From Leaf to Cup: Forces Behind Tea-Based Radical Innovations in Sri Lanka

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Abstract. Proven health benefits on tea (Camellia sinensis) directed many developed countries to produce tea-based innovations in commercial scale. Majority of tea producing countries including Sri Lanka retain only as a bulk tea supplier receiving lower gains from tea export. Objectives of the study were to 1) examine if producing tea-based radical innovations can have a significant impact on firm performance and 2) identify the determinants of producing tea-based radical innovations in Sri Lanka. A questionnaire survey was conducted for 43 exporters out of 180 exporters in Sri Lanka. Mann-Whitney U test, Principal Components Analysis and Generalized Linear Model were employed to analyze data. Results revealed that radical innovations contribute significantly on firm performance (sales gain). With respect to determinants, 1) firm strategy (no. of food technologists, no. of market destinations, no. of CIM/CIMA qualified employees): 2. firm resources (direct links to plantations and processing factories); and 3) CEO's science and technology qualifications have significant positive impact on producing radical innovations. Firm size has a significant negative impact on producing radical innovations.

Keywords: Tea (*Camellia sinensis*), Radical innovations, Incremental innovations, Value-addition, Sri Lanka

1 Introduction

Scientific evidence that shows the anti-viral, anti-carcinogenic and anti-diabetic properties in tea (*Camellia sinensis*) due to the presence of high levels of antioxidants have been around for a long time (Kumar et al., 2025). The major tea producing countries including Sri Lanka have appreciated the increased attention to these properties as the Covid-19 pandemic has boosted demand for tea from importing countries.

In 2024, Sri Lanka was the fourth largest tea exporter in the world, accounting for 12% of total global tea exports (International Trade Centre, 2025). The country mainly exports black tea as a primary processed product in bulk form. Almost 57% of the tea exported in 2024 was in bulk form. Black tea in bulk form is sold at lower prices than value-added tea forms such as packaged, flavored, bagged, or instant teas. In 2024, the average price of Sri Lankan bulk tea was 5 US$/kg, while the average prices for Sri Lankan green tea and instant tea were 12.90US$/kg and 10.34US$/kg respectively (Sri Lanka Tea Board, 2025). During the last ten years (2015-2024) Sri Lanka on average earned only 5 US$/kg from tea exports. Apart from beverage type teas, there are hardly

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any non-beverage products made from tea in Sri Lanka that exported, robbing the country of potential revenues sources.

In contrast to Sri Lanka, countries like Japan, which accounts for only 2% of total global tea exports, earn substantially higher amount of revenue from its tea exports on a per kilogram basis. Japan earned an average of 28 US$/kg during 2015-2024. It produces a large number of tea-based products (about 25 types of beverage teas and hundreds of non-beverage tea-based products such as confectionaries, tea wine, pharmaceuticals and cosmetics) from the same tea (*Camellia sinensis*) plant that Sri Lanka gets its bulk black tea from.

Large tea importing countries such as the USA, Germany and Netherlands (the 2nd, 3rd and 4th largest tea importers in-terms of exported value respectively in 2024) also produce tea-based non-beverage products, using processed tea imported from tea producing countries such as Sri Lanka (Koch et al., 2019). The fact these countries earn money from tea products and they do not even grow tea demonstrates a lost opportunity for tea producing countries like Sri Lanka where "tea" plays a major role in the economy in terms of earning foreign income and generating employment. According to the Central Bank of Sri Lanka, tea accounted for 11% of the total foreign income earned in the year 2024.

Sri Lanka is facing more competition in the global black tea market as more producers enter into it. This affects Sri Lanka in two ways: 1) increased competition for market share; and 2) low prices for bulk tea. The gap between tea production and consumption increased from 127 million excess kilograms in 2010 to 300 million excess kilograms in 2022 affecting the tea prices. According to the Intergovernmental group of Food and Agricultural Organization (FAO-IGG), average tea prices were 2.7US$/kg and 2.5US$/kg in 2010 and 2023 respectively (FAO-IGG,2024). This clearly shows there is more money to be made with innovative tea-based products (called innovations or product innovations in this paper) with high added-on value than in exporting bulk tea on a per kilogram basis.

Product innovations based on tea can be categorized basically into two types: 1) incremental innovations (e.g., flavoring, bagging, and packaging) and 2) radical innovations (tea concentrates, cordials, confectionary and cosmetics). In 2024, Sri Lanka exported 42% of tea in packet form and 11% in bag form but hardly any in innovative tea type forms (Sri Lanka Tea Board, 2025). There was not very much variety in terms of types of teas either: 98% of the tea exported by Sri Lanka was black tea. Accordingly, the specific research questions that this study expects to cover are: 1) How does product innovation take place in the Sri Lankan tea industry? 2) Do innovative firms perform better than that of non-innovative firms in the tea industry? and 3) What are the entrepreneurial and firm related factors influence on producing innovations in the tea industry? Framed with this background, this study attempts to: 1) examine if producing tea-based radical innovations can have a significant impact on firm performance and 2) determine the factors affecting radical innovations in Sri Lanka.

The structure of the paper is as follows: Section 2 describes the theoretical background of product innovation with special reference to the food and beverage industry. We develop the conceptual framework for our research and explain our variables based on theories and previous research findings in section 3. We present our methodology in

section 4. In section 5 we present our results. The last section (section 6) contains our conclusions and recommendations.

2 Literature Review

The Oslo manual (OECD,2018), introduces "innovation" in two broad contexts: its either a process or an outcome. New outcomes are the results of the new developmental and financial activities (process) undertaken by a firm. In this study, our focus is on new outcomes that we measure in terms of new products. In order to evaluate the "new outcomes" or "novelty" embodied in tea-based products, we follow the definition of the Oslo manual (OECD,2005). It introduces two dimensions of innovation: 1) incremental; and 2) radical. An incremental innovation is defined as a result of continuous changes, and a radical innovation is defined as a result of intense changes. In this paper we consider incremental innovation as continuous changes to black tea production, embracing things like blending, flavoring, and packaging. Radical innovation is considered a significant change made by a black-tea-producing firm, embracing products such as oolong tea, green tea, tea-based cosmetics, tea wine, confectionaries and compressed tea. Miyanoshita et al., (2020) through research on 192 Japanese food manufacturers revealed that incremental product innovations, especially in packaging and design affected sales growth. A study on Food and Beverage industry conducted in Spain revealed that radical innovations lead long term competitiveness (García-Sánchez et al., 2025).

