PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
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E-mail: editorpjn@gmail.com

OPEN ACCESS Pakistan Journal of Nutrition

ISSN 1680-5194
DOI: 10.3923/pjn.2016.1017.1025

Research Article
Development of a Plant Based Confectionary to Combat Micro-sleepiness due to Fatigue in Hectic Life-styles and Cerebral Relaxation

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Abstract

Background: Micro-sleepiness (MS) is a temporary biological disorder, which can lasts from fraction of second to 30 sec and an individual fails to respond for some arbitrary sensory inputs. It has become one of the major social issues that cause fatalities, material losses, productivity and quality dilapidation and eventually negative impact on national GDP. **Methodology:** To combat this adverse biological phenomenon, plant based phytochemicals in berries of *Piper nigrum*, beans of *Coffea arabica*, bark of *Cinnamomum verum* and rhizomes of *Zingiber officinale* were extracted and incorporated to develop an effective confectionary. Boosting the self-confident level, mortar function, gustatory stung action, astonish olfactory and tingling actions and chemical energy were impregnated into the confection using aforesaid raw materials to combat MS. Series of confectionaries were developed based on advanced Thaguchi statistical design and best treatment was selected organoleptically against five sensory stimuli: Color, taste, mouth feel, texture, odour and overall acceptability. **Results:** Results revealed mean deviations of above sensory attributes were 3.85±0.81, 3.65±0.58, 3.6±0.94, 3.55±0.94, 3.45±0.76 and 3.75±0.55, respectively. Piperine, caffeine, cinnamaldehyde and gingerol were at 12.727, 5.277, 1.333 and 0.533 mg, respectively in the developed product and below the WHO standards. The developed product was capable to suppress MS completely, controlled at a satisfactory level and fails to control for 15, 65 and 15%, respectively. Further 35, 30, 20 and 15% expressed that they didn't feel MS 1-2, <1, 2-3, 3-4 h respectively. **Conclusion:** Thus the developed product was capable to combat MS in modern busy life styles without any adverse effects or allergies.

Key words: Micro-sleepiness, piperine, caffeine, cinnamaldehyde, gingerol

Received: October 11, 2016 Accepted: October 31, 2016 Published: November 15, 2016

Citation: Rumesh Liyanage, S.B. Navaratne, Indira Wickramasinghe and K.K.D.S. Ranaweera, 2016. Development of a plant based confectionary to combat micro-sleepiness due to fatigue in hectic life-styles and cerebral relaxation. Pak. J. Nutr., 15: 1017-1025.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Sleep may be phenomenon logically characterized by four criteria: A species-specific posture, characteristic changes in the electroencephalogram (EEG), an increase in response threshold to environmental stimuli and quick reversibility. Moreover using these criteria, sleep can be further divided into two main stages, Slow Wave Sleep (SWS) and Rapid Eye Movement (REM) sleep[1]. Two types of sleepiness have been identified as natural sleepiness and micro-sleepiness for humans. These both biological phenomenon may occur all around the clock and this study based on to combat the micro-sleepiness, which may adversely affects for today activities.

Micro Sleepiness (MS) is a temporary episode of sleep, which may last for a fraction of a second or up to 30 sec where an individual fails to respond to some arbitrary sensory input and becomes unconscious. Moreover, MS reduces the reaction time slower, a special problem when driving or doing work or other tasks that require a quick response[2].

The MS has become a major concern for road accidents, low productivity, low quality of work and numbness in the society. According to the National Highway Traffic and Safety Administration UK (NHTSA) one in four fatal road accidents may occur due to the micro sleepiness and more than 1550 deaths, 71000 injuries and US $12.5 billion monetary losses were reported. According to the Sri Lanka Police Traffic Statistical Division, road accidents have been increased at an alarming rate from 2005-2015 and more than 60 fatal road accidents were reported in 2015 due to micro-sleepiness while driving[3]. Peak intensity of MS occurs in between 14-16 h, especially after taking heavy meal.

Furthermore, bad weather and poor luminosity, psychological stress, effect of sleep promoting hormones (such as melatonin, serotonin and tryptophan), effect of alcohol, traffic jams and heavy diets are the other probable factors for MS. Driving while sleepy is like driving with a blood alcohol content of 0.08% over the legal limit in many states. And drinking and drowsiness are double trouble when driving because sleep deprivation magnifies the affects of alcohol[4].

