysis of 15 observational studies with 16,885 participants. A 31% decrease in risk was linked to every 10g/day increase in dietary fiber. The study offers compelling evidence that the risk of Barrett's esophagus and esophageal cancer is negatively correlated with dietary fiber consumption. Reduced exposure to carcinogens through enhanced gut motility, the anti-inflammatory properties of fiber fermentation products (like butyrate), and immune response and gut microbiota regulation are probably some of the protective mechanisms (Sun et al., 2018).

To assess the relationship between dietary fiber consumption and the risk of esophageal cancer and its precursors, including Barrett's esophagus and esophageal adenocarcinoma (EA), a systematic review and meta-analysis of ten case-control studies was conducted. The review demonstrates that dietary fiber protects against the development of esophageal cancer, particularly adenocarcinoma and Barrett's esophagus, its precursor. Weight control, metabolic regulation, anti-inflammatory and antioxidant benefits, and a decrease in gastric reflux are some of the hypothesized processes. Fiber-rich diets, particularly those rich in fruits, vegetables, and whole grains, may help prevent esophageal cancer, according to one study (Coleman et al., 2013).

Gastric cancer

A higher intake of TDF significantly reduces the incidence of stomach cancer. In Zhang's study, the risk of gastric cancer was considerably lower for those who consumed the most TDF than for those who consumed the least. Additionally, a dose-response relationship analysis showed that the incidence of gastric cancer decreased with every 10 g/day increase in dietary fiber consumption (Zhang et al., 2013).

To investigate the relationship between particular dietary practices and nutrients and the risk of stomach cancer. excessive consumption of red and processed meats, alcohol, nitrates and nitrites, and foods that have been salted, smoked, or pickled. These foods raise the risk of cancer and harm the stomach mucosa, particularly when paired with Helicobacter pylori infection. Probiotics and prebiotics, green tea, resveratrol, and vitamins C, E, and D are all beneficial dietary components. These nutrients may provide protection against stomach cancer by lowering oxidative stress, inflammation, and DNA damage. This review made clear how important nutrition is in causing and avoiding stomach cancer. Risk may be considerably decreased by moving away from processed, high-sodium diets and toward plant-based, antioxidant-rich foods (Richa et al., 2022).

Bladder cancer

The association between dietary fiber intake and bladder cancer was examined in a study that included 3,214 cases and 574,726 subjects. The findings indicated that, in comparison to the lowest consumption, the highest TDF consumption was associated with a decreased incidence of bladder cancer. Additionally, each extra 5 g/day of dietary fiber consumption was linked to a lower risk of bladder cancer, according to dose-response analysis (Evan et al., 2020).

Protective Role of Dietary Fiber in Cancer Prevention: Evidence from Umbrella Reviews and Meta-Analyses

Higher dietary fiber consumption is generally protective against a variety of cancer types, particularly those of the digestive and reproductive systems, according to an umbrella review of meta-analyses. The evidence for fiber's significance in preventing cancer is strong, but further high-quality research is required (Hu et al., 2023). Through indirect but potent processes, dietary fiber supplementation can have a favorable effect on tumors outside of the gastrointestinal tract, including breast, lung, and melanoma. Short-chain fatty acids (SCFAs), such as butyrate, are produced in greater quantities when fiber changes the gut microbiota. These SCFAs circulate throughout the body and have anti-inflammatory, immune-boosting, and metabolic-regulating properties. Even in tumors that are far from the gut, these modifications can improve tumor management, boost immunotherapy responses, and lessen side effects from treatment (Asim et al., 2023).

In order to assess the relationship between dietary fiber consumption and lowering the risk of developing certain cancer types, an umbrella review of 19 meta-analyses was conducted. Reduced risk of colon, breast, esophageal, endometrial, and pancreatic cancers has been consistently linked to high dietary fiber consumption. The evaluation discovered that the majority of the included studies showed statistically significant inverse relationships between fiber consumption and cancer risk. The strongest evidence was for colorectal cancer, where consumption levels and fiber types were associated with risk reductions of 10% to 30%. Thus, McRae's (2018) assessment backed up the finding that dietary fiber protects against a variety of cancers, with colorectal cancer showing the strongest evidence. The results support the public health advice to consume more whole grains, fruits, vegetables, and legumes to boost fiber intake (McRae et al., 2018).

II. Conclusion

The evidence presented in this study substantially supports the significance of dietary fiber as a preventive factor against a variety of cancers, notably those affecting the digestive and reproductive systems. High fiber consumption, particularly from whole grains, fruits, vegetables, and legumes, is consistently linked to a lower risk of colorectal, breast, pancreatic, esophageal, gastric, ovarian, and bladder cancer. Emerging data also point to possible benefits for liver, lung, and melanoma tumors via indirect mechanisms such as gut microbiota modification, anti-inflammatory short-chain fatty acid synthesis, and enhanced metabolic and immunological response. The strongest results relate to colorectal cancer, where fiber consumption demonstrates dose-dependent risk decreases, though the quality of the evidence differs throughout cancer types. Increasing dietary fiber is a low-cost, easily accessible cancer prevention method, according to the body of research, despite significant discrepancies and research gaps. As part of comprehensive cancer prevention efforts, public health campaigns should place a high priority on diets high in fiber. Additionally, more high-quality research is required to elucidate the function of fiber in less-studied cancers and optimize dietary recommendations.

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