Benefits of product innovations can be viewed both on the firm level (micro scale) and on the industry level (macro scale). According to Shumpeterian innovation theory, entrepreneurs (Chief Executive Officers or the CEOs of the firms in this study) invest in new resource combinations and change the existing production system (i.e., process innovations) (Shumpeter, 1934). This may create a new leader among firms in a sector such as the tea industry. Knowledge of an innovation may spill over to other firms and provide opportunities for imitation (Acs et al., 2009). Gradually, the new technology is adopted by other firms and helps raise the efficiency of the whole industry. Spence's model (1984) emphasizes the need for state intervention and collaborative research to promote innovation (Spence et al., 1984). In line with this, Lazzarotti and the team stated that public expenditure on research and development (R&D) that occurs through government, universities, research institutes and non-profit organizations plays a major role in low-tech industries such as food and beverage (Lazzarotti et al., 2013).

Trade is very open and efficient today. Most importing countries have mother companies and subsidiaries in the producing and exporting countries where they do business. Under such conditions, foreign firms have employed management and technological changes to reduce former disadvantages and create new advantages (Porter, 1998). To avoid becoming mere suppliers of raw materials and missing out on opportunities to make money further up the supply chain, local firms in the exporting countries must develop products that find a place in more sophisticated industry segments (Sengupta, 2004). The relationship between a firm's resources and competitiveness is explained

under the resource-based view by Barney (1991). It states that valuable, rare, inimitable, and non-substitutable resources and capabilities (based in human capital) enable a firm to sustain its competitiveness (Barney,1991).

From latter half of the 19th century to the first half of 20th century, the Sri Lankan black tea sector enjoyed the comparative advantages over other black tea producing countries (e.g., Kenya and India) due its cheap labor supply and favorable climate. However, this is no longer the case due to climate change and increasing labor wages. Ali, Choudhry and Lister studied the competitiveness of primary black tea manufacturing in Sri Lanka and said that Sri Lanka's competitiveness in the 1990s was low compared to other major tea producers in the world such Kenya (Ali et al., 1997). In order to remain competitive, Sri Lanka made a strategic change by investing in incremental innovations (such as packaging in 1962 and bagging in 1976). Along with this, Sri Lanka started producing instant tea (a radical innovation) in 1962. Production of incremental innovations in tea increased gradually and now make up a significant portion of exports (tea packets were 42% of and tea bags: were 11% of total tea exports in 2024) while the production of radical innovations has remained low and unchanged (green tea and instant tea each made up 2% and 1% of exports respectively in 2024). Ariyawardana (2001) studied the competitiveness of incremental innovations in tea (flavoring, bagging, and packaging) in Sri Lanka using Porter's Diamond Model and found that adding value through incremental innovations produced only slightly favorable results in terms of revenues and competitiveness. Her conclusion was that Sri Lanka's relatively poor performances was due to: 1) factor conditions - lack of technology, lack of capital, and poor physical infrastructure; 2) demand conditions - limited domestic market; 3) strategy, structure and rivalry - low management skills, little product innovation; and 4) related and supporting industries - poor linkage with flavoring and packaging industries, and unavailability of market information (Ariyawardana, 2001). Sri Lanka's poor performance in these areas highlights the need for tea innovations if the Sri Lankan tea sector wants to remain competitive and grow. One of the primary aims of our research is to figure out how Sri Lanka can produce meaningful radical innovations in the tea sector.

We found two major gaps in the current literature on radical innovations in the food and beverage industry in Sri Lanka: 1) most findings are based on case studies, from which it is often difficult to generalize to related industries such as tea; and 2) there is a focus on incremental rather than radical innovations. We hope that our research will help fill these gaps by identifying determining factors that affect tea-based radical innovations in Sri Lanka.

3 Conceptual framework

As shown in Figure 1, our first aim is to examine the relationship between firm performance and innovations. Enzing and the team argues that "actual sales" or "profits" are the best measures of firm performance since they represent financial performance, opportunity performance and impact on the market (Enzing et al., 2009). Return on Assets (ROA) and earnings before interests and taxes are some other widely used measures of

firm performance. We considered sales revenue per unit weight export (Rs/kg) to measure the performance. One of the primary focuses is to measure the number of radical innovations produced during our review time period, from 2014 to 2019. We have considered the number of incremental innovations as a means of comparison. There are various indicators used to measure innovation in the literature. For instance, Bogetoft considered innovative outcome of a firm as a dummy variable (Yes if the firm produced any innovative product; No if no innovations occurred) (Bogetoft et al., 2024). Research compared the sales share of innovative products to total sales to measure the innovation output of a firm (Stucki et al., 2018). In this study we use the number of radical and incremental innovations of a firm within the reviewed time (2014-2019) to measure the firm's tea-based innovations.

We categorized the independent variables into two groups based on previous research and our own observations as: 1) firm characteristics and 2) the innovative behavior of the firm. Elaborated concepts under firm characteristics are based on 1). Knowledge spillover theory (entrepreneurial characteristics derived from experience and scientific knowledge) and 2) Resource-based view (strategic resources a firm can exploit such as knowledge to achieve sustainable competitive advantage based on the availability of rare, non-substitutable physical resources).

We formulated six hypotheses under firm characteristics. For the first hypothesis, we anticipated that a CEO's characteristics have a significant impact on producing tea-based radical innovations. We used two factors to capture the influence of the CEO; 1) technological capability—if the CEO has a degree level qualification in the field of science and technology; and 2) experience in the tea sector. Thus, we hypothesized that having degree level qualification in the field of science and technology and experience in tea sector would positively impact product innovation in tea.