Melatonin (N-acetyl-5-methoxytryptamine) is a neuro-hormone which is the most responsible hormone for regulating sleep-wake cycle in brain that is primarily produced by the pineal gland, located behind the 3rd ventricle in the brain and it helps to regulate other hormones and maintains the body's circadian rhythm. The circadian rhythm is an internal 24 h "Clock" that plays a critical role when we fall asleep and when we wake up. When it is dark, pineal gland produces more melatonin. When it is light, the production of melatonin drops. Being exposed to bright lights in the evening or too little light during the day, can disrupt the body's normal melatonin cycles[5].

Adenosine agonists decrease wakefulness and increase sleep. Furthermore, such agonists also tend to increase deeper stages of SWS at the expense of lighter SWS, with deep and light stages defined on the basis of amount of slow waves, greater than 50% epoch^{-1} versus less than 50% epoch^{-1}, respectively. Conversely, adenosine receptor antagonists increase wakefulness and decrease sleep. One of the most commonly used pharmacological agents, caffeine is a no selective adenosine antagonist, which primarily acts at two of the four adenosine receptor subtypes, the A_1R and $A_{2a}R$ to influence sleep/waking behaviour. The estimated daily intake of caffeine in American citizens is about 280 mg, which is above the functional dose for decreasing sleep[6].

Boosting the self confident level, mortar function (Oral activity due to biting), gustatory stung and tingling actions over the mouth cavity, astonish olfactory action in the nasal cavity (as a result of aromatic compounds) and chemical energy by various means have been identified as the principal influences which can be used to prevent MS. The aim of this study was to develop a confectionary by impregnating the constituents responsible for above influences. In developing the confectionary, special emphasis has given to minimize the incorporation of caffeine levels because it may be cause for addict and also adversely affect for the user.

MATERIALS AND METHODS

Identification of plant based raw materials and beneficial constituents to suppress MS: Raw materials selection were carried out based on literature survey, interviews with knowledgeable persons and experts in the Department of Food Science and Technology, University of Sri Jayewardenepura, Minor Crop Export Department, Mathale, Physicians in Bandaranayake Memorial Aurevedic Research Centre, Navinna and Researchers in Medical Research Institute, Colombo, Sri Lanka. Thereafter beneficial ingredients, which can combat MS were identified and quantified using Gas Chromatography (GC), Mass Spectrometry (MS), Gas Liquid Chromatography (GLC) and spectro-photometer.

Development of a prototype confectionary product to combat MS: As a prelude, flavour profiles of ingredients were sensorially detected with a view to find out whether there is

