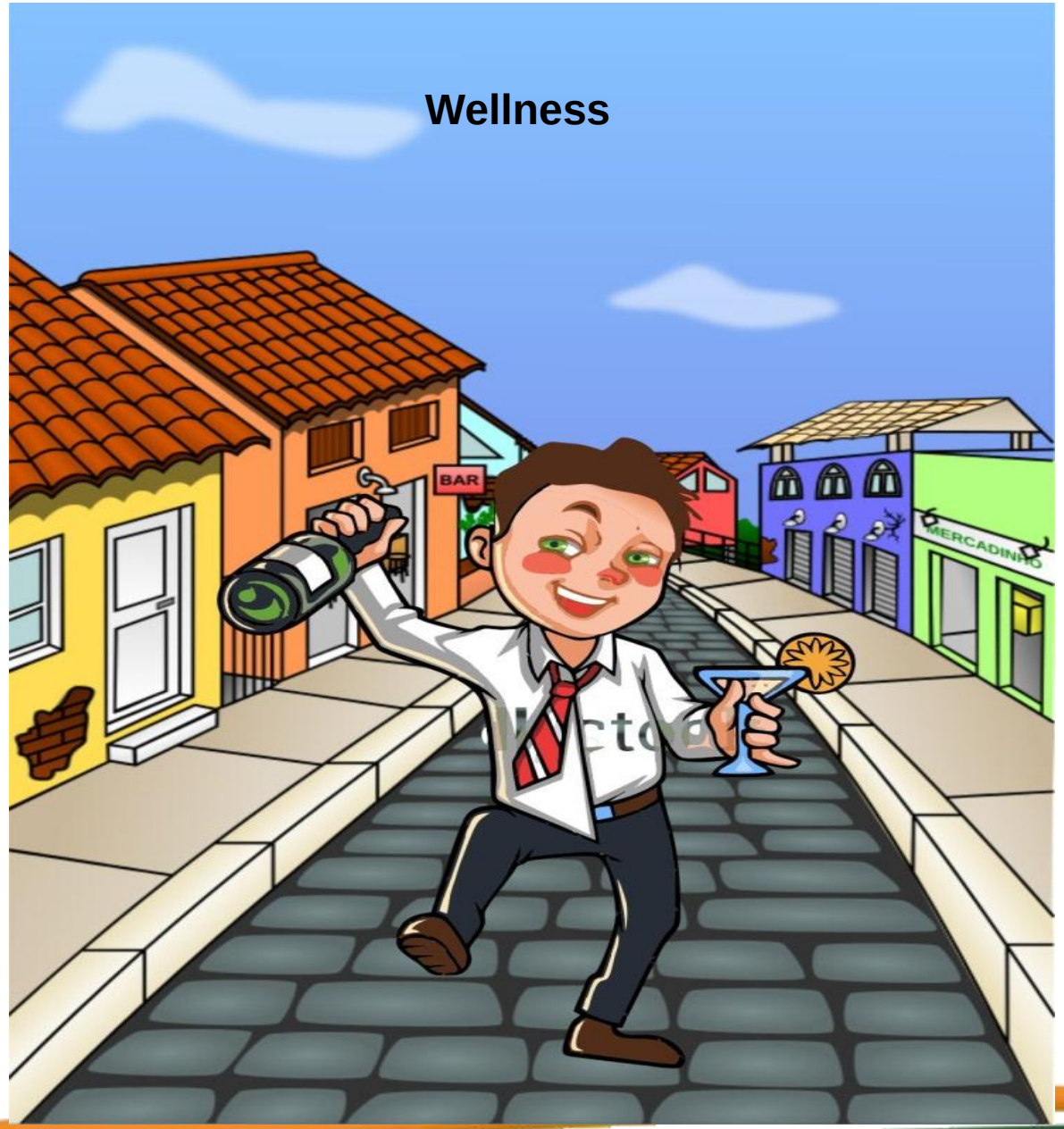
New perspectives on functional diets: The case of tea.

By Francis N. Wachira



"The doctor of the future of the future will no longer treat the human frame with drugs, but rather will cure and prevent disease with nutrition"- Thomas Edison

Humans have for centuries attributed diets to health

Functional foods

Foods with **medical or health benefits** beyond basic nutrition because of the presence of physiologically active compounds are called Functional foods.

Concept of functional foods - first developed in Japan in the 1980s.

Increasing evidence that some foods have physiological or health enhancing properties.

Functional Food	*Key Component*	*Health Benefits*
Broccoli	**Sulforaphane, fibre**	**Reduce risk for cancer**
Fish	**Omega-3 fatty acids**	**Reduce risk for heart disease**
Fruits and Vegetables	**Phytochemicals, carotene, flavonoids**	**Reduce risk for cancer and heart disease**
Garlic	**Sulfur compounds**	**Reduce risk for cancer and heart disease**
Oats	**Soluble fiber, beta glucan**	**Reduce cholesterol, Gastrointestinal health, antihypertensive**
Soy foods	**Soy protein, plant steroids, saponins**	**Reduce cholesterol, mimic oestrogens (HRT)**
Tomatoes	**Lycopene**	**Reduce risk for cancer**
Yogurt/fermented dairy prodts	**Probiotics**	**Improve gastrointestinal health, stimulate immunity**
Purple grape juice	**Polyphenolic compounds**	**Support normal, healthy cardiovascular function**

AGRICULTURE IN KENYA

- Agric. contributes to economic devt.: 24% of GDP and 65% of total export earnings.
- Cash crops are a major source of export revenue in Kenya: **tea**, horticulture, coffee account for 65% of the country's export earnings.
- **Tea - 4% of GDP and 26% of all export earnings**.
- The Compound Average Growth Rate (CAGR) in agriculture in 2001-2010 was 5.2%, export growth was much higher, at 8% indicating the potential for growing the export capacity of agricultural products including tea.
- About 65% of the production is by small scale farmers.

The tea value chain in Kenya is strong

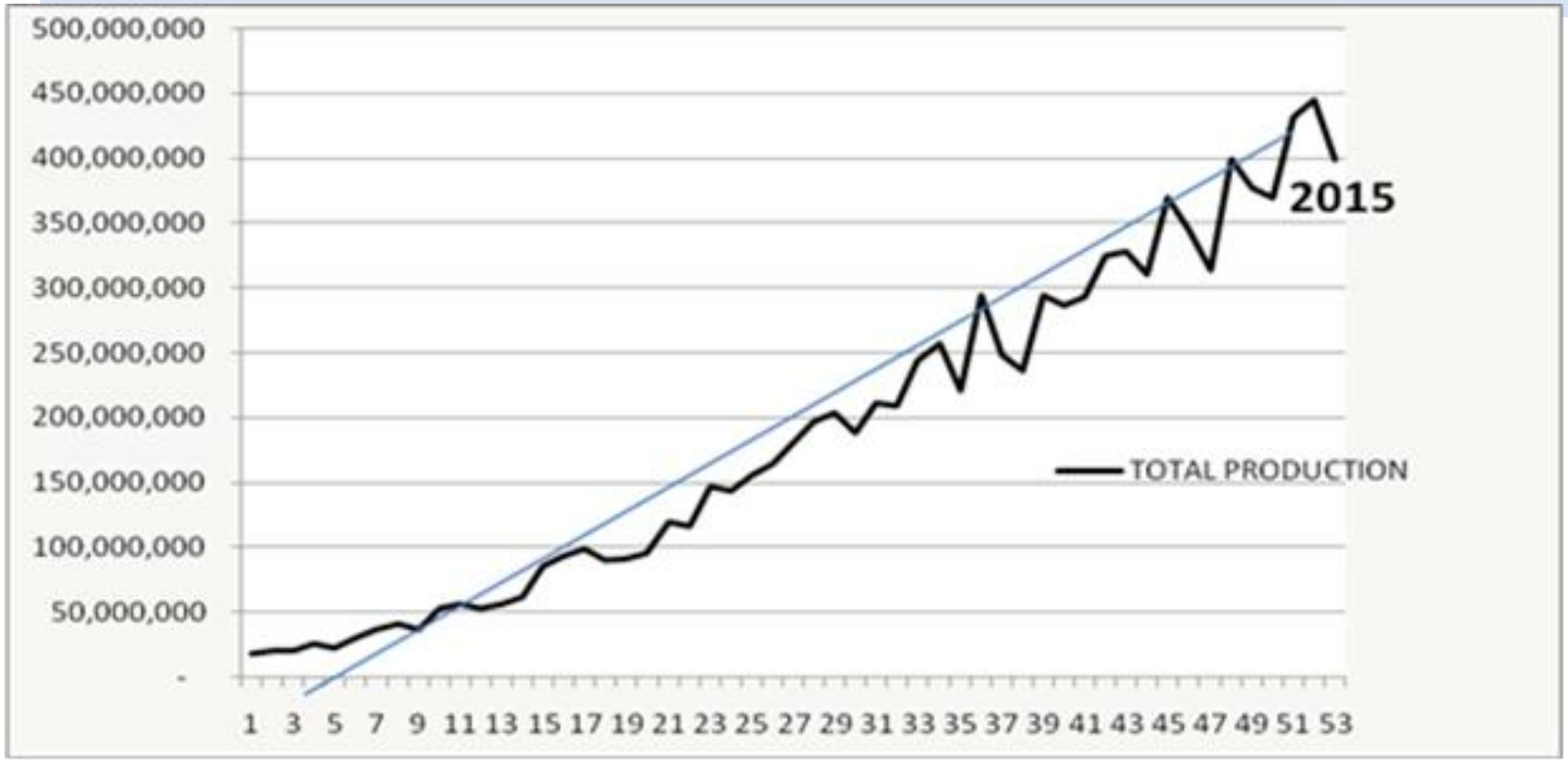
Specific Inputs	Production	Transformation	Commerce & Trade	Consumption
Functions				
- Propagation and Supply of clonal seedlings. - Supply of agro-chemicals and fertilizers - Supply of information to farmers - Supply of farm implements	- Planting of clonal seedlings - Weeding, fertilizing, spraying - Bringing tea into bearing (pruning) - Harvesting - Sorting of leaf - Hiring offarm workers and Labourers - Delivery of leaf to a green leaf collection center -Post-harvest handling (grading included) - Certification	- Purchase of green leaf. - Leaf sorting at leaf collection center - Loading and Transportation of leaf to factory - Primary Tea processing - Grading - Bulk Packaging - Tea packing for domestic market - Certification	- Transportation of processed tea to ware houses - Storage and Post-harvest handling in ware houses - Sale of tea at auction center in Mombasa - Direct exportation	- Consumption of processed tea
Participating actors				
- Nursery owners - Agrochemical and fertilizer dealers - KTDA Extension agents and TRI researchers - Farm implement dealers - Transporters - Regulators (KEBs, PCPB, AFA)	- Small- andlarge scale farmers - Producers' associations/Organisations (KTDA, KTGA) - Outgrowers - Seasonal labourers - Regulators (AFA) - Labour Unions	- Green leaf clerks - Transporters - Processors/ Factory personnel - Wage labourers - Labour Unions	- Brokerage firms/Agents/traders - Wholesalers/retailers (supermarkets) - Transporters - Exporters and Marketing agencies (eg EATA) - Importers/buyers - Standards organizations	- Households (urban, domestic & export) - Hotels - Restaurants

