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COMPARATIVE ANALYSIS OF ANTIOXIDANT CAPACITY AND PHYTOCHEMICAL COMPOSITION IN PLANT AND ANIMAL BASED FOODS

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ABSTRACT

Antioxidants play a crucial role in reducing oxidative stress by neutralizing free radicals, thereby protecting cellular components and maintaining overall health. Dietary antioxidants are primarily obtained from plant-based foods. The present study aimed to comparatively evaluate the antioxidant capacity of selected plant-based (vegan) and animal-based (non-vegan) foods using the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay. Quantitative assessment of antioxidant compounds was executed using a spectrophotometric method. Methanolic extracts of selected vegan foods, including fruit pulp of *Syzygium cumini* (jamun), whole grain of *Pennisetum glaucum* (bajra), seeds of *Glycine max* (soybean) and polished grain of *Oryza sativa* (rice), as well as non-vegan foods such as muscle tissue of *Catla catla* (fish), muscle tissue of *Gallus gallus domesticus* (chicken), whole milk and a milk-based probiotic drink, were prepared and analyzed. The DPPH assay demonstrated that *Syzygium cumini* depicted the highest radical scavenging activity with 95.54% inhibition at 100 µL. *Glycine max* and *Pennisetum glaucum* also showed strong antioxidant potential, whereas rice displayed comparatively lower activity among the vegan samples. Among the non-vegan foods, chicken and fish exhibited moderate inhibition (approximately 77–88%), while milk and the probiotic drink showed relatively lower antioxidant activity. Overall, the results indicate that plant-based foods possess greater antioxidant diversity and stronger radical scavenging potential compared to the animal-derived foods examined. These findings underscore the nutritional importance of plant-based foods and demonstrate the effectiveness of spectrophotometric techniques for antioxidant screening, while highlighting the need for complementary assays to fully characterize antioxidant capacity.

Key words : Antioxidant activity, Plant-based foods, Animal-based foods, Phenolic compounds, Flavonoids.

Introduction

In recent decades, the increasing prevalence of chronic diseases has intensified scientific interest in the role of diet as a preventive and therapeutic strategy. At the cellular level, health depends on a delicate balance between pro-oxidants and antioxidants. However, this balance can be disrupted by endogenous metabolic processes as well as environmental factors such as pollution, radiation and ultraviolet (UV) exposure, resulting in oxidative stress.

Oxidative stress arises due to the excessive production of highly reactive molecules known as free

radicals. Among these, Reactive Oxygen Species (ROS) represent a major group that includes superoxide radicals (O_2^-), hydrogen peroxide (H_2O_2), peroxy radicals ($ROO\cdot$) and hydroxyl radicals ($\cdot OH$). Although ROS play essential roles in cellular signaling and immune responses at low concentrations, their excessive accumulation can lead to severe cellular damage.

These reactive molecules can attack essential biological macromolecules such as DNA, proteins and lipids, thereby contributing to inflammation, aging and the development of various diseases including neurodegenerative disorders, cardiovascular diseases, cancer, and diabetes. Antioxidants are bioactive

compounds capable of neutralizing free radicals by donating hydrogen atoms or electrons, thereby suppressing oxidative damage and maintaining cellular homeostasis.

Dietary intake is one of the primary sources of antioxidants. Plant-based foods, including fruits, vegetables, legumes and whole grains, are rich in natural antioxidants such as vitamin C, vitamin E, carotenoids, polyphenols, and flavonoids. These compounds exhibit strong free radical scavenging properties and play important roles in protecting the body against oxidative stress. *Syzygium cumini* has been extensively studied showing strong DPPH radical scavenging activity (Septiani *et al.*, 2018). Its high antioxidant capacity is attributed due to rich phenolic and flavonoid content including gallic acid, catechin, caffeic acid, and anthocyanins with varying potency in regards to the plant part used such as seed, pulp, leaf, bark and extraction solvent (Ahmed *et al.*, 2021; Aqil *et al.*, 2012; Hussain *et al.*, 2015). Cereals and legumes such as *Oryza sativa*, *Triticum* sp., *Glycine max* and *Pennisetum glaucum* have also demonstrated measurable DPPH scavenging activity and improved oxidative stability in food matrices with respect to the extraction solvent and the plant part used (Yogesh *et al.*, 2014).