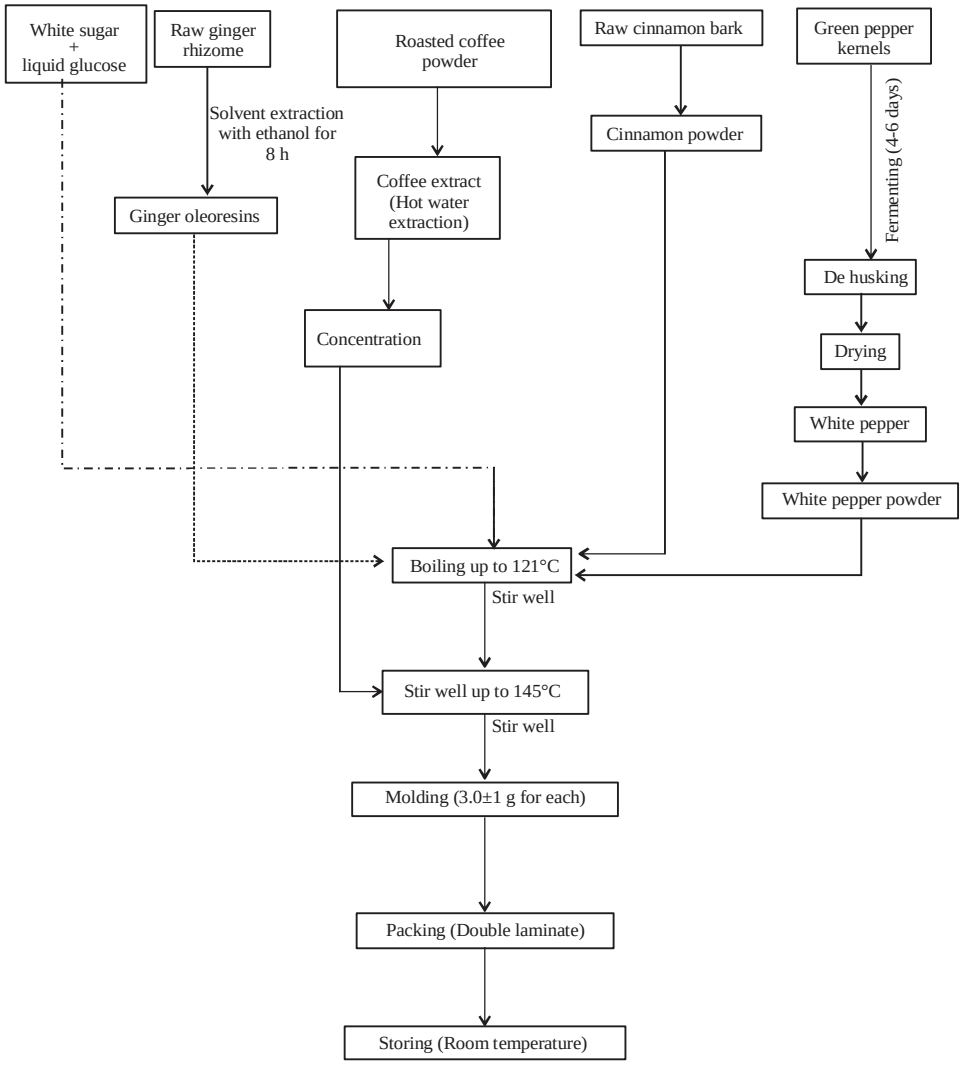

Fig. 1: Process flow diagram

any flavor disturbance while mixing the selected ingredients together. Thereafter, eight treatment combinations were formulated according to the Taguchi orthogonal L-8 standard statistical design. Formulated products were subjected to sensory evaluation and best three treatment combinations were selected according to the response of respondents. Afterward acceptability of these three prototype products were tested in the laboratory as well as in the field with a view to select the best treatment combination. All collected data were analyzed by Friedman Test-Minitab 15 statistical package.

Product development procedure: Initially 80% of white sugar (Domestic) and 20% of liquid glucose (Domestic) were mixed together (91%) and boiled up to 121°C and ginger oleoresin (0.8%), cinnamon powder (1.8%) and white pepper powder (1.4%) were added into it. Thereafter the mixture was heated up to 145°C continuously and concentrated coffee extract (5%) and mixed it well and poured into a molder to get the proper shape. Ultimately the products were packed in a double laminated packaging, which is having strong barrier properties for aroma, chemicals and moisture. Different techniques (Fig. 1) are crucially important to mold the product with proper shape, preservation of critical chemical components and to maintain required gustatory sensory property.

Quantification of the functional ingredients in developed product against MS: Piperine (PubChem CID: 638024), caffeine (PubChem CID: 2519), cinnamaldehyde (PubChem CID: 637511) and gingerol (PubChem CID: 442793) have been

identified as the beneficial constituents of *Piper nigrum*, *Coffea arabica*, *Cinnamomum verum* and *Zingiber officinale* respectively to combat MS. Piperine and caffeine contents of the final product were analyzed using a spectrophotometer (Thermo-Model: Genesys 10-S-USA, at wavelength 343 nm) according to ISO 5564-1982 and AOAC, 19th Edition, 2012:987.07 official method and SLS:285-1974 methods respectively. Gas Liquid Chromatographic (GLC) method was used to quantify cinnamaldehyde and gingerols in the developed product. Cinnamaldehyde quantity of the end product was determined using ASTA method 2.0, 1997 and SLS81:2010 standard methods and moisture content of the sample was determined through AOAC, 1999-dean and stark methods. Amount of gingerols was also quantified [Industrial Technology Institute, Sri Lanka (ITI)] using GLC method.

Estimating of efficacy of the developed product against MS: Efficacy of the developed product was analyzed through a survey with the participation of 30 cramming students in the Department of Food Science and Technology, Faculty of Applied Sciences, University o f Sri Jayewardenepura and 40 Shift based workers at Suviska Tea Factory (Pvt.) Ltd., Neluwa, Sri Lanka. Most of the respondents were lecturers (20%) and undergraduates (20%) and there were 15, 15 and 15% of study assistants, demonstrators and technical officers respectively, rest of 100% are clerks (5%) and lab attendants (10%). In the other hand 70% of the flow level workers, 17.5 and 12.5% of office workers and drivers were participated, respectively for the survey.

Before conducting the survey, prior approval for Ethical Clearances was taken from Ethics Review Committee, Faculty of Medical Sciences, University of Sri Jayewardenepura, Sri Lanka under the application number 38/16 on 26th August 2016 to serve the developed confection among the respondents. Pre-prepared structured questioner was used as the study instrument, in addition to that, information sheet was served and consent form the respondents were collected. Further, respondents were verbally explained about the objectives and the way of conducting the study. Lastly the developed confections were served, questioners were given among the respondents and data pertaining to the MS were collected and analyzed using Minitab 17 statistical software.