Highly integrated (vertical And Horizontal Linkages)

Kenya's small holder tea sub-sector is well established

The SmallholderTea sub-sector is a good model of farmer empowerment.
(Farmers share of the profit from tea is on average about 70%)

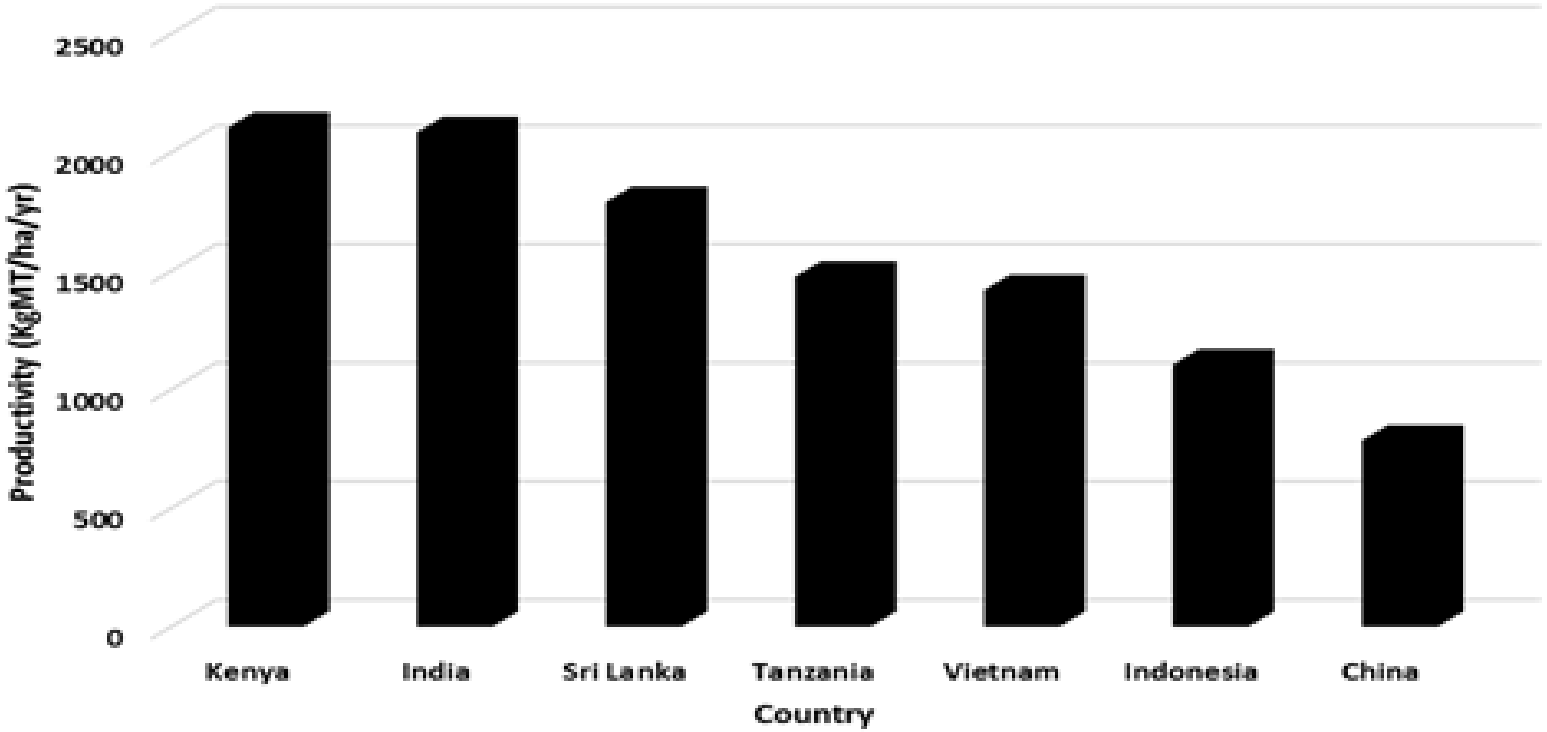
Kenyan Tea industry has in the past done well



Total tea production (Tons) from 1963 to 2015.

Linear growth- But-For how long?