Consequently, dietary patterns that emphasize plant-based foods, such as vegan diets, are often considered beneficial for improving antioxidant intake. In contrast, animal-derived foods such as meat, fish, and dairy products are not traditionally regarded as major antioxidant sources but they contain antioxidants primarily in the form of vitamins (A, E), minerals (selenium, zinc), and bioactive peptides. However, the antioxidant capacity of animal-derived foods is generally lower than that of plant-based foods rich in polyphenols. Milk contains antioxidant proteins and peptides, while muscle tissues (fish, chicken) contain carnosine, anserine, and other histidine-containing dipeptides with antioxidant properties. Direct comparative studies between plant-based and animal-based whole foods for antioxidant capacity are limited in the literature.

Despite increasing interest in dietary antioxidants, limited experimental studies have directly compared the antioxidant potential of commonly consumed vegan and non-vegan foods using standardized biochemical assays. Therefore, the present study aimed to evaluate and compare the antioxidant capacity of selected vegan and non-vegan food samples using the DPPH radical scavenging assay.

The findings of this study provide insights into the comparative antioxidant potential of plant-based and animal-derived foods and contribute to the understanding

of dietary antioxidant sources and their implications for human health.

Materials and Methods

Sample collection

All food samples used in this study were procured from local commercial sources in Delhi, India. The selected vegan samples included fruits of *Syzygium cumini* (jamun), grains of *Pennisetum glaucum* (bajra), seeds of *Glycine max* (soybean), and grains of *Oryza sativa* (rice). The non-vegan samples comprised fish (*Catla catla*), chicken (*Gallus domesticus*), pasteurized milk, and a commercially available probiotic drink. All samples were transported to the laboratory under hygienic conditions and stored at 4°C until further processing. Sample preparation and extraction were performed within 24 hours of collection to minimize degradation of antioxidant compounds.

Determination of Antioxidant activity and Phytochemical contents

DPPH Radical Scavenging assay

The free radical scavenging activity of the extracts was estimated using the DPPH (2,2-diphenyl-1-picrylhydrazyl) assay following the method of Blois (1958) with slight modifications, as adapted in recent study (Shahidi and Ambigaipalan, 2015). Briefly, a 0.1 mM DPPH solution was prepared in methanol. An aliquot of 1 mL of the sample extract was mixed with 3 mL of DPPH solution and incubated in the dark at room temperature for 30 min. The absorbance was recorded at 517 nm using a UV–Vis spectrophotometer against a methanol blank. A control containing DPPH solution without extract was used. The radical scavenging activity was expressed as percentage inhibition using the formula:

$$\% \text{ inhibition} = \frac{A_c - A_s}{A_c} \times 100$$

where, A_c is the absorbance of the control and A_s is the absorbance of the sample.

Total Phenolic Content (TPC)

The total phenolic content of the extracts was determined using the Folin–Ciocalteu method as described by Singleton and Rossi (1965), with modifications reported in recent study (Domínguez-Rodríguez *et al.*, 2017). Briefly, 0.5 mL of the extract was mixed with 2.5 mL of 10% (v/v) Folin–Ciocalteu reagent and allowed to react for 5 min. Subsequently, 2 mL of 7.5% (w/v) sodium carbonate solution was added, and the mixture was incubated at room temperature for 30 min. The

absorbance was measured at 765 nm. Gallic acid was used as a standard and the results were expressed as mg gallic acid equivalents (GAE) per gram of sample.

Total Flavonoid Content (TFC)

Total flavonoid content was determined following the method of Zhishen *et al.* (1999) with slight modifications. Briefly, 0.2 g of fresh sample tissue was homogenized in hot double distilled water (DDW) and centrifuged to obtain a clear supernatant. An aliquot of the extract was mixed with 5% (w/v) sodium nitrite (NaNO_2) and allowed to stand for 5 min. Subsequently, 10% (w/v) aluminum chloride (AlCl_3) was added and incubated for 6 min. Thereafter, 1 M sodium hydroxide (NaOH) was added, and the reaction mixture was allowed to stand for 15 min for color development. The absorbance was measured at 510 nm using a UV–Vis spectrophotometer against an appropriate blank. Total flavonoid content was calculated using a quercetin standard curve and expressed as mg quercetin equivalents (QE) per gram of fresh weight (FW).