RESULTS

Product development and standardization of the product against MS: According to the result of literature survey and personal interviews with knowledgeable persons, several plant-based raw materials were identified. Finally *Piper nigrum*, *Coffea arabica*, *Cinnamomum verum* and *Zingiber officinale* were selected as the best raw materials for the developed product while considering availability, efficiency and instructions of physicians of BMARI. The product formulations were carried out according to Thaguchi designs and three best treatment combinations were selected according to response of the respondents and outcome of the evaluation (Table 1).

Best treatment combination was 247 because sensory stimuli colour and odour of this product are significantly different to the other two-treatment combination at <0.05 except taste, mouth feel, texture, after taste and overall acceptability (Table 1). To validate outcome of this conclusion further, the sensory profile of the developed products is given in Fig. 2.

The sensory profile of treatment No. 247 (Fig. 1) is the most acceptable profile comparatively other two treatments 201 and 214.

Major herbal based components incorporated into this product usually available in today culinary products except caffeine, which is also present in routine drink of coffee brew. In the case of developed product, which also contains different proportions of caffeine, cinnamaldehyde, gingerol and piperine. During sensory evaluation, sensory receptors of respondents were stimulated by these compounds into different degrees and respondents perceived best product

Table 1: Results of final sensory evaluation

	Median			Sum of ranks			Grand median				
Sensory attribute	201	214	247	201	214	247	201	214	247	p-value	Results
Colour	3.6667	4.0000	4.3333	29.5	40.0	50.5		4.0000		0.004	p<0.05
Odour	3.0000	3.0000	4.0000	30.5	39.5	50.0		3.3333		0.002	p<0.05
Taste	4.0000	3.0000	3.0000	46.5	37.5	36.0		3.3333		0.199	p>0.05
Texture	4.0000	4.0000	4.0000	38.0	40.0	36.0		4.0000		0.641	p>0.05
Mouth feel	3.3333	3.0000	3.1667	45.5	35.0	39.5		3.1667		0.123	p>0.05
After taste	3.0000	3.0000	3.0000	35.0	38.0	41.0		3.0000		0.397	p>0.05
Overall acceptability	3.0000	3.0000	3.0000	40.0	40.5	39.5		3.0000		0.984	p>0.05

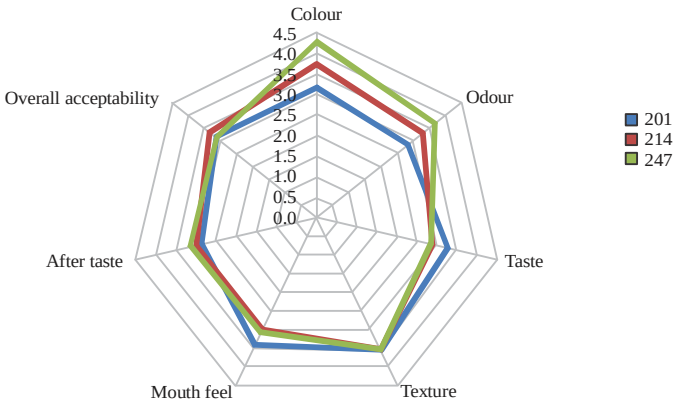

Fig. 2: Sensory profiles of the developed products

Table 2: Quantified active ingredients of the developed product, referred test methods and techniques

Ingredients	Quantity in final product (1 confectionary) (mg)	Recommended levels	Reference method
Piperine	12.727	N/A	Spectro photometric method. (Thermo-Model: Genesys10-S-USA) solvent-ethanol (AR) wavelength: 343 nm, AOAC, 19th edition, 2012. Official method 987.07
Caffeine	5.277	400 mg day^{-1}	Spectro photometric method. (Thermo-Model: Genesys10-S-USA) solvent-ethanol (AR) wavelength: 343 nm, SLS: 258-1974
Cinnamaldehyde	1.333	N/A	Gas Liquid Chromatography (GLC) method. (Shimadzy: GC-8A), Carrier gas-Ar, T_{in} = 60°C, Tem range: 60-210°C, column: 3 m×3 mm stainless steel column packed with 10% carbowax 20 M on chromsorb WAW 40/80 mesh inject vol: 0.3 µL, ASTA method No. 2.0
Gingerols	0.533	N/A	Gas Liquid Chromatography (GLC) method. (Shimadzy: GC-8A), Carrier gas-Ar, T_{in} = 60°C, Temperature range: 60-210°C, colum: 3 m×3 mm stainless steel column packed with 10% carbowax 20 M on chromsorb WAW 40/80 mesh inject vol: 0.3 µL, ginger, booklet No. 7 ginger, ITI (CISIR)

formulated according to their cumulative response. Thus the best cumulative response is possessed with the treatment No. 247.