We also wanted to determine if having skilled employees had a significant impact on innovation. Under this, we forward the second hypothesis: having skilled employees significantly impact the production of tea-based innovative products. To measure this, we counted the number of CIM (Chartered Institute of Marketing) qualified and CIMA (Chartered Institute of Management Accounts) qualified officers, the number of tea technologists and the number of food technologists, all regarded as skilled employees on the staff of the firm. Research conducted in Denmark used the number of qualified technical staff in a firm to capture the in-house scientific and technological capability in their study on product and process innovations (Bogetoft et al., 2024).

For the third hypothesis we looked to the resource-based view, which says that rare, non-substitutable resources contribute to innovation and help a firm retain competitiveness. We considered owning tea plantations (to start innovations in the field e.g., shading for matcha tea, hand-made tea) and primary processing factories (e.g., to process orthodox tea, CTC tea, green tea) and secondary processing factories (to produce tea cookies, tea cordial etc.). We hypothesized that firm's access to physical resources contribute positively on innovation. To measure this, we used three indicators possesses or not possessed by a firm: 1) owning or directly linking to tea plantations, 2) owning or directly linking to primary processing and 3) owning or directly linking to secondary processing factories to make value added tea-based products. According to resource-based view, innovative firms first build a resource pool and then diversify into markets

to exploit "economies of scope" (Deligianni et al., 2014). With all this in mind we hypothesize a positive impact of market diversification on radical innovations

For the fourth hypothesis, we expect a positive impact of market diversification on innovation. For this we consider the average number of countries that firms exported their products for three years (2017-2019) as the measure of market diversification. Hashai and Delios have used the same measurement to evaluate the degree of market diversification in their study on product and market diversification on Japanese multinational firms (Hashai et al., 2012). According to Arte and the group observed higher firm performance in firms which followed related product diversification. Our study hypothesizes that there is a positive impact of market diversification on innovation in the tea industry (the fourth hypothesis) (Arte et al., 2022).

The fifth and sixth hypotheses are based on our field observations. For the fifth hypothesis, we hypothesized that firm size (economies of scale) and foreign investments significantly impact on radical innovations. We considered average annual export volume as a proxy of firm size. We followed the Sri Lanka Tea Board classification to determine firm size: 1) Large scale: firms whose annual export equals or exceeds one million kilograms. 2) Medium and small scale: firms whose annual export volume are lower than one million kilograms. Oxford Bibliographies define innovative behavior as the introduction and application of new ideas, products, or procedures to a person's work role or to an organization (Yuan et al., 2015). Following this idea, we broadly consider four types of initiatives that a typical firm in a food and beverage sector adopts in order to broaden its capabilities for innovation: 1) if the firm had undertaken any kind of collaborative R&D activity with another institute, university etc.; 2) if the firm has provided training for its employees; and 3) if the firm has contacted the Tea Research Institute of Sri Lanka (TRI) for updates or any support during the time reviewed and 4) if the firm contacts consumers for feedback on its products.

We hypothesize that the concepts pertaining to the firm's innovative behavior have a significant impact on radical innovations (the seventh hypothesis). We observed hardly any tea exporting firms had a separate budget for R&D, thus excluded this way of measuring the innovative behavior of the firm in this study. Avermaete and team showed an insignificant relationship between R&D expenditure and innovative output in the in the food and beverage industry (Avermaete et al., 2004).