Total Anthocyanin Content (TAC)

Total anthocyanin content was determined following the method of Fuleki and Francis (1968) with slight modifications. Briefly, 0.2 g of fresh sample tissue was homogenized in 2 mL of acidified ethanol (ethanol containing 1% HCl, v/v). The homogenate was centrifuged at 10,000 rpm for 10 min, and the supernatant was collected. The absorbance of the extract was measured at 535 nm using a UV–Vis spectrophotometer against acidified ethanol as a blank. Total anthocyanin content was calculated using an appropriate extinction coefficient and expressed as mg cyanidin-3-glucoside equivalents per gram of fresh weight (FW).

Statistical analysis

All experiments were conducted using three independent replicates and repeated twice to ensure reproducibility. The data were expressed as mean $\pm$ standard deviation (SD). Statistical analysis was performed using analysis of variance (ANOVA) to determine significant differences among treatments at a significance level of $p \leq 0.05$. Tukey's multiple comparison test was applied for post hoc analysis to evaluate differences between samples. All analyses were carried out using GraphPad Prism version 8.0.

Results

DPPH Radical Scavenging activity

The antioxidant potential of different food samples was evaluated using the DPPH radical scavenging assay at varying sample volumes (20–100 μL) (Fig. 1). A

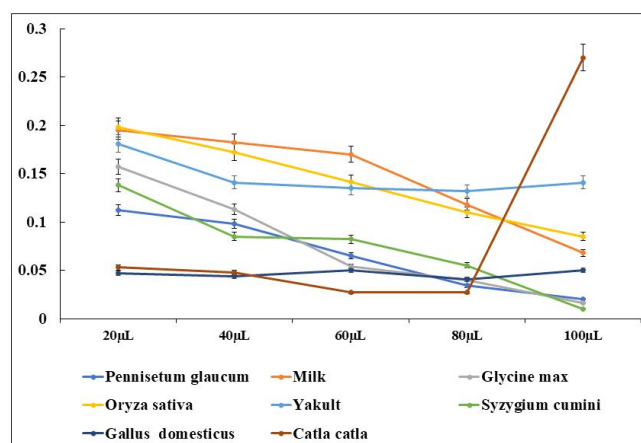


Fig. 1 : DPPH radical scavenging assay at 20–100 μL .

general decline in absorbance was observed with increasing sample concentration, indicating enhanced free radical scavenging activity. Among the tested samples, *Syzygium cumini* exhibited the strongest antioxidant activity, with absorbance decreasing from 0.138 at 20 μL to 0.01 at 100 μL , suggesting efficient quenching of DPPH radicals. *Pennisetum glaucum* also demonstrated substantial antioxidant potential, showing a marked reduction in absorbance from 0.112 at 20 μL to 0.02 at 100 μL .

Soybean extracts exhibited pronounced concentration-dependent scavenging activity, with absorbance values decreasing from 0.157 at 20 μL to 0.03 at 100 μL . Rice showed moderate antioxidant activity, with absorbance declining from 0.198 at 20 μL to 0.075 at 100 μL . The probiotic drink displayed moderate DPPH scavenging activity, with absorbance decreasing from 0.181 at 20 μL to 0.132 at 80 μL . Similarly, milk showed a reduction in absorbance from 0.195 at 20 μL to 0.068 at 80 μL , indicating moderate antioxidant potential.

In contrast, chicken and fish samples exhibited relatively low antioxidant activity, as reflected by their consistently low changes in absorbance values across the tested concentrations. Chicken absorbance remained between 0.041 and 0.050, while fish absorbance decreased from 0.053 at 20 μL to 0.027 at 80 μL .