Ginger oleoresins were identified as the most suitable form of ginger to obtain the astonished flavour for the product and concentrated coffee extract and cinnamon bark powder were taken as the other raw materials. White pepper powder was taken as a main ingredient for the product to start the gustatory stung action over the mouth cavity.

Quantification of active ingredients in the developed product: Quantification of active ingredients in the developed product was carried out using GLC and spectrophotometric methods and results (Table 2).

Piperine, caffeine, cinnamaldehyde and gingerol content of the best product (Treatment No. 247) were 12.727, 5.277, 1.333 and 0.533 mg, respectively (Table 2). According to the World Health Organization (WHO) standards, 400 mg is the maximum allowable level of caffeine consumption per day. However, there are no recommended levels for other active ingredients because they are usually contained in today culinaries. Results pertaining to the cinnamaldehyde and gingerol according to GLC analysis are given in Fig. 3.

Determination of the efficacy of the developed product against MS: The main objective of this study was to combat MS using plant based active ingredients incorporated confectionary which is merely developed to combat MS particularly for highway drivers, shift based workers, cramming students and other beneficiaries who encountered with MS during their today activities. Initially two studies were carried out to find the efficacy of the developed product at (1) Department of Food Science and Technology, Faculty of Applied Sciences, University of Sri Jayewardenepura-USJP, Sri Lanka and (2) A reputed Tea Factory (Suviska Tea Factory-STF), Neluwa, Sri Lanka. The results pertaining to the confidence level, self-experience and effective time period against MS after consuming the product of different categories of the employment are given in Fig. 4-6, respectively.

Confidence level: Confidence level of the participants owing the product in their possession is given in Fig. 4. Confidence level of the respondents due to owing the product depends on the respondent's own attitude. This is a psychological phenomenon and this one has been boosted to 81-100% level in the 45% of the two populations. As a general, almost all the respondents have more than 50% of confidence level to combat the MS by owing the developed product.