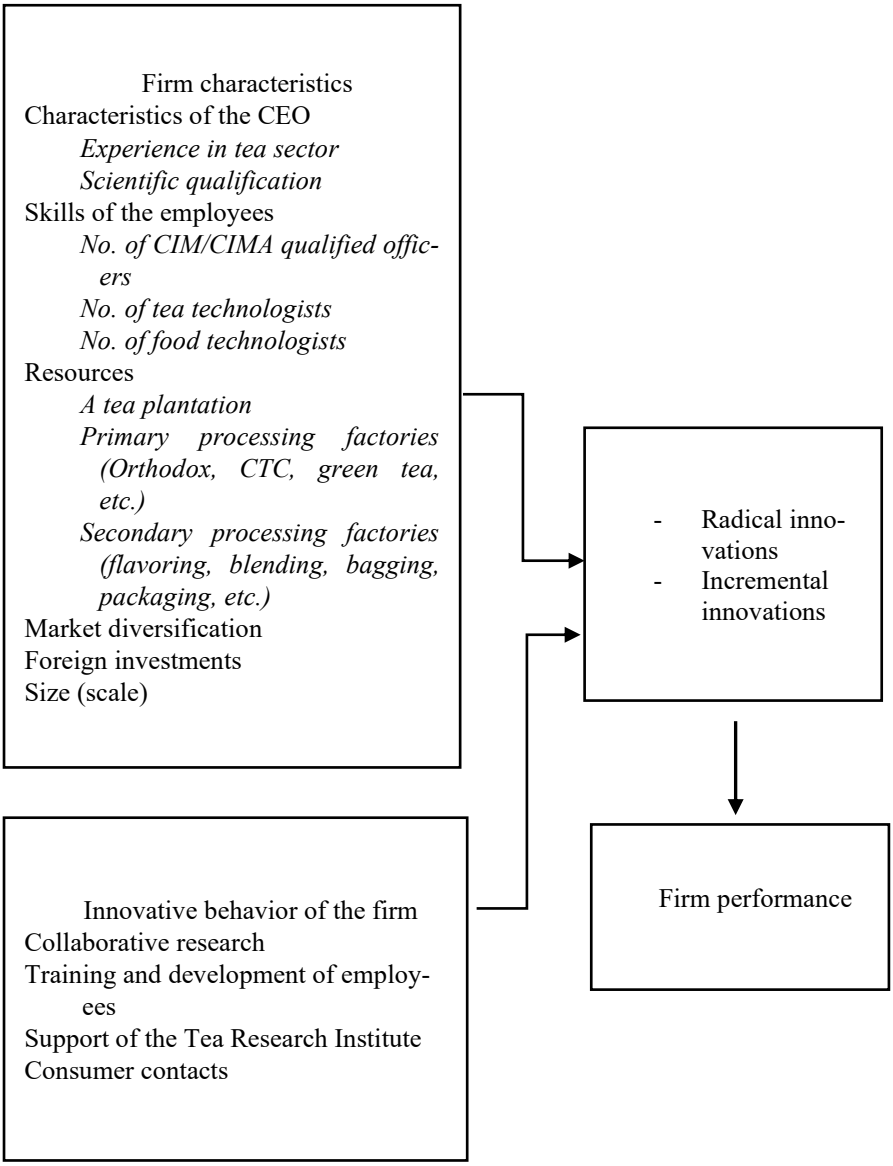

Fig.1. Conceptual framework to determine factors affecting incremental and radical innovations in Sri Lankan tea manufacturing industry

4 Methodology

This study is based on a survey of tea exporters involved in incremental and radical innovations in Sri Lanka in 2019. The survey collected data from 43 of the 180 major active tea exporters in Sri Lanka. These 43 firms produce nearly 60% of the total export volume of tea in Sri Lanka. As revealed in the preliminary discussions with Dri Lanka Tea Board (SLTB), structure (resources that the firms have), strategies (series of decisions and activities they take) mainly depend on their scale of operation (i.e., small, medium and large). Since my hypotheses of interest strictly related to structure and strategies of the firms in-relation to product innovation, stratified random sampling technique suited best in order to derive the study sample.

The SLTB has categorized all the registered tea exporting firms according into three categories to average annual export volume: 1) Large scale: firms those annual export equals or exceeds one million kilograms (53 exporters), 2) Medium scale: firms those annual export volume equals or greater than fifty thousand kilograms and lower than one million kilograms (102 exporters) and 3) Small scale: firms that annual export volume is lower than fifty thousand kilograms (115 exporters). In-depth interviews with the Chief Executive Officer (CEO) of each exporting firm were also conducted. These interviews lasted one to one and half hours. In-addition, five key informant discussions were held with: 1) the Commissioner of the Sri Lanka Tea Board; 2) the Secretary of the Ceylon Tea Traders Association; 3) the President of the Tea Brokers Association in Sri Lanka; 4) a consultant of Unilever, Sri Lanka; and 5) an independent researcher on tea-based innovations in Sri Lanka. Key informant discussions are in-depth interviews of a selected (non-random) group of experts who are most knowledgeable of the organization or issue. Insights of the key informants were used as supplements to elaborate our findings.

In addition to the surveys in Sri Lanka, we also conducted interviews and key informant discussions in Japan with officials of the Tea Research Station of Ureshino, Saga Agricultural Cooperative, and three owners of family-managed tea processing firms in Ureshino in Saga Prefecture of Japan. We use examples for innovations from the Japanese tea industry wherever relevant.

In the paper we first summarize the variables using descriptive statistics. We applied: 1) the Mann-Whitney-U test[1] to determine if there is a significant difference in the firms that produced radical innovations (we compared the average sales gain of the firms that produced higher number of radical innovations above the average with that of the firms produced below the average number of innovations); 2) the Principal Component Analysis to reduce the number of variables and to generate non-correlated set of independent variables; and 3) The Generalized Linear Model to identify the determinants of producing tea-based radical innovations. With respect to the required sample size for factor analysis, number of observations should be at least four or five times as the number of variables. Our sample consists of 43 observations (number of firms) and we have seven

[1] Mann-Whitney U test: non-parametric alternative to independent sample t-test that is used to compare difference in the medians in two independent groups when the dependent variable is not normally distributed.

corelated continuous variables that we expect to generate a minimum number of non-corelated variables (Malhotra et al., 2017). Thus, our sample comply with Malhotra's sample size requirement.

The link function for Poisson regression is a logarithm function as follows.

$$\ln (E [Y |x]) = \beta_0 + \beta_1 x$$

The expected count for i th individual in the sample is given by λ,

$$\ln(\lambda i) = \beta_0 + \beta_1 xi$$

$$Yi \sim \text{Poisson } (\lambda i)$$

To obtain estimated counts, the inverse of the logarithm function (the exponential function) is used to connect β values to the expected count,

$$\lambda = \ln{-1} (\beta_0 + \beta_1 x) = \exp (\beta_0 + \beta_1 x)$$

The strength of a predictor's impact on model-expected counts is typically described via an incidence rate ratio. Let $\lambda a = E [Y |x = a]$ and a be a value of x. β_1 is equivalent to taking the difference in the log of expected counts for a 1-unit change in x.

$$\begin{aligned} \ln (\lambda a+1) - \ln (\lambda_a) &= (\beta_0 + \beta_1(a + 1)) - (\beta_0 + \beta_{1a}) \\ &= \beta_0 + \beta_{1a} + \beta_1 - \beta_0 - \beta_{1a} \\ &= \beta_1 \end{aligned}$$

Therefore, unit change in x affects the ratio of expected counts as,

$$\begin{aligned} \beta_1 &= \ln(\lambda a+1) - \ln(\lambda_a) \\ &= \ln (\lambda a+1/ \lambda_a) \\ \exp(\beta_1) &= \lambda a+1/ \lambda a = \text{incidence rate ratio (IRR)} \end{aligned}$$

Thus, IRR describes the proportional change in incidence rate when increasing x by one unit.

5 Results and Discussion

The results and discussion section is mainly comprised of; i) information related to radical and incremental innovations in tea, ii) empirical analysis on the determinants of tea-based radical innovations.