Total Phenolic, flavonoid and Anthocyanin Contents of selected Food samples

The total phenolic, flavonoid and anthocyanin contents varied considerably among the analyzed food samples (Fig. 2). Among all samples, *Syzygium cumini* (Jamun) exhibited the highest levels of total phenolics (711.7 mg GAE/g), total flavonoids (26.66 mg QE/g), and total anthocyanins (32.86 mg C3G/g), indicating its rich antioxidant phytochemical composition. Among the cereal grains, *Pennisetum glaucum* and *Oryza sativa* showed

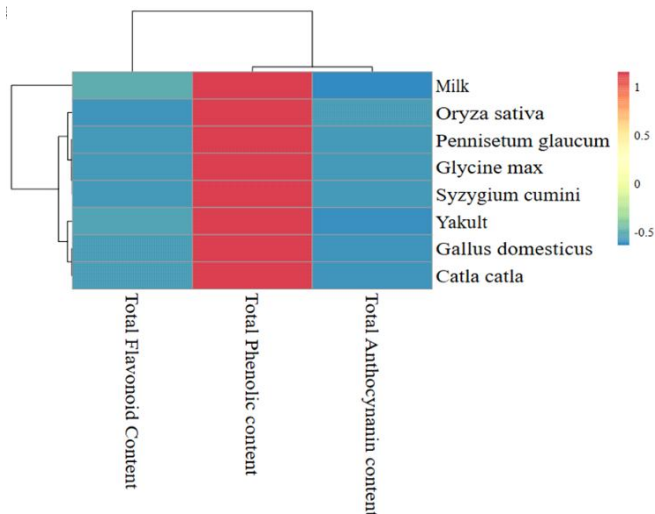


Fig. 2 : Total phenolic, flavonoid and anthocyanin content among the analyzed food samples.

substantial phenolic contents of 519.77 mg GAE/g and 412.47 mg GAE/g, respectively. Similarly, *Glycine max* contained a high phenolic content (494.07 mg GAE/g) along with appreciable flavonoid (13.73 mg QE/g) and anthocyanin (16.9 mg C3G/g) levels. Bajra also exhibited elevated flavonoid (17.5 mg QE/g) and anthocyanin (17.2 mg C3G/g) contents compared with the other cereal samples. Milk and milk-based probiotic drink contained comparatively lower amounts of phenolics and flavonoids, with anthocyanins being undetectable in both samples. Specifically, milk recorded phenolic and flavonoid contents of 15.64 mg QE/g and 1.10 mg QE/g, respectively, whereas milk-based probiotic drink showed the lowest phenolic content (6.7 mg GAE/g) among all analyzed samples.

Animal-derived samples exhibited relatively low concentrations of antioxidant phytochemicals. *Gallus domesticus* (chicken) contained phenolic and flavonoid contents of 11.4 mg GAE/g and 0.13 mg QE/g, respectively, while *Catla catla* (fish) showed values of 35.7 mg GAE/g and 0.65 mg QE/g, respectively. Anthocyanins were not detected in either sample.

Principal component analysis of Antioxidant activity and Phytochemical composition

The PCA biplot explained 97.79% of the total variation, with PC1 accounting for 84.7% and PC2 accounting for 13.09% of the variance (Fig. 3). The variables total phenolic content, total flavonoid content, and total anthocyanin content were positively associated with each other, as indicated by their close clustering and similar vector directions. These phytochemical parameters were positively correlated with *Pennisetum glaucum*, *Glycine max* and *Gallus domesticus*, which

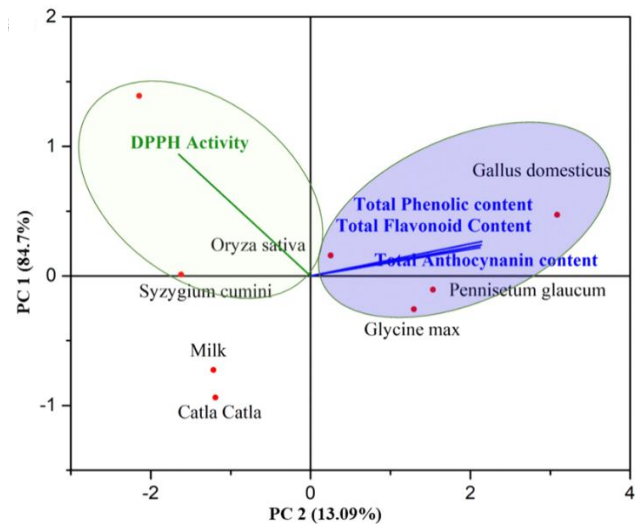


Fig. 3 : Principal component analysis biplot showing associations among DPPH antioxidant activity, total phenolic content, total flavonoid content and total anthocyanin content in selected food samples. PC1 and PC2 explained 84.70% and 13.09% of the total variance, respectively. Samples were grouped according to similarities in antioxidant and phytochemical profiles.