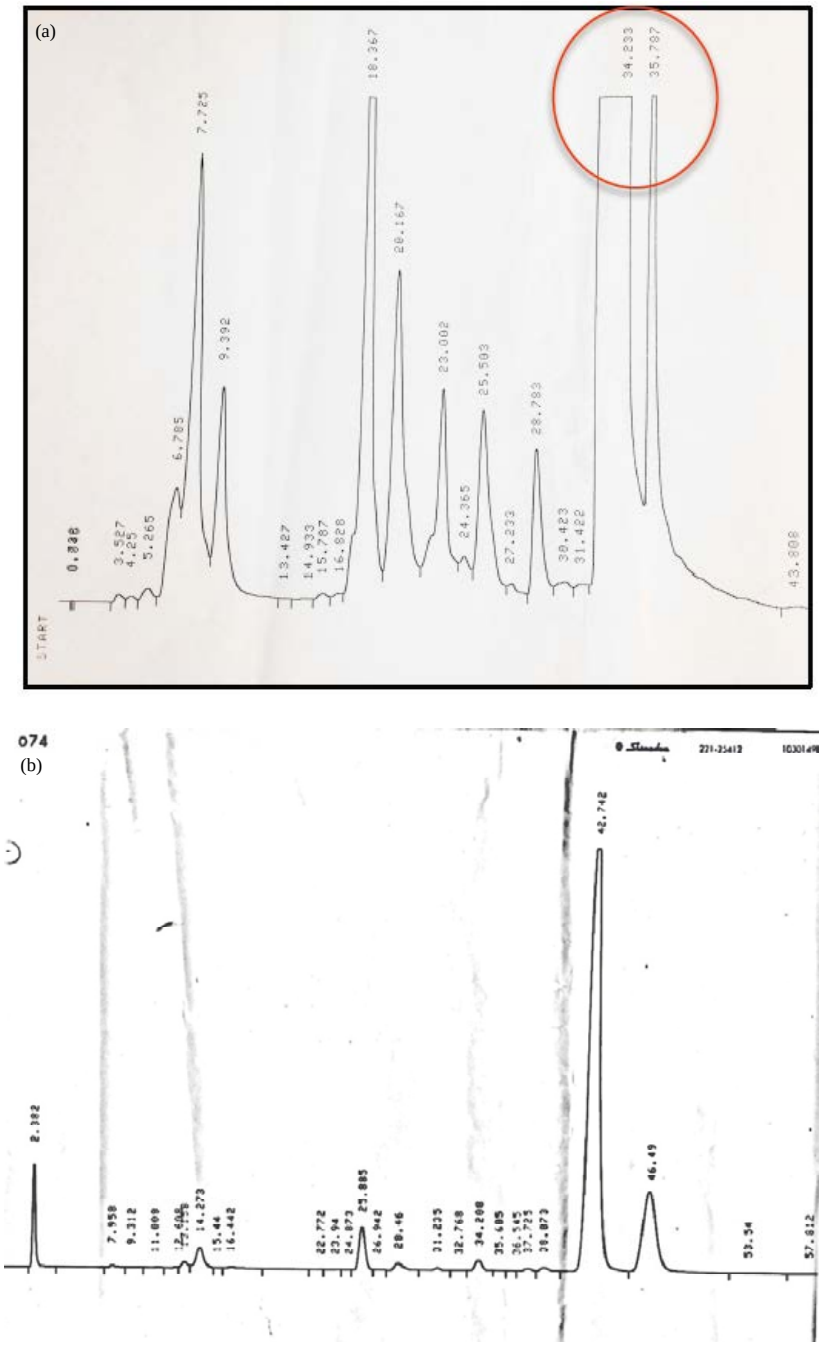

Fig. 3(a-b): Quantification of (a) Cinnamaldehyde and (b) Gingerols in the product using GLC technique

Self-experience: Self-experience of the respondents in different categories of employment in two establishments after consuming the developed product is given in Fig. 5a and b.

Figure 6a indicates that developed product was capable to fully control, satisfactorily control and no control of the respondents 15, 65 and 15%, respectively. According to the shift based workers (Fig. 5b) fully control, satisfactorily control and no control of the respondents were 27.5, 7.5 and 50%, respectively. As a whole, the product had the capacity to combat the MS for more than 80% of the respondents.

Reasons for this consequence are gustatory stung and tingling actions of the white pepper and ginger as well as astonish olfactory action of the aromatic flavours in cinnamon against MS. Further, chemical energy from caffeine acting