5.1 Tea-based radical and incremental innovations produced by the firms

In Table 1, we present types and frequencies of tea-based innovative products produced by the firms that we studied during the period of review (2014-2019). Forty-two firms (98%) produced at least one innovative product. As mentioned earlier, product innovations in tea can be broadly categorized into two types as: 1) incremental (e.g., ones involving blending, flavoring and packaging) and 2) radical (new beverage type teas such as oolong tea, ready-to-drink tea and non-beverage type products like confectionary, cosmetics and tea-based food products). Of the 43 firms, 12 (28%) firms produced only radical innovations, 23 (53%) produced only incremental innovations and 7 (16%) produced at least one radical innovation and one incremental innovation. As mentioned before, radical innovations produced at the primary processing stage indicate that the innovations are produced directly from the green leaves. Radical innovations produced

at the secondary processing stage use the final product of primary processing (black tea or green tea) or intermediate products (e.g., tea brew) as the inputs. Our study reveals two major findings at this point: 1) more than half of the tea exporting firms in Sri Lanka have their main strategic focus on incremental innovations; and 2) among the firms who produced incremental innovations, many of them (47%) prioritize innovations in packaging.

Table 1. Type of tea-based Radical and Incremental Innovations in Sri Lanka

Radical product innovations				Incremental product innovations (At secondary processing stage)	
At primary processing stage		At the secondary processing stage			
Product	No. of firms (%)	Product	No. of firms (%)	Product	No. of firms (%)
Oolong tea	4 (9)	Tea capsule for Nespresso machine	2 (5)	Pyramid tea bag	6 (14)
Silver tips and golden tips	3 (7)	Tea aroma	1 (2)	Bio-degradable tea bag	3 (7)
Hand crafted tea	3 (7)	Tea concentrate	3 (7)	Regional tea pack	8 (19)
Ceylon green tea	2 (5)	Matcha energy drink	2 (5)	Tea gift pack	4 (9)
Ceylon matcha	2 (5)	Bubble tea	1 (2)	Different packages*	20 (47)
Compressed tea	2 (5)	Ready to Drink Tea	3 (7)	Flavored tea	7 (16)
		Tea cookies	1 (2)	Glass container with a strainer	1 (2)
		Tea cordial	1 (2)		
		Tea premix	2 (5)		
		Instant tea	3 (7)		
		Tea stick	1 (2)		

*e.g., wooden and cane boxes, cloth bags, cartoon, etc./ (percentage of number of firms)

Source: Authors' survey in Sri Lanka in 2019

As shown in Table 2, on average, one firm on average produced one incremental innovation and one radical innovation within the time period reviewed. On average, each firm employed at least one food technologist and three CIM/CIMA (marketing/accounting) qualified employees. Seventeen (40%) of the firms did not have a single food technologist and 26 (60%) didn't have tea technologists. On average the tea firm CEOs had 15 years of education, with 16 (37%) of them having undergraduate degrees and 10 (23%) of them having postgraduate qualifications. Eleven percent (23%) of the CEOs are science and technology graduates, 30 (70%) of the firms have provided training for

their employees and 13 (30%) of the firms have contacted the TRI for updates.

Table 2. Summary statistics: variables for factor analysis

Variable	Min.	Max.	Mean	SD
Number of radical innovations	0	6	1	1.55
Number of incremental innovations	0	6	1	1.24
Number of food technologists	0	10	1	1.81
Number of tea technology graduates	0	4	1	152.23
CIM/CIMA qualified employees	0	15	3	151.87
CEO's experience in tea (years)	5	50	27.3	11.28
CEO's education (years)	11	20	15.6	2.81
Number of export destinations	1	120	30	26.42
Variable			Yes	No
CEO has a qualification in science and technology			11 (23)	32 (77)
Provide training			30 (70)	13 (30)
Contacted TRI			13 (30)	30 (70)
Collaborative training			10 (23)	33 (77)
Consumer contacts			18 (42)	25 (43)
Foreign investments			17 (40)	26 (60)
Variable	Min.	Max.	Mean	SD
Number of radical innovations	0	6	1	1.55
Number of incremental innovations	0	6	1	1.24
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Consumer contacts			18 (42)	25 (43)
Foreign investments			17 (40)	26 (60)

5.2 Empirical analysis on the determinants of tea-based radical innovations

One of objectives of our study is to identify if there is significant gain in producing radical innovations over incremental innovations. To examine that, we divided the sample into two groups: 1) firms that produced above the average number of radical innovations during the review period (2014-2019) and 2) firms that produced below the

average of number of radical innovations during the review period. Sales gain per unit export (Rs/kg) is the dependent variable. Since the dependent variable did not follow a normal distribution, we compared the average sales gain of the two groups using the Mann-Whitney U test.

As shown in Table 3, the results revealed that the firms that produced above the average number of innovations (average number of innovations=1) had significantly higher sales gain (2186.79 Rs/kg) than the firm that did not (1111.77 Rs/kg). We used the same analysis for the firms that produced a higher number of incremental innovations. Results revealed that there is no significant difference between the firms that produced a higher number of incremental innovations than the average and the firms that produced below the average number of incremental innovations. This supports the important conclusion that radical innovations lead to higher sales gains than incremental innovations. Therefore, from this point on, our major focus is on tea-based radical innovations.

Table 3. Type of innovation and firm performance

Category		Sales gain per unit export (Rs./kg)	
	n	Mean	Median
Firms produced above average number of radical innovations (n>1)	10	2186.79	2400.00
Firms produced below average number of innovations (n≤1)	33	1111.77	919.57
Mann-Whitney U test results			U= 21.5, p=0.000
Firms produced above average number of radical innovations (n>1)	13	1370.91	1091.26
Firms produced below average number of radical innovations (n≤1)	30	1357.82	1045.40
Mann-Whitney U test			U=182.0, p=0.731

Table 4 summarize the variables and their definitions that we use for the subsequent analysis. In order to identify the determinants of producing radical innovations, first we examined the correlation matrix of the hypothesized quantitative independent variables (no. of food technologists, no. of tea technology graduates, CIM/CIMA qualified employees, CEO's experience in the tea sector, CEO's education and no. of export destinations). We found significant correlations among important variables of our interest (i.e., no. of food technologists, no. of CIMA qualified employees and no. of export destinations).