were positioned on the positive side of PC2. In contrast, DPPH activity was oriented in the opposite direction to TPC, TFC and TAC, indicating a negative relationship between antioxidant activity and phytochemical contents. *Syzygium cumini* (jamun) and *Oryza sativa* (rice) were closely associated with DPPH activity and were separated from the phytochemical-rich group along PC2. Milk and *Catla catla* (fish) were located in the negative region of both principal components, indicating comparatively low contributions from both antioxidant activity and phytochemical parameters.

Discussion

The present study demonstrated significant variation in antioxidant activity and phytochemical composition among plant and animal-derived foods. Overall, plant-based samples exhibited greater antioxidant potential and higher concentrations of phenolic, flavonoid, and anthocyanin compounds than animal-derived foods, highlighting the importance of plant foods as major dietary sources of natural antioxidants.

Among all tested samples, *Syzygium cumini* exhibited the strongest DPPH radical scavenging activity together with the highest total phenolic, flavonoid, and anthocyanin contents. These findings are consistent with previous reports describing jamun as a phytochemical-rich fruit containing anthocyanins, ellagic acid, gallic acid, quercetin, myricetin, and numerous polyphenolic compounds that contribute to its exceptional antioxidant properties though

values vary widely depending on plant part, solvent and extraction conditions (Ahmed *et al.*, 2021; Priya *et al.*, 2017). Jamun anthocyanins have been reported to possess strong free-radical scavenging activity and play important roles in mitigating oxidative stress-related disorders. The remarkably high antioxidant activity observed in the present study might appear to be a direct consequence of the elevated accumulation of these bioactive metabolites. Furthermore, recent reviews have highlighted that the antioxidant potential of *S. cumini* is largely driven by its high anthocyanin and total phenolic content, supporting the strong DPPH inhibition observed in our investigation (Jinjiri *et al.*, 2025; Chhikara *et al.*, 2018).

Pennisetum glaucum and *Glycine max* also displayed substantial antioxidant activity accompanied by elevated levels of phenolics and flavonoids. Pearl millet is recognized as a functional cereal rich in phenolic acids, including ferulic acid, caffeic acid and p-coumaric acid, which act as efficient hydrogen donors and radical scavengers. Similarly, soybean contains abundant isoflavones, particularly genistein and daidzein, which have been extensively associated with antioxidant, anti-inflammatory, and health-promoting effects. The high antioxidant activities of bajra and soybean observed in this study therefore likely reflect the cumulative effects of these phytochemical constituents (Chandrasekara and Shahidi, 2011; Patel, 2023). The close association of these crops with phenolic and flavonoid accumulation further emphasizes their nutritional significance as functional foods capable of reducing oxidative stress.

Although, *Oryza sativa* contained appreciable phenolic content and moderate antioxidant activity, its radical scavenging potential was lower than that of jamun, bajra and soybean (de mira *et al.*, 2009). Polished rice has reduced antioxidant content compared to whole grains, as many antioxidant compounds are concentrated in the bran and germ layers that are removed during milling. This observation suggests that antioxidant activity depends not only on the total quantity of phenolic compounds but also on their structural diversity, redox properties, and synergistic interactions. Different phenolic compounds possess varying capacities to donate electrons and stabilize free radicals; consequently, foods with similar phenolic concentrations may exhibit markedly different antioxidant activities.

In contrast to plant-derived foods, milk, probiotic drink, chicken and fish exhibited comparatively lower antioxidant activities and phytochemical contents (Virtanen *et al.*, 2007; Centenaro *et al.*, 2014). These findings are

expected because phenolics, flavonoids and anthocyanins are synthesized predominantly through plant secondary metabolic pathways and are generally absent or present only in trace amounts in animal-derived products. Nevertheless, the moderate antioxidant activity observed in fish and chicken may arise from antioxidant peptides, amino acids, vitamins, and trace minerals generated during metabolism or protein degradation. The relatively low antioxidant activity observed in milk and probiotic drink may similarly be attributed to the presence of bioactive peptides and microbial metabolites rather than polyphenolic compounds.