Kenyan tea industry has been competitive this far

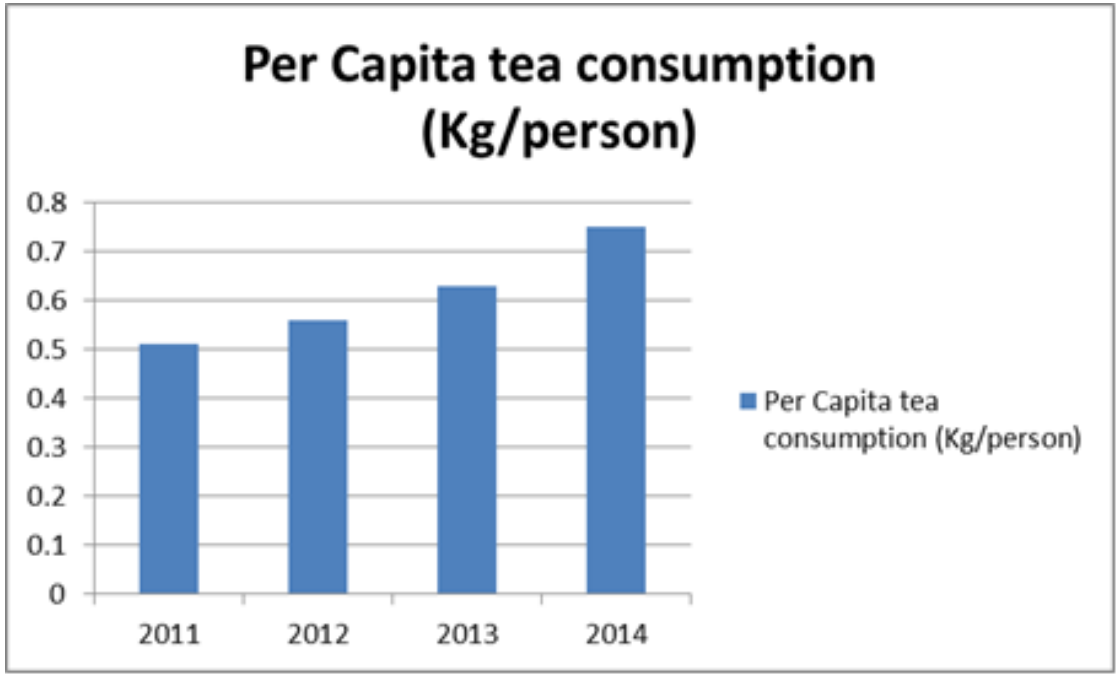


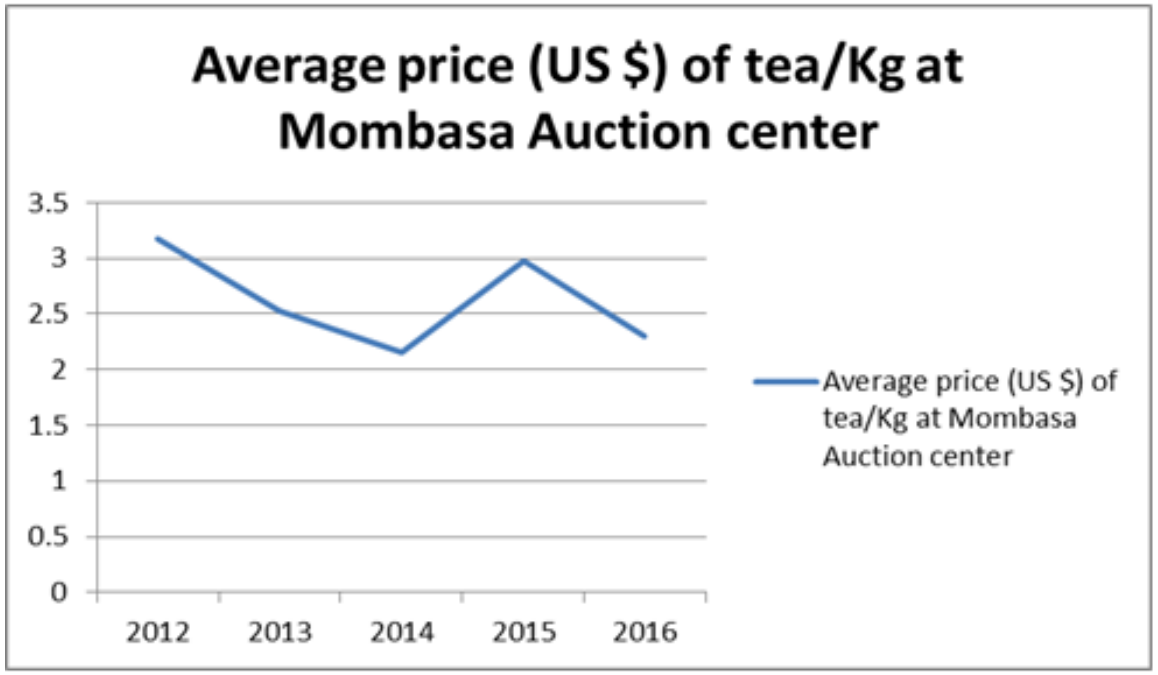
Yield gap Between Smallholders And Estates remains.

Tea productivity in major producing countries in 2015

(Source: International Tea Committee: Annual Bulletin of Statistics – 2016)

Kenya Tea industry remains export oriented



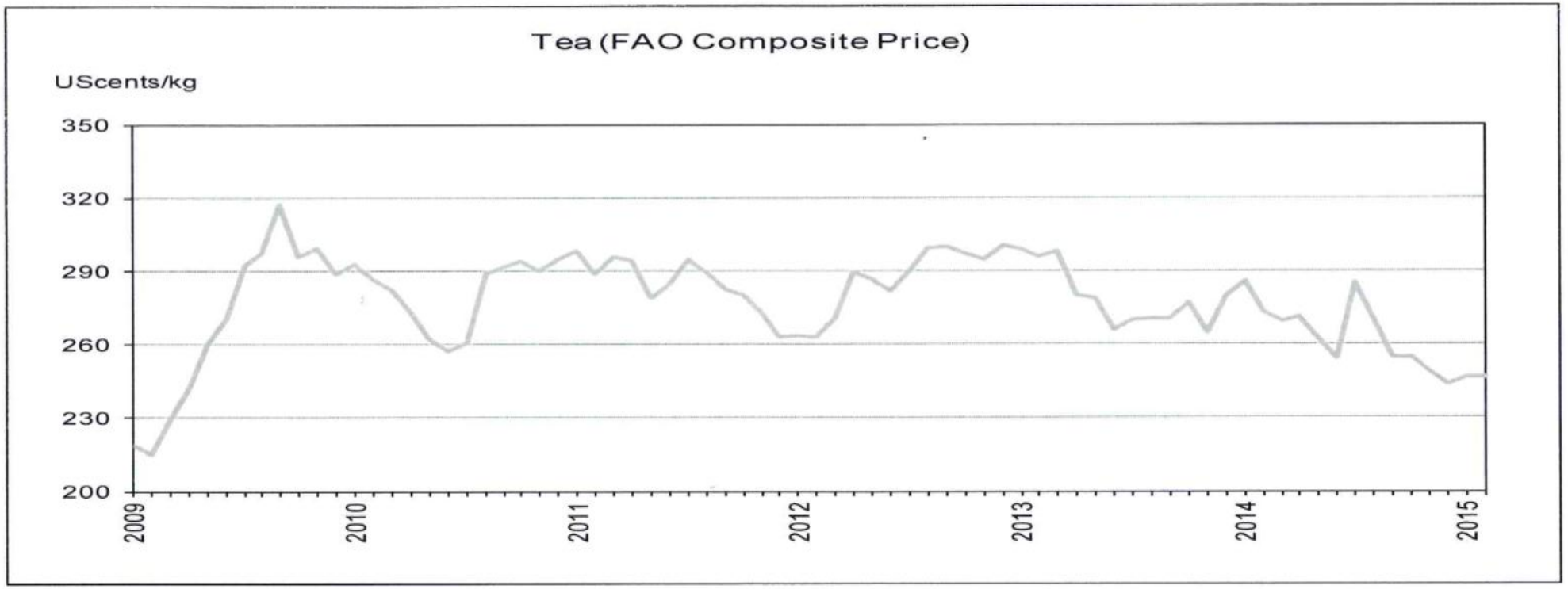


Low domestic consumption

Auction prices have generally stagnated (same for FAO composite prices), Markets are getting limited, Production costs are increasing.

Reduced (MRR) Net returns?

Global Tea prices have stagnated or declined



Source: FAO IGG Secretariat

Global tea prices are inelastic and have declined from 2009

Returns to small holder farmers have declined

How sustainable is the Kenyan tea business model?

KENYA PREDOMINANTLY PRODUCES CTC BLACK TEA

Little product diversification and value addition

Kenya must grow her sales

Growth of tea sales will be driven by

Product Convenience/

New Applications

Product Functionality eg

Health / Wellbeing of consumer

Taste experience

HOW IS THE INDUSTRY RESPONDING TO THESE TRENDS?

What are the opportunities?