Table 4. Determinants of radical and incremental innovation in tea

Variable	Definition
Firm characteristics	
Characteristics of the CEO	
Experience in tea sector	CEO's number of years of experience in the tea sector
Level of education of CEO	Number of years of education
Science and Technology education	Dummy: 1 - if the CEO has a degree in the field of Science or Technology; 0 - otherwise
Skills of the employees	

No. of CIM/CIMA qualified officers	Number of CIM/CIMA (diploma level and above) qualified employees
No. of tea technologists	Number of tea technology and value addition graduates
No. of food technologists	Number of food technology graduates
Resources	Number of direct links to physical resources-backward links (tea plantations, primary processing factories, secondary processing factories)
Size (scale)	Dummy: 1 - if belongs to large scale; 0 - otherwise
Foreign investments	Dummy: 1 - if the firm has foreign investments; 0 - otherwise
Market diversification	Average number of countries that a firm exported its products during last three years (2017-2019)
Innovative behavior of the firm	
Collaborative research	Dummy: 1 - if the firm involved in collaborative research during (2014-2019); 0 - otherwise
Training and development	Dummy: 1 - if the firm provided training for the staff during (2014-2019); 0 - otherwise
Contacts of Tea Research Institute (TRI)	Dummy: 1 - if the firm contacts TRI; 0 - otherwise
Consumer contacts	Dummy: 1 - if the firm gets consumer feedback; 0 - otherwise

Source: Authors' explanation of variables

From here, our analysis continues in two phases, using: 1) the Principal Component Analysis (PCA) and 2) the Generalized Linear Model (GLM). We performed a PCA with two objectives: 1) to identify if the correlations among the independent variables were statistically significant; and 2) to formulate uncorrelated set of variables if the correlations were found to be statistically significant. Bartlett's test of sphericity revealed that the correlations between independent variables were statistically significant (Chi square value for Bartlett's test of sphericity was 68.4 ($p=0.001$). Next, we continued using PCA to formulate uncorrelated independent variables (factors) for GLM, using the original independent variables. The Kaiser-Meyer-Olkin value (KMO=0.626) showed that our sampling adequacy was good enough to proceed to factor analysis (KMO should be between 0.5 to 1). We used extraction technique with Varimax rotation and for the selection of number of factors, we applied latent root criterion requiring eigen values greater than one (Malhotra et al., 2017).

According to Table 5, the first three variables (factor 1- firm strategy) together contributed for 35% of the total variance while the three variables (factor 2- firm resources) that follow the first four variables accounted for 19% of the total variance. Likewise, the third factor (expertise in tea, composed of two variables) contributed 15% of the total variance. Results revealed high correlations between the variables with the factor that they belonged to (this is indicated by the factor loading mentioned in the 3rd column). Thus, the three factors explained 68% of the variance in the data. The PCA reduced the initial seven correlated independent variables into three uncorrelated variables (factors): 1) firm strategy, 2) firm resources and 3) expertise in tea. Three variables;

no. of food technologists, no. of destinations and no. of CIM/CIMA qualified officers correlate positively with the "firm strategy" factor. Similarly, two variables; CEO's experience in tea and no. of tea technologists correlate positively to the "expertise in tea" factor. It should be noted that education level of the CEO correlates negatively while no. of backward links corelates positively to the "firm resources" factor. We elaborate on the negative impact of the level of education of the CEOs in our discussion under "Firm resources" below.

Next, we decided to examine the distribution of dependent variable prior to the subsequent analysis. Although our objective is to identify the determinants of tea-based radical innovations (using the no. of radical innovations as dependent variable), we performed the same analysis for incremental innovations (using the no. of incremental innovations as the dependent variable) as a means of comparison and elaboration. Analysis confirmed that both dependent variables followed a Poisson distribution[2]. With this issue clarified, we proceeded with GLM in order to identify the determinants of producing tea-based radical innovations. The independent variables in the GLM are the factors generated through PCA (in Table 5) and another seven nominal independent variables:1) CEO's science and technology qualification, 2) TRI contacts, 3) collaborative research, 4) training, 5) consumer contacts, 6) firm size and 7) foreign investments.

Table 5. Factor analysis matrix

Factor	Factor interpretation (% variance)	Loading	Variables included
1	Firm Strategy (34.91)	0.899	No. of food technologists
		0.874	No. of destinations
		0.848	No. of CIM/CIMA qualified officers
2	Firm Resources (18.78)	0.759	No. of backward links
		-0.769	Level of Education of the CEO
3	Expertise in tea (14.50)	0.769	CEO's experience in tea
		0.633	No. of tea technologists

As shown in Table 6, the deviance value and the Omnibus test suggest that the derived GLM fits for the data (deviance should be approximately equal to zero and the Omnibus test should be significant at a 0.05 significance level). Our findings indicate that firm strategy, firm resources, CEO's science and technology qualification have a significant positive impact on producing radical innovations while the size of the firm (scale) has a significant negative impact on radical innovations.