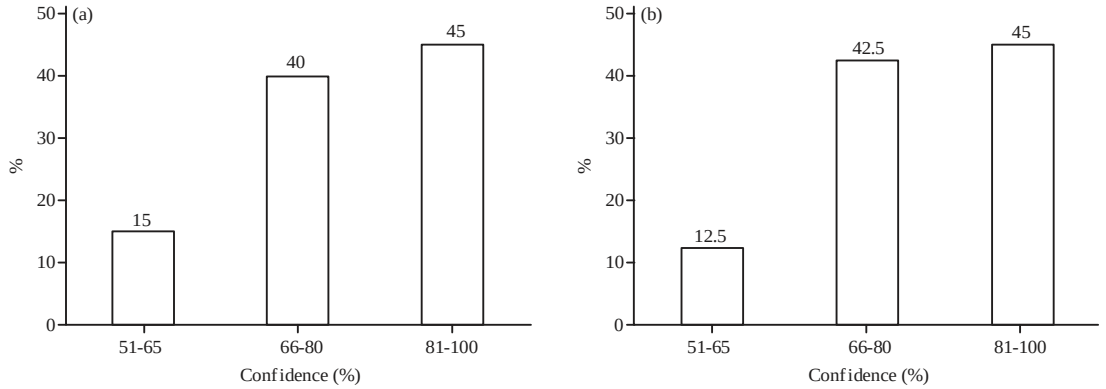

Fig. 4(a-b): Confidence level in combating micro-sleeping owing of the product

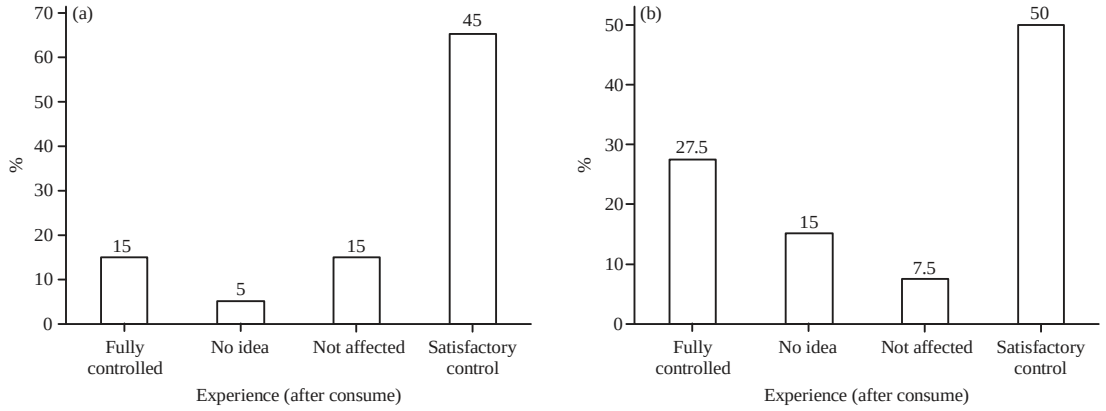

Fig. 5(a-b): Self-experience in combating micro-sleepiness after consuming the product

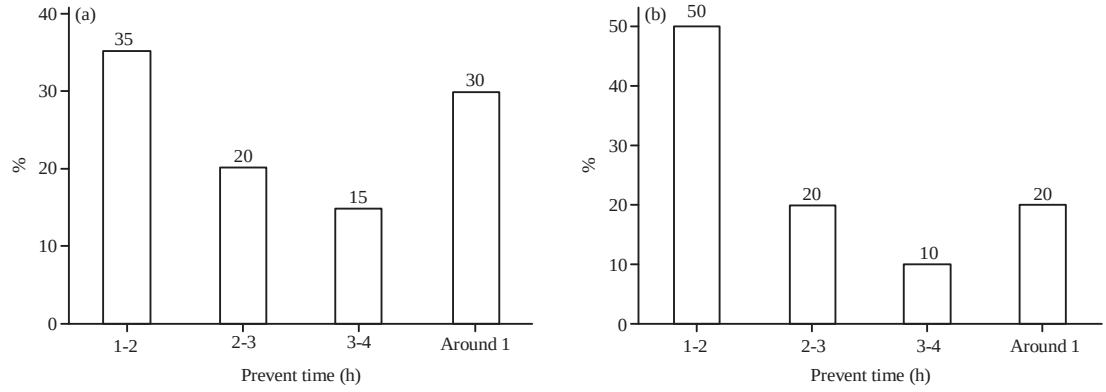

Fig. 6(a-b): Effective time period of micro sleepiness after having the product

against melatonin mechanism were influenced the brain stimulants and receptors which positively contribute to combat MS remarkably.

Effective time period: Effective time period against to combat MS in different categories of employment in two institutes after having the developed product is given in Fig. 6a and b.

The graphs in Fig. 6a and b clearly indicate that all most all the respondents had the experience to combat MS at least 1-2 h after consuming the developed product. Furthermore, by considering (Fig. 7a) 35, 30, 20 and 15% of the respondents

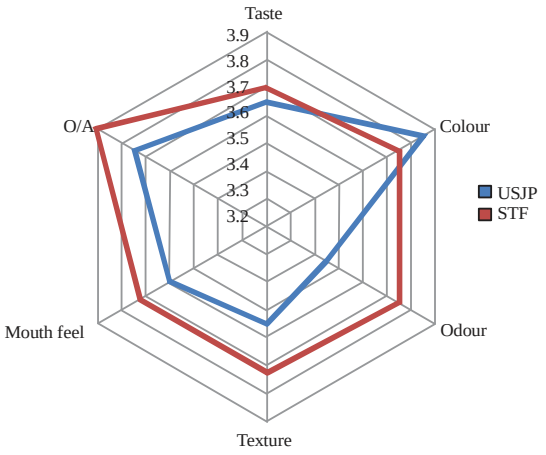

Fig. 7: Acceptable level of the sensory profile of the developed product

in USJP had 1-2, around 1, 2-3 and 3-4 h effective time period, respectively while shift based workers had 1-2, 2-3, around 1 and 3-4 h effective time periods of 50, 20, 20 and 10% respectively against MS.

In-house sensory evaluation for the developed product: The data gathered for the response of five sensory stimuli of respondents in two institutions (USJP, STF) (Fig. 7).

According to the web diagram (Fig. 7) most of the respondents in STF prefer the sensory attributes of the developed product. The mean score given for sensory stimuli colour, taste, mouth feel, texture, odour and overall acceptability by the respondents (USJP) 3.85, 3.65, 3.6, 3.55 3.45 and 3.75, respectively in the sensory profile. Moreover, response of the respondents in STF for the same sensory stimuli was 3.75, 3.65, 3.72, 3.55, 3.45 and 3.75, respectively. Hence, preferability of the developed product among STF was more than that of USJP respondents.