2010 STRATEGY TO MARKET KENYAN TEA AS A FUNCTIONAL PRODUCT

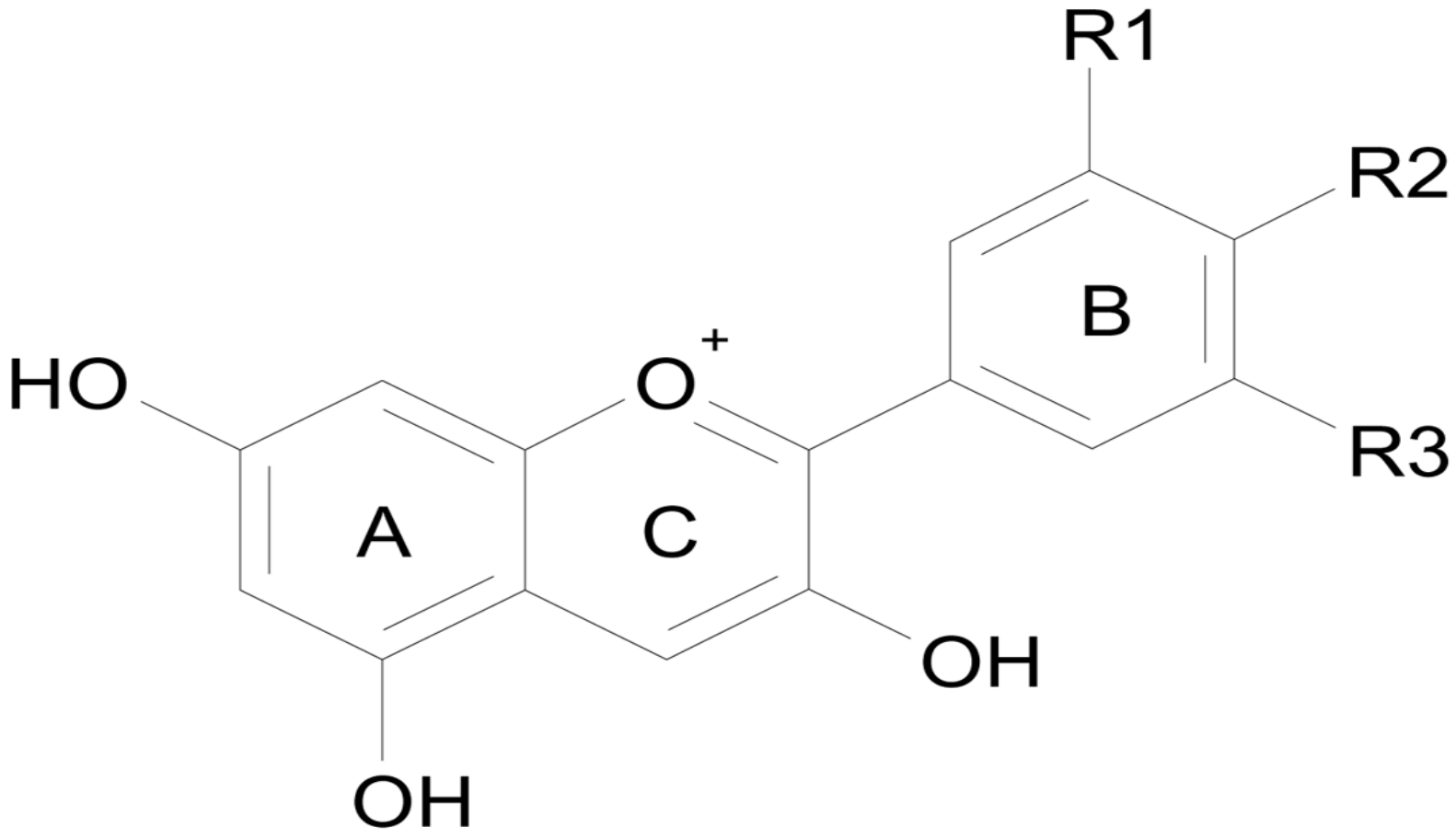
Tea for better health

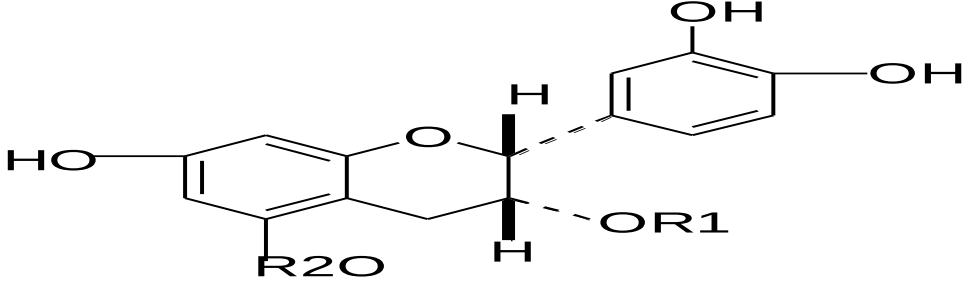
HAVE YOU HAD YOUR CUP TODAY ?

Greater understanding of the Chemistry of Tea

- Chemical composition of tea leaf is complex: polyphenols (flavonoids), alkaloids, amino acids, minerals and other compounds.
- Polyphenols (flavonoids) are the main bioactive molecules (antioxidants)

BIOACTIVE FLAVONOIDS- The flavylium cation

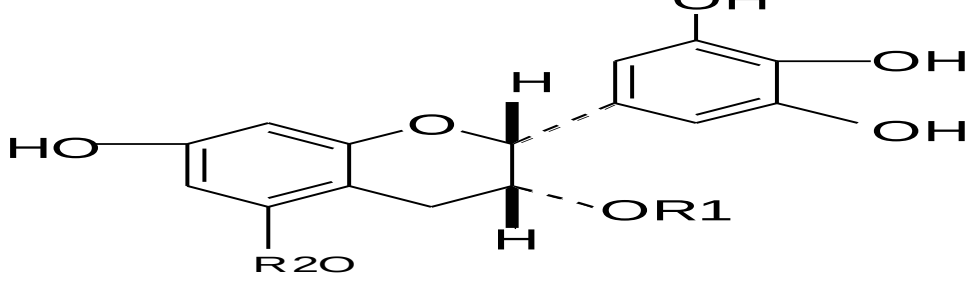




i (-)-epicatechin
R1=R2=H

ii(-)epicatechin-3-gallate
R1=3,4,5-trihydroxy-benzoyl
R2=H

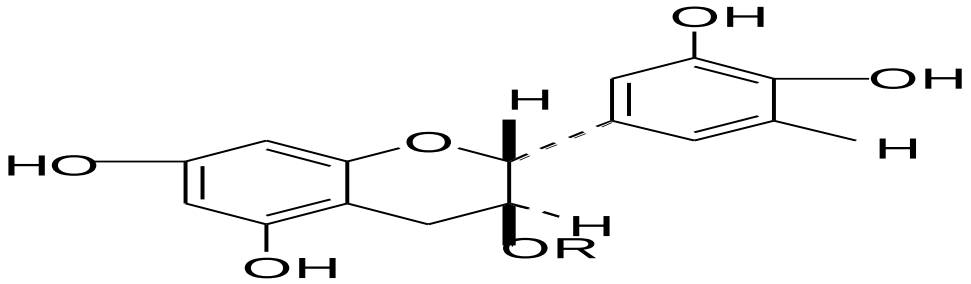
iii(-)-epicatechin-3-digallate
R1=R2=3,4,5-trihydroxybenzoyl



i (-)-epigallocatechin
R=R2=H

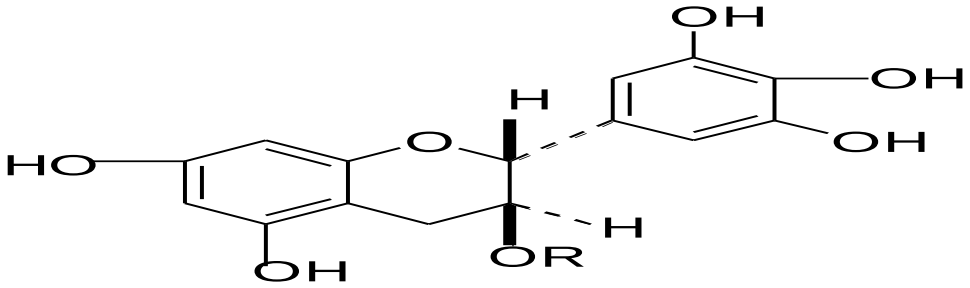
ii(-)-Epigallocatechin-3-gallate
R1=3,4,5-trihydroxybenzoyl
R2=H