[2] The variable should have count data that where the mean is less than 10. (Kolmogorov-Smirnov z for number of radical innovations (Y_1) and number of incremental innovations (Y_2) were 1.17 (p=0.133) and 0.38 (p=0.99). Further, mean ($\bar{Y}$) and variance (S^2) of both dependent variables are approximately identical ($\bar{Y}_1$= 1.0, S_1^2= 2.3 and $\bar{Y}_2$= 1.1, S_2^2= 1.5)

Table 6. Parameter Estimates for the determinants of producing tea-based innovations

Variable	Radical innovations			Incremental innovations		
	β	Exp (β)	Wald statistic	β	Exp (β)	Wald statistic
Firm Strategy	0.36**	1.44	2.92	-0.35**	0.70	2.76
Firm Resources	0.70*	2.03	14.51	-0.35**	0.70	3.26
Expertise on tea	0.29	1.34	1.03	0.03	1.03	0.02
CEO's science and technology qualifications (yes)	1.65*	5.19	7.20	-0.89	0.40	2.79
TRI contacts (yes)	0.75	2.11	2.01	0.14	1.15	0.10
Collaborative research (yes)	0.52	1.69	1.27	0.24	1.30	0.62
Provide training (yes)	-0.68	0.53	1.35	0.26	1.30	0.30
Consumer contacts (yes)	-0.10	0.90	0.05	0.68	1.98	4.22
Size of the firm (large)	-0.75**	0.46	2.79	0.08	1.09	0.06
Foreign investments (yes)	-0.47	0.62	1.08	-0.47	0.62	1.68
Intercept	-0.33	0.71	0.50	-0.25	0.78	0.29
Goodness of fit						
	value	df	value/df	value	df	value/df
Deviance	30.90	30	1.03	33.52	30	1.11
	Likelihood ratio chi square	df	Sig.	Likelihood ratio chi square	df	Sig.
Omnibus test	52.87	10	0.00	19.74	10	0.03

Note - * significant at 0.05 significance level, ** significant at 0.1 significance level.

Since the factor "firm strategy", is composed of three correlated variables (i.e. – number of food technologists, number of destinations and number of CIM/CIMA qualified employees) we can conclude that all these factors impact positively on producing radical innovations. The negative sign before the number for firm strategy on incremental innovations indicates that absence of food technologists, CIM/CIMA qualified employees and exporting only to a few market destinations favor incremental innovations. Food technologists indicate the presence of people with technical knowledge and skills while CIM/CIMA qualified employees indicates presence of people with marketing and management knowledge and skills in a firm. This suggests that a firm can promote tea-based radical innovations based on its potential benefits (e.g., as a functional food or as a major input for cosmetics) and as a marketing strategy. Thus, the involvement of skilled technical, managerial, and marketing personnel is vital for radical innovation. A study conducted with 1,240 farmers in the Netherlands says that a lack of technological skills is a major reason for poor innovation (Diedren et al., 2003). Our previous research in Japan revealed that all tea farmers and processors in Japan take a two-year professional course to get hands on experience in tea cultivation manufacturing and management. Entrepreneurs in Japan are directly linked to professionals in Japanese universities and

research stations through government intermediary organizations (Industrial Technology Research Center).

According to our results, a large number of export destinations favors radical innovations. We observed that the firm that produced the highest number of radical innovations (six radical innovations and six incremental innovations during the review period) exported to the largest number of destinations (120 countries). We further observed that firms that produce larger numbers of radical innovations focus more on immerging niche markets rather than the traditional destinations of Sri Lankan tea, mostly in the Middle East. For instance, the top five destinations of the eight firms that produce above the average number of radical innovations include Japan (all 8 firms), Australia and China (4 firms). Similar to our findings, a study on pulse based radical innovations, conclude that most products are targeted for niche markets (e.g., organic shops, schools and hospitals) (Lascialfari et al., 2019). A study conducted on food-based small and medium enterprises (SMEs) in six European countries reveals that the placement of innovative products in new geographical areas and targeting new potential customers are defender strategies[3] mainly adopted by the food SMEs (Minarelli et al., 2015).

Firm resources are also major determinants impacting positively on radical innovations and negatively on incremental innovations. We considered the number of direct links that the 43 tea firms we studied have to tea plantations, primary and secondary processing factories, to evaluate the impact of resources on radical innovations. Only eight firms (18% out of 43 firms) had direct links with tea plantations. Eight firms have orthodox black tea factories, three firms have CTC tea factories and six firms have green tea processing factories. As we observed, firms that have their own plantations or backward links to plantations and the firms that have processing factories produced more beverage type innovations (e.g., handmade teas, green tea, teas, compressed tea etc.). These firms use green leaves as a raw material. Other firms produce radical innovations such as gold-plated tea by processing made tea purchased from the Colombo auction. We can assume that the negative sign before the number for "firm resources" towards incremental innovations indicates that once a firm has its own resources (own plantations and processing factories) the tendency to pursue incremental innovations decreases.

According to our factor analysis matrix in Table 5, the level of the education variable has a negative correlation to "firm resources". Therefore, we assume that the impact of level of education towards radical innovations is negative. This may be because until recently, the Sri Lankan education system did not promote innovation (e.g., according to Central Bank, in 2018, 48% graduated in Arts and Oriental Studies out of the total graduates in 2018 26,024 in Sri Lanka). Rather it focused more on using social sciences to produce human resources needed for white color jobs in the public sector. According to our observation the majority of the CEOs who had post graduate qualifications had degrees in business administration. The passion of CEOs for innovation perhaps comes from his/her experience in the tea sector and scientific background rather than number of years of schooling. Similar to our finding, the study on farmers in the Netherlands reveals that there is no relationship between the education level of entrepreneurs and innovativeness (Diederen et al., 2003). However, a study on product innovations in the

[3] A defender strategy is a competitive strategy where a firm attempts to retain its consumer base by offering exclusive superior quality or lower prices.

manufacturing sector in Finland, found that entrepreneurs with post-secondary school qualifications seemed more innovative than the entrepreneurs who had only school secondary education (Leiponen, 2000).

Science and technology education of the CEO is positive and highly significant. According to our observation, the majority of the CEOs started their career as tea tasters that does not require a science education. However, this was different when it comes to the family-owned firms managed by CEOs who are 2nd or 3rd generation family member. These CEOs tended to have science and technology degrees and their firms were much innovative than others.