DISCUSSION

According to the national statistical data 0.539, 0.529, 0.817, 1.106, 0.578 and 1.208% of road accidents and 0.895, 0.934, 1.718, 2.074, 2.172 and 1.640% of fatalities have been reported due to driver sleepiness from 2010-2015 in Sri Lanka[3,7]. Whereas, it is estimated to underlie about 20% of car crashes in Europe in 2011, of that a total of 3970 fatal accidents took place on French roads, 732 cases level. So the product complies with the occurred on straight roads, 85% of which were reported due to sleepy driving. Further 25% of all fatal road accidents in Germany and 22% of road accidents in Italy have also been reported due to this psychological disorder[8,9]. There were three major zones have been identified for occurrence of MS as low risk zone (8-10, 14-16 and 18-20 h), manageable (10-12 h) and high-risk zone (14-16 h)[7].

Several studies have been carried out to detect and control sleepiness while driving. As automation technology has progressed, more and more modern functions such as pre-crash systems, advanced automatic collision notification, automotive night vision with pedestrian detection, lane departure systems, vehicle tracking systems, adaptive cruise control and adaptive headlamps have been incorporated to automobiles to assist drivers in controlling sleepiness[10].

Due to more comfort in modern automobiles, the person at the wheel inadvertently felt in to the state of MS. In order to cope with this situation high tech systems were introduced in to vehicles to monitor driver-behavior unintentionally, such as eye movement, facial feature movement, brain waves (using electroencephalography-EEG) and steering wheel grip[11]. Moreover previous experiments have also been carried out using coffee and similar caffeinated and decaffeinated drink. After having such drink immediately before a 15 min nap or 'doze' was also very effective way for drivers to overcome sleepiness for a short time span[9,12].

In this study, five major factors such as boosting the self-confident level, mortar function, gustatory stung action, astonish olfactory and tingling actions and chemical energy contribute to combat micro-sleepiness were identified and it can be controlled MS more than 1 h without any harmful effects and addiction for a considerable price.

CONCLUSION

Piper nigrum, *Coffea arabica*, *Cinnamomum verum* and *Zingiber officinale* were identified as the major raw materials for the development of the confection against MS based on the active ingredients, availability of raw materials, cost and intensity of availability of the active ingredients.

The S-7 sample was identified as the best initial product formulation and 247 sample was selected as the most acceptable product formulation with desirable sensory attributes after carrying out series of sensory evaluations which was having 0.8 ginger oleoresin, 1.8 cinnamon powder, 1.4 white pepper powder and 5% concentrated coffee extract.

The beneficial ingredients quantified in the final product were 12.727, 5.277, 1.333 and 0.533 mg of piperine, caffeine, cinnamaldehyde and gingerol, respectively.

According to the world standards (WHO) the product consists with natural ingredients in the approved

recommended level. So the product compiles with the excising local (Sri Lanka Standards Institution-SLS) as well as international standards.

The minimum confidence level to combat MS by owing the developed confection was 50%. Further, the developed product had the capacity to combat MS for at least 1-2 h effectively. So the product is capable to combat MS while driving, cramming and working in modern busy life styles without any adverse effects or allergies.

SIGNIFICANCE STATEMENTS

- The MS is a temporary biological disorder, which causes to fail responses for normal sensory stimuli and it has been a major episode for road accidents that leading to material losses, deaths, disabilities, numbness and significant economic losses
- According to available statistical data, over 1.3 million people die on the road and 20-50 m people suffer non-fatal injuries and 100,000 vehicle crashes and approximately 1,550 deaths, 71,000 injuries and $12.5 billion in monetary losses may occur each year due to MS
- There is no available data on plant based, ready to use and cheap confectionary to combat MS

To combat MS while driving, studying and working; a plant-based, effective, low cost and chewable confectionary have been developed using *Piper nigrum*, *Coffea arabica*, *Cinnamomum verum* and *Zingiber officinale*.

ACKNOWLEDGMENTS

The authors gratefully acknowledge Advanced Material Research Centre, Faculty of Applied Sciences, University of Sri Jayewardenepura, Sri Lanka for the financial support to conduct the research study. Division of Post Harvest Technology, Central research station, Department of Export Agriculture, Mathale, Sri Lanka for their great support to extract active ingredients in the product and further analyzing process.

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