iii(-)-Epigallocatechin-3,5-digallate
R1=R2=3,4,5-trihydroxybenzoyl



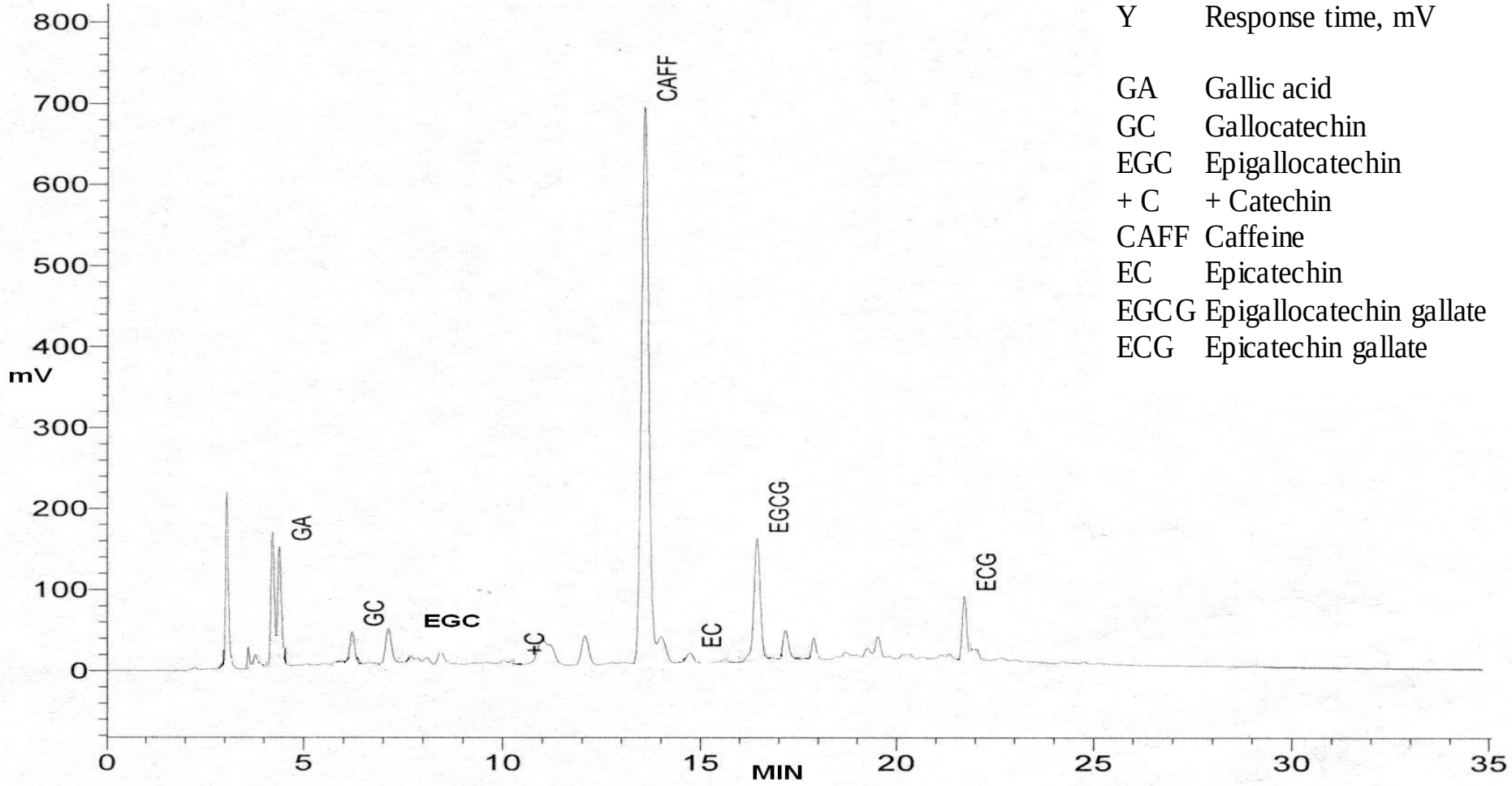
i(+)-epicatechin
R=H

ii(+)-catechin-3-gallate
R=3,4,5-Trihydroxybenzoyl



i(+)-Gallocatechin
R=H

ii(+)-Gallocatechin-3-gallate
R=3,4,5-trihydroxybenzoyl



Key

X	Retention time, min
Y	Response time, mV
GA	Gallic acid
GC	Gallocatechin
EGC	Epigallocatechin
+ C	+ Catechin
CAFF	Caffeine
EC	Epicatechin
EGCG	Epigallocatechin gallate
ECG	Epicatechin gallate

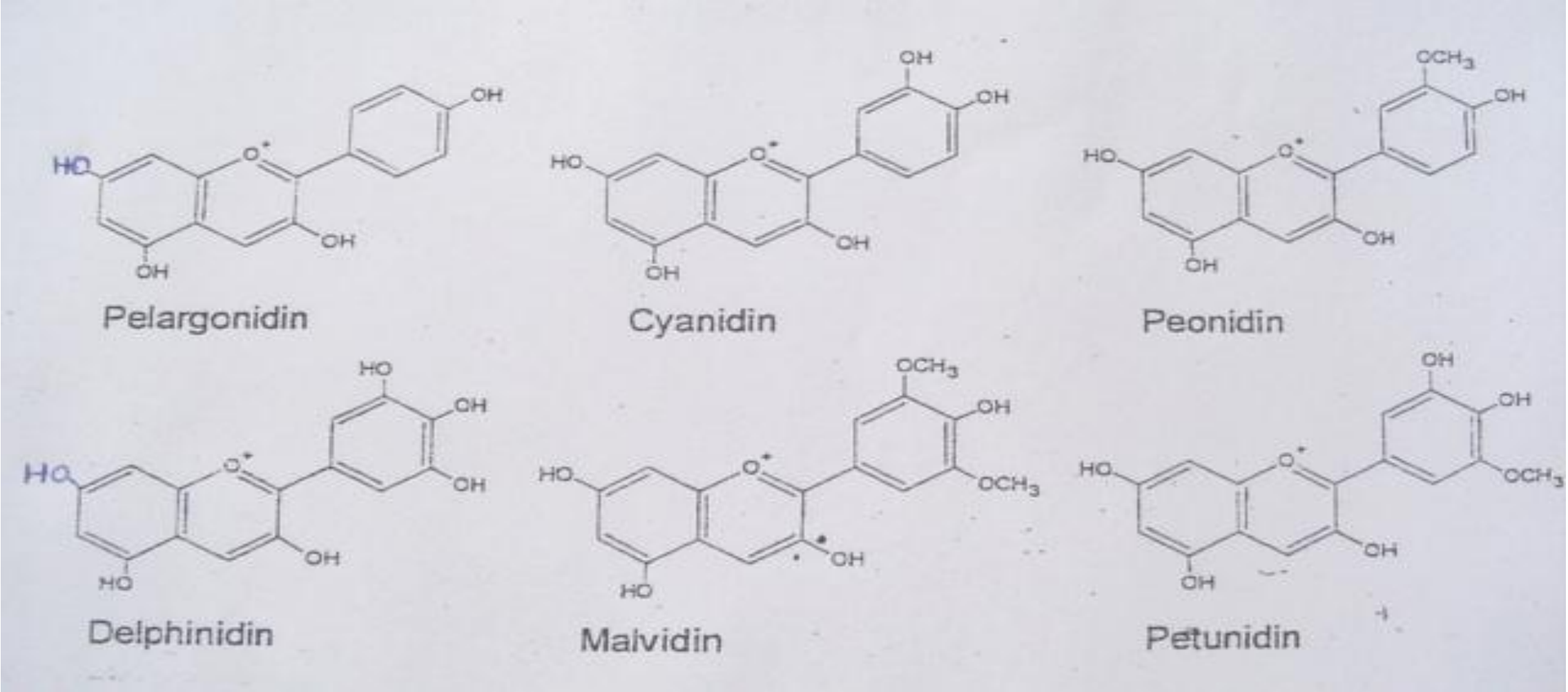
A high performance liquid chromatogram of green BP CTC Kenyan tea sample.

DEVELOPMENT OF MORE BIOACTIVE TEA GERMPLASM

Anthocyanin/Anthocynidin rich tea

Tea rich in catechins, Theanine, GABA, Caffeine other alkaloids

Major Anthocyanidins in unique tea germplasm

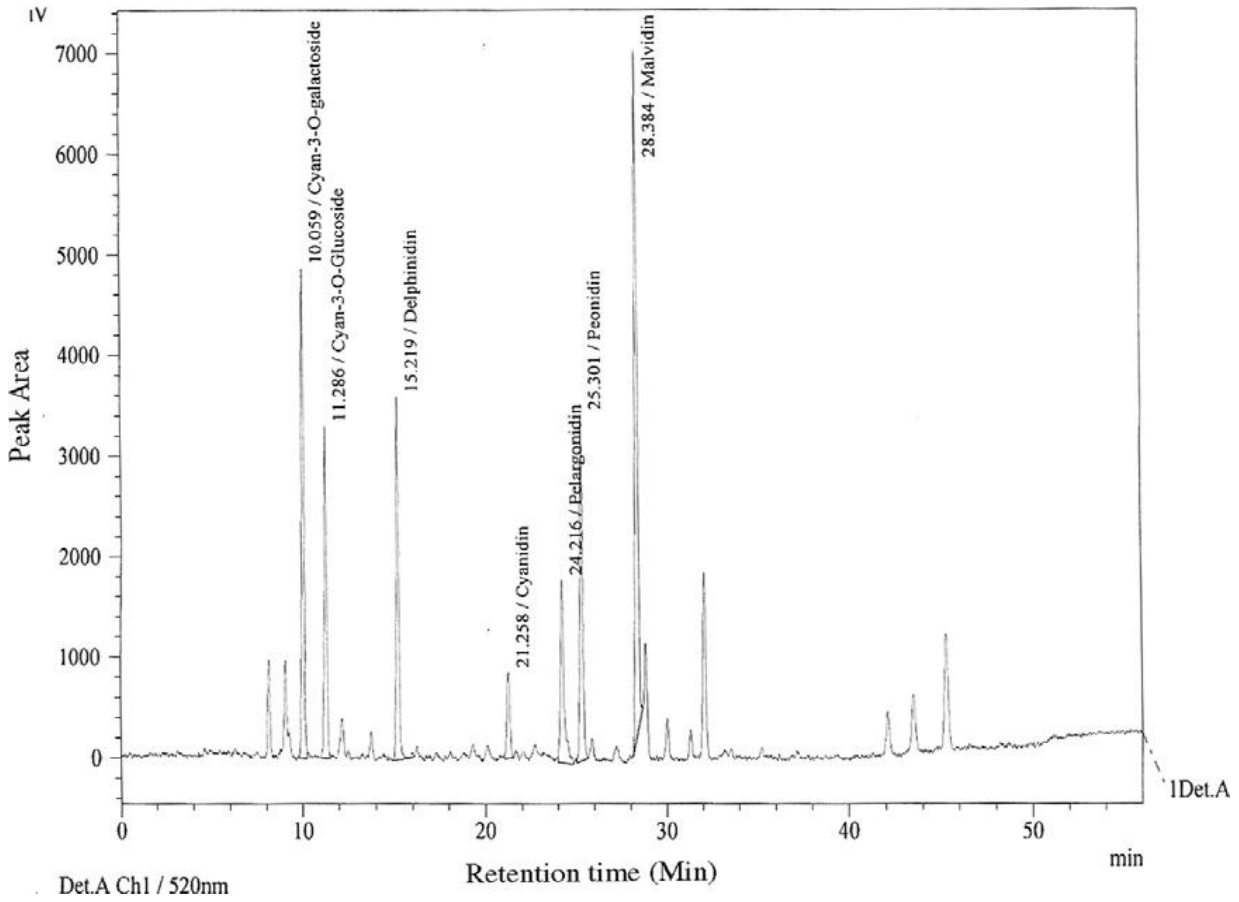


Anthocyanins (ACN) in Kenyan Tea

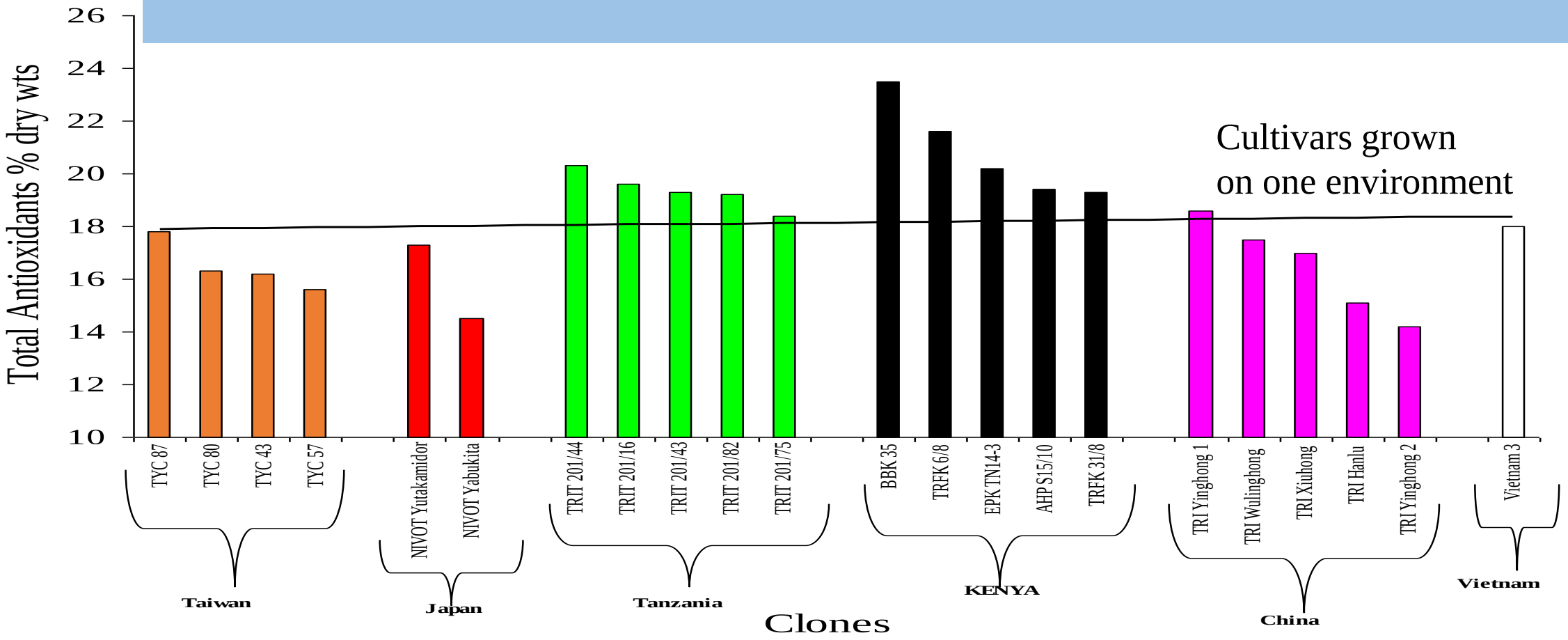
- ACN & anthocyanidins in tea are similar to those in **red wine** (Malvidin, cynidin, delphidin and pelagonidin- Prevalent)

- Anthcyanins are potent antioxidants with **anti-aging** properties

- Unique polyphenol (1,2-di-Galloyl-4,6-Hexahydroxydiphenoyl-D-Glucose)(**GHG**) not in green tea found in purple tea- **anti-obesity**



POPULAR KENYAN TEA CULTIVARS ARE RICH IN TOTALS POLYPHENOLS



Kenyan germplasm can process polyphenol rich tea or be used as raw material for extraction of total polyphenols; high out turn of Total polyphenols

Diversity of Tannin content in Kenyan tea clones

Tannin	Lowest(%) W/W	Highest(%) W/W
Epigallocatechin (EGC)	1.59	17.62
Epigallocatechin gallate (EGCG)	0.00	10.05
Epicatechin (EC)	0.00	4.50
Epicatechin gallate (ECG)	2.61	8.60
Caffeine	0.35	4.87

Kenyan tea can be used:

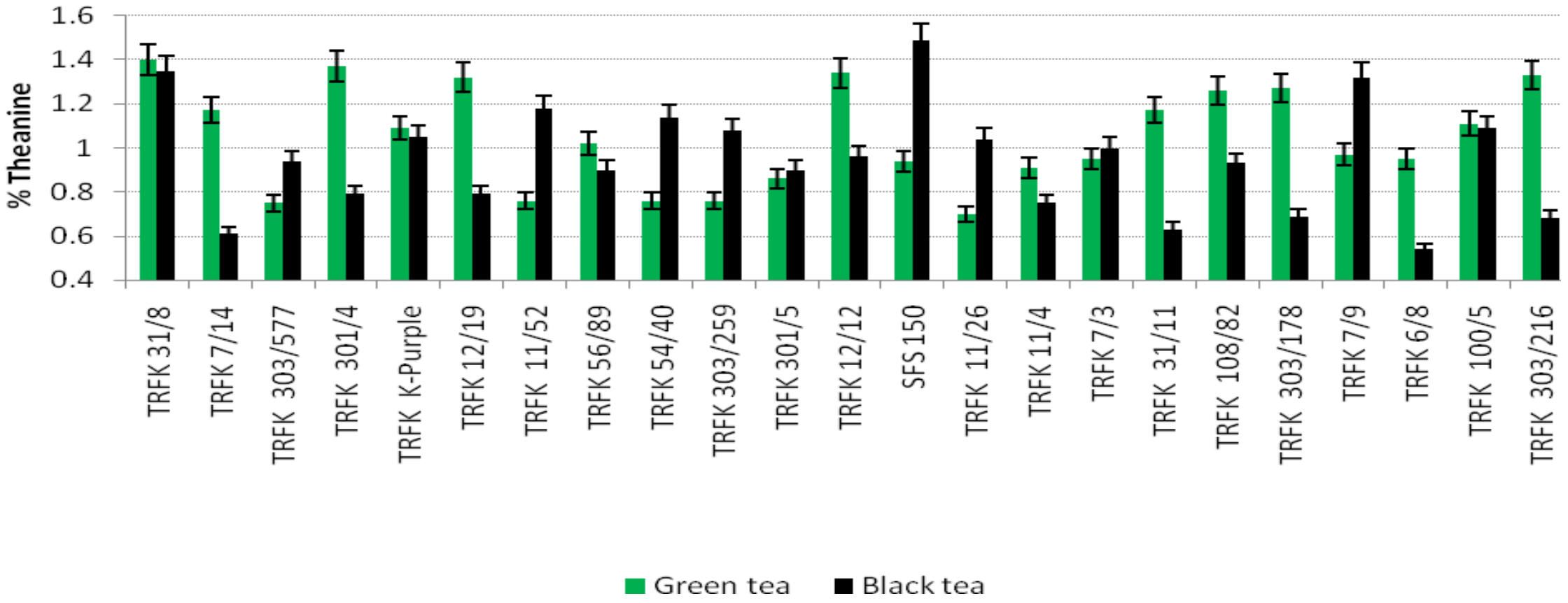
- To process diversified tea products;

Teas rich in specific catechins eg trihydroxylated catechins

Teas with different levels of alkaloids eg low caffeine

- To extract catechins- high out turn of catechins

TEA CONTAINS THEANINE A UNIQUE NON-PROTEIN AMINO ACID



Theanine has anti-hypertensive properties

Functionality: Health and Wellbeing

- **Diseases- imbalance between ROs/Anti-oxidants**
- **Endogenous antioxidant defense mechanism is insufficient .**
- **Need to supplement with dietary sources. Tea is a good source.**

PHARMACOLOGY OF TEA

Health outcome

Research to develop empirical data on the pharmacology of tea

Mechanism of action

Tea consumption

Tea has potent anti-0xidant properties

1. FL-OH + $R^{\cdot}$ → $FLO^{\cdot}$ + RH (scavenging rxn)
2. $FLO^{\cdot}$ + $R^{\cdot}$ → FLO-R (radical- radical
3. $FLO^{\cdot}$ + $FLO^{\cdot}$ → FLO-OFL coupling rxn)

FL-OH - Flavonoid, $R^{\cdot}$ - Free radical
$FLO^{\cdot}$ - Flavonoid phenoxyl radical

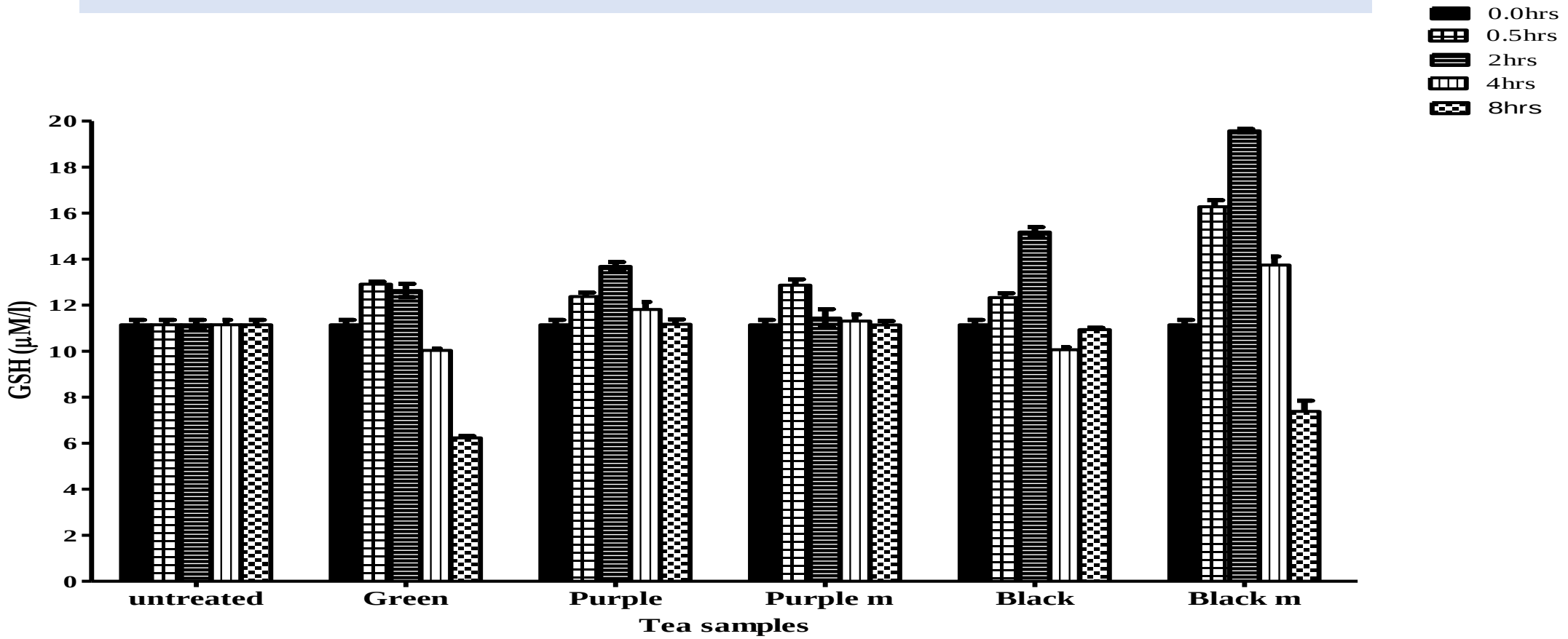
Addition of Milk lowers AA activity (%) of tea

Milk concentrations (%)	Antioxidant activity (%) – *In vitro* DPPH Assay	
	Green	Black
0	92.34 a	91.28 a
2	91.65 ab	90.59 a
4	91.20 abc	90.07ab
6	90.52 bc	88.91 abc
8	90.01 bc	88.01 bc
10	89.49 c	86.93 c
20	87.13 d	81.37 d
40	79.61 e	56.05 e
Mean	88.94	84.17
C.V. (%)	1.21	1.78
LSD	1.756	2.442

Flavourings/sweeteners can impact the antioxidant properties of a tea

Tea Treatment	Antioxidant Activity (%)- *In vitro* DPPH Assay	
	Plain Black Tea	Milk Fortified Black Tea
No sweetener	**91.57 a**	**84.19a**
0.1g stevia/100ml	**91.57 a**	**84.98a**
0.3g stevia/100ml	**90.48 a**	**84.61 a**
3g sugar/100ml	**84.13 b**	**75.15 b**
10g sugar/100ml	**46.48 d**	**44.68 d**
3g honey/100ml	**54.22 c**	**46.53 c**
10g honey/100ml	**37.14 e**	**33.05d**
C.V (%)	**2.8**	**3.75**
LSD	**3.2**	**4.07**

Effect of tea on Glutathione (GSH) levels in Plasma in animal model



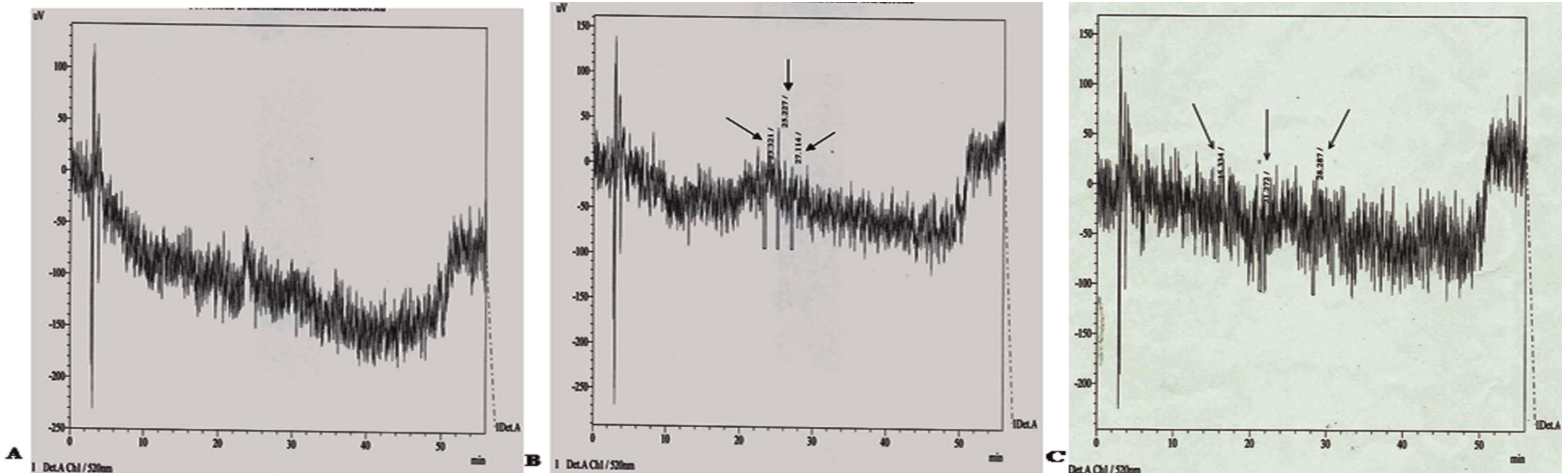
Highest levels of GSH were generally recorded after 2 hrs .

Kenyan Black teas have the highest levels while green teas showed the lowest.

Tea enhances tissue GSH

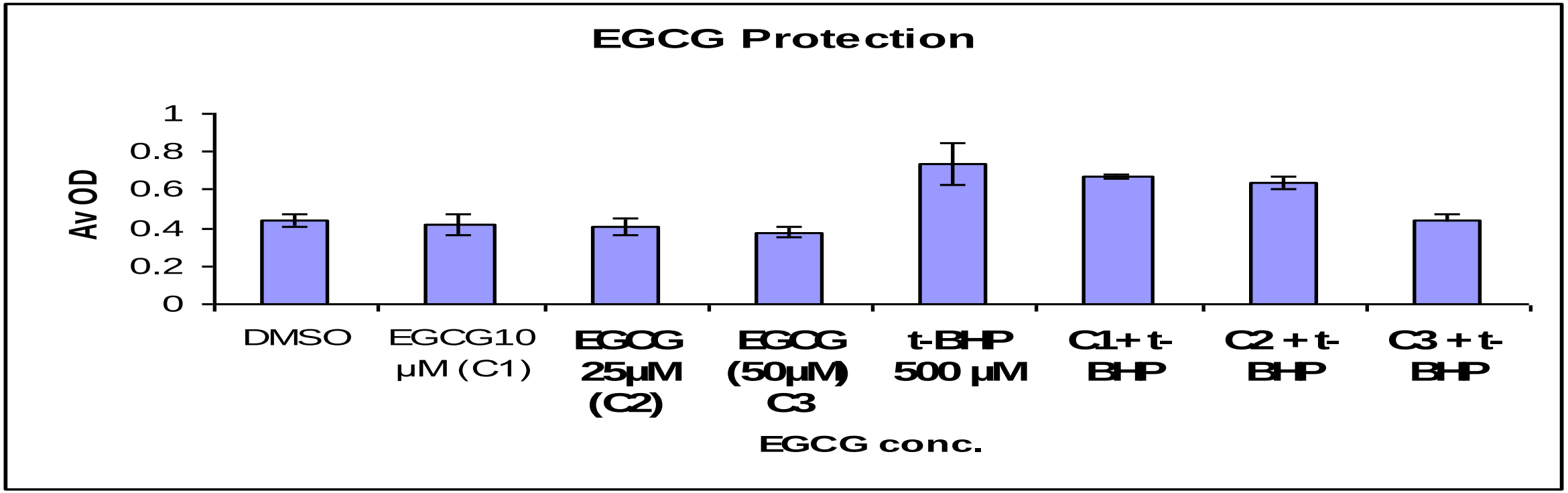
- Different types of tea significantly enhance GSH in kidney, liver and Brain
- Peak levels are attained 2-3 hrs after consumption of tea

TEA ANTHOCYANINs PASS THRO' THE BLOOD BRAIN BARRIER AND ENHANCE BRAIN ANTIXIDANT CAPACITY



HPLC Chromatogram showing tea Anthocyanin (ACN) metabolites in brain homogenate of animals fed on anthocyanin rich tea (B): (A)- Negative control (not fed on ACN rich tea),
(C)- Positive control (Fed on Co-Q10)

Tea catechin attenuates against oxidative stress (LDH leakage) in Human embryonic kidney cells (HEK 293 WT)



DMSO- Control, t-BHP causes oxidative stress, EGCG reduces LDH leakage from HEK cells in a dose dependent manner.

Tea lowers parasitemia in Trypanosoma infected animal model

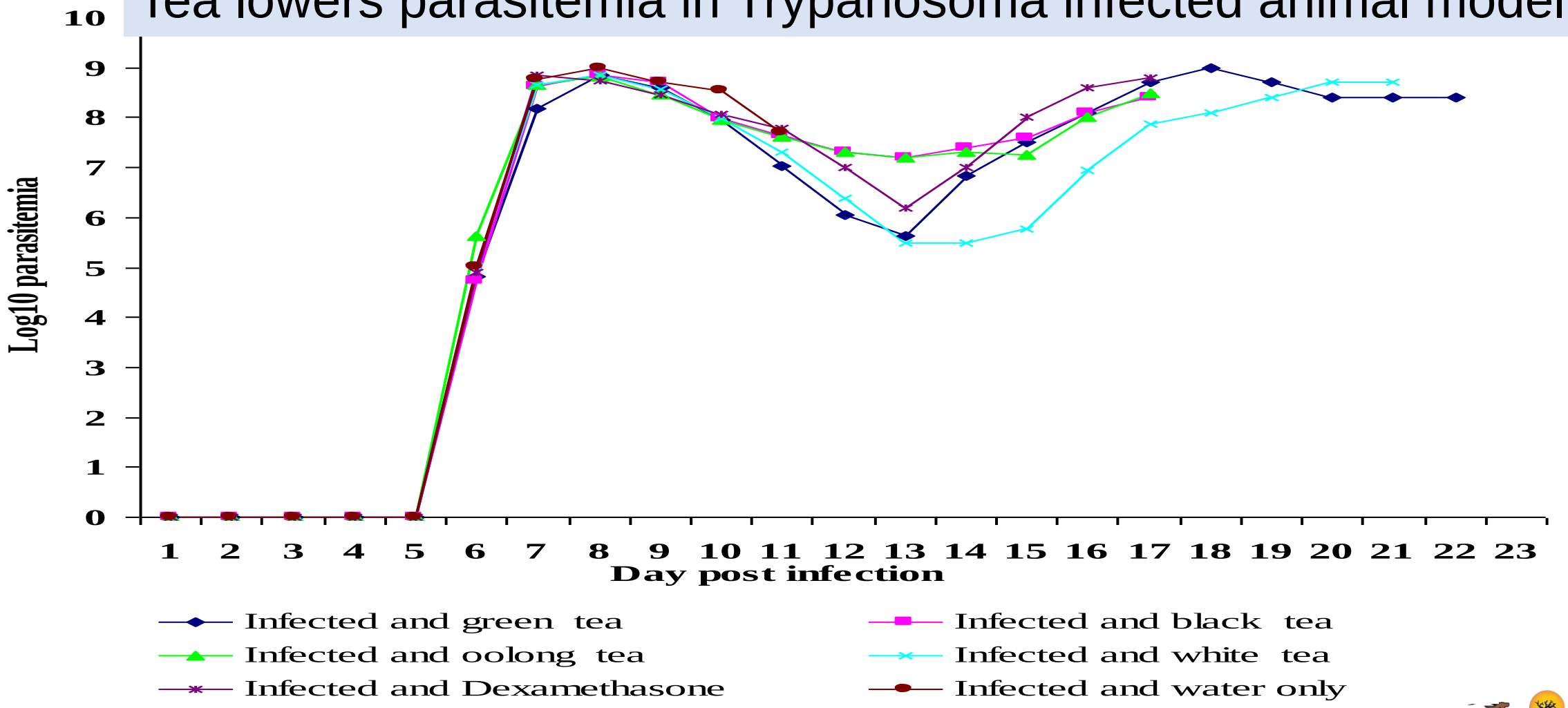
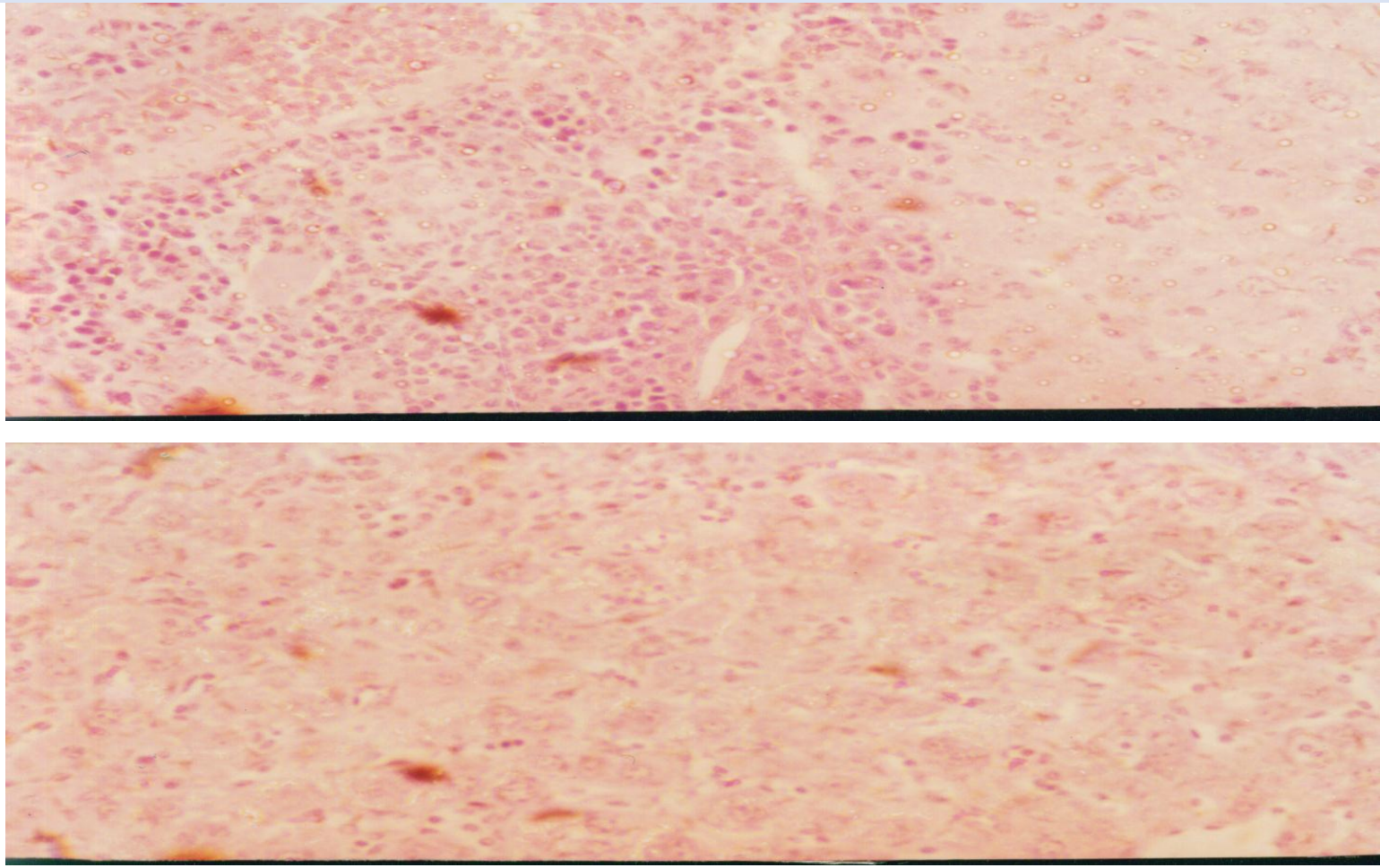


Figure : Time course of *Trypanosoma brucei brucei* stabilate KETRI 2710 for different treatments plotted as Log10 of parasites per milliliter of blood; the scale is linear and ranges from 0-10

Tea ameliorates effects of chronic inflammation in the liver



Water only

White tea

Figure: Representative liver sections showing histopathological profiles of mice infected using *Trypanosoma brucei brucei* and given water only (top) and white tea (bottom) as seen on day 7 post infection. The liver sections were stained with hematoxylin and eosin dyes and magnified at x1875

Tea elongates survival of Trypanosoma infected animals