Our study revealed the firm size negatively impacts radical innovations. Our study sample of 43 firms included 24 large tea exporting firms and 19 small and medium size firms. Only seven of the large firms (29%) produced at least one radical innovation during the period under review. Out of the 19 small and medium size firms, 63% produced at least one tea-based radical innovation while only one third of the large firms did. We observed that most of the tea-based innovations of large firms involved sophisticated technology for things like tea concentrate, instant tea, and tea cordial. In contrast, the number of these kinds of high-tech products is low at small and medium size firms. Instead, they produce products such as Ceylon matcha, compressed tea, and oolong tea which do need sophisticated technology. Previous research states that small food firms tend to produce specialized regional products that are different than those produced by large, established firms who focus on mass markets (Avermaete et al., 2004).

As an aside we found that while food scientists positively contributed to tea innovations as noted earlier, tea-technology graduates from the four-year degree program in "tea technology and value-addition" started at Uva Wellassa University in 2008 have made less of contribution to innovation, which implies the curriculum needs to be updated to make it so graduates make a more significant impact.

Our study also revealed that contacts between the tea firms and Sri Lanka's TRI (Tea Research Institute) has no significant impact on radical innovations. The TRI, founded in 1925, is a government institute and one of the oldest tea research institutes in the world. It was established to provide research input to the industry. Out of the 19 firms that produced radical innovations, only five firms contacted the TRI and they did so to get the latest updates on certification procedures not product development. However, this contrasts with findings from other countries. Research conducted in Belgium on food innovations found that contacts with research institutes in Belgium were major determinants on innovation in food SMEs (Avermaete et al., 2004). This finding highlights the lack of research in product innovation at the TRI and need for such research to maintain the sustainability of the industry.

Conducting collaborative research, providing training on technology and management, getting consumer feedback and foreign investments are not statistically significant towards radical innovation. Out of the 43 firms, only one, five and four firms had conducted collaborative research with TRI, universities and foreign institutes respectively. The tea firm CEOs stated that hardly any of those researches were related to radical innovations. Similarly, 30 firms (70%) provided training for their staff but most of it dealt with management, quality improvement or packaging not radical innovations. With respect to consumer contacts, 18 firms (41%) had at least one means of consumer

feedback (9 firms maintained a consumer contact e-mail database, 15 firms posted updated product catalogues to selected consumers and 10 firms managed to conduct consumer surveys). All the firms that maintained a consumer contacts through e-mail belonged to small and medium scale. In general, tea firms in Sri Lanka had few direct contacts with local consumers and even less with consumers abroad.
We argue that the existing Colombo auction centered structure, where 98% of tea production is sold, as a major obstacle for radical innovations as it limits the producer-consumer contacts and deprives tea firms of knowledge about consumer needs and desires and this negatively impacts radical innovation development. In Japan, tea manufacturers promote direct sales to both domestic and export markets and the government helps pay for a webpage for direct marketing Our study revealed that foreign investments have no significant impacts on radical innovations. Foreign investment mainly focuses on traditional Ceylon tea brand exports rather than product innovations.

6 Conclusions and recommendations

The objectives of this study have been to identify the impact of radical innovations on firm performance and to identify the determinants of tea-based radical innovations in Sri Lanka through a questionnaire survey, CEO interviews and key informant discussions. Although there are number of tea-based radical innovations that can be produced using the tea plant, which Japan has demonstrated, only 19 firms (44% out of 43) in Sri Lanka produced a radical innovation product during the time reviewed (2014-2019). This is unfortunate for Sri Lankan tea industry, which needs to expand out of its dependance on bulk tea exports into higher-value --- radical innovative --- products.
Four determinants have significantly impacted the production of tea-based radical innovations in Sri Lanka. Of these, three determinants --- 1) firm strategy (no. of food technologists, no. of market destinations, no. of CIM/CIMA qualified employees): 2. firm resources (direct links to plantations and processing factories); and 3) CEO's science and technology qualifications --- have a significant positive impact on producing radical innovations. Firm size has a significant negative impact on producing radical innovations.
In view of the hypotheses, we outlined at the beginning of the paper our findings have led us to the following conclusions: 1) CEO science and technology qualifications have a significant impact on producing radical innovations; 2) skilled labor contributions (determined by the number of food technologists and CIM/CIMA qualified officers) and 3) market diversification made a significant contribution to the production of radical innovations. In regard to resources, our study confirmed that 4) having direct links to raw materials (plantations) and primary and secondary factories significantly impact on radical innovations and CEO's education level has negative impact on radical innovations.
Our study could not support the hypotheses: 1) providing training on technology and management impact positively on radical innovations, 2) Foreign investments impact positively on radical innovations, 3) collaborative research impacts positively on radical innovation; 4) direct consumer contacts impact positively on radical innovations;

and 5) CEO's experience and no. of tea technologists in the firm improve radical innovations.

In-relation to these findings, in order to improve radical innovative product development, we recommend developing or improving: 1) Human capital (knowledge and skills related to radical innovations); 2. physical capital (establish links between plantations, other raw material suppliers and processing factories (i.e., vertical and horizontal integration); and 3) social capital (establish links with financial institutes and associations to identify emerging niche market destinations). Both beverage type and non-beverage types of radical innovations in tea need to be developed and promoted. The Tea Research Institute, Industrial Technology Institute and universities in Sri Lanka need to: 1) set up or improve programs related to product innovation; and 2) provide the necessary technology, R&D and skilled labor; and 3) reforms R&D mandate and improve links to private sector tea manufacturers.

Existing policies need to focus more on quality improvement in tea rather than simply on quantity. While large firms dominate the mass-scale supply of orthodox black tea, there is a lot of potential for SMEs to grow by promoting and producing radical innovations aimed at smaller domestic and export niche markets. Pursuing direct sales online, with government help, is one way to achieve this. We believe the Covid-19 pandemic shed light on a new era for tea (*Camellia sinensis*) for both producer and consumers. This would motivate inventors to research more on different applications of *Camellia sinensis* to utilize its beneficial nutrients, innovators to broaden its consumer-base through increasing the product scope (i.e.- beverage type and non-beverage type innovations in tea) and consumers to enjoy wider range of products.

Conflict of interest disclosure

The authors declare that there are no competing interests

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