The phytochemical analysis further supported the DPPH results. Jamun possessed the highest total phenolic, flavonoid, and anthocyanin contents, whereas milk, milk based probiotic drink, chicken and fish contained substantially lower concentrations. Phenolic compounds are widely regarded as one of the most important classes of natural antioxidants because they can effectively donate hydrogen atoms or electrons to neutralize reactive oxygen species. Flavonoids additionally contribute through radical scavenging and metal-chelating mechanisms, while anthocyanins provide strong antioxidant protection owing to their conjugated aromatic structures. Previous studies have consistently demonstrated positive relationships between total phenolic content and antioxidant activity in fruits, cereals, and legumes, suggesting that phenolics are major contributors to free-radical scavenging potential (Nayak *et al.*, 2025; Shahidi and Ambigaipalan, 2015).

Principal component analysis provided further insight into the relationships among antioxidant activity and phytochemical traits. The first two principal components explained 97.79% of the total variation, indicating that the measured variables effectively captured the biochemical diversity of the analyzed foods. The close clustering of total phenolics, flavonoids, and anthocyanins revealed strong positive correlations among these variables, suggesting coordinated accumulation of antioxidant phytochemicals within plant tissues. Such relationships have frequently been reported in phytochemical studies, where phenolic-rich foods often exhibit elevated flavonoid and anthocyanin concentrations (Cruz-Carrión *et al.*, 2023).

Interestingly, DPPH activity appeared opposite to the phytochemical vectors in the PCA biplot. This pattern is likely related to the use of DPPH absorbance values rather than percentage inhibition. Because lower absorbance values correspond to greater radical scavenging activity, samples exhibiting stronger antioxidant activity become separated from those with higher absorbance values.

Consequently, the negative orientation observed in the PCA should not be interpreted as evidence that phenolics reduce antioxidant activity. Rather, it reflects the inverse mathematical relationship between DPPH absorbance and antioxidant capacity. This interpretation is supported by the biochemical results, which clearly demonstrate that jamun simultaneously possessed the highest phytochemical concentrations and the strongest radical scavenging activity.

The PCA further distinguished two major groups of samples. The first group, represented primarily by bajra and soybean, was characterized by high phenolic, flavonoid, and anthocyanin contents. The second group, represented by jamun and rice, was associated with antioxidant activity. Milk and fish occupied the negative region of both principal components, reflecting their comparatively lower phytochemical abundance and antioxidant potential. These separations demonstrate that food origin strongly influences antioxidant composition and activity.

Collectively, the findings of this study indicate that plant-derived foods are substantially richer sources of antioxidant phytochemicals than animal-derived foods. In particular, *Syzygium cumini*, *Pennisetum glaucum*, and *Glycine max* emerged as valuable dietary sources of phenolics, flavonoids, and anthocyanins with strong free-radical scavenging potential. The strong antioxidant capacity observed in these foods supports their inclusion in functional diets aimed at reducing oxidative stress and lowering the risk of chronic diseases associated with reactive oxygen species. Furthermore, the integration of DPPH assays, phytochemical quantification, and multivariate statistical analysis provides a comprehensive framework for evaluating the nutritional and functional properties of food systems.

Conclusion

The present study revealed significant differences in antioxidant activity and phytochemical composition between plant-based and animal-derived foods. Among all samples, *Syzygium cumini* exhibited the highest DPPH radical scavenging activity along with the greatest concentrations of total phenolics, flavonoids, and anthocyanins, highlighting its exceptional antioxidant potential. *Pennisetum glaucum* and *Glycine max* also demonstrated strong antioxidant activities, attributable to their rich phytochemical profiles. In contrast, milk, probiotic drink, chicken and fish contained comparatively lower levels of antioxidant compounds and exhibited reduced antioxidant capacity. Principal component analysis further confirmed the close association between

phytochemical accumulation and antioxidant potential, clearly distinguishing plant-derived foods from animal-derived samples. Overall, the findings indicate that plant-based foods are superior sources of natural antioxidants and bioactive phytochemicals. The study emphasizes the nutritional importance of incorporating phytochemical-rich foods into the diet to combat oxidative stress and promote long-term health benefits.

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Competing interests

The authors have no relevant financial or non-financial interests to disclose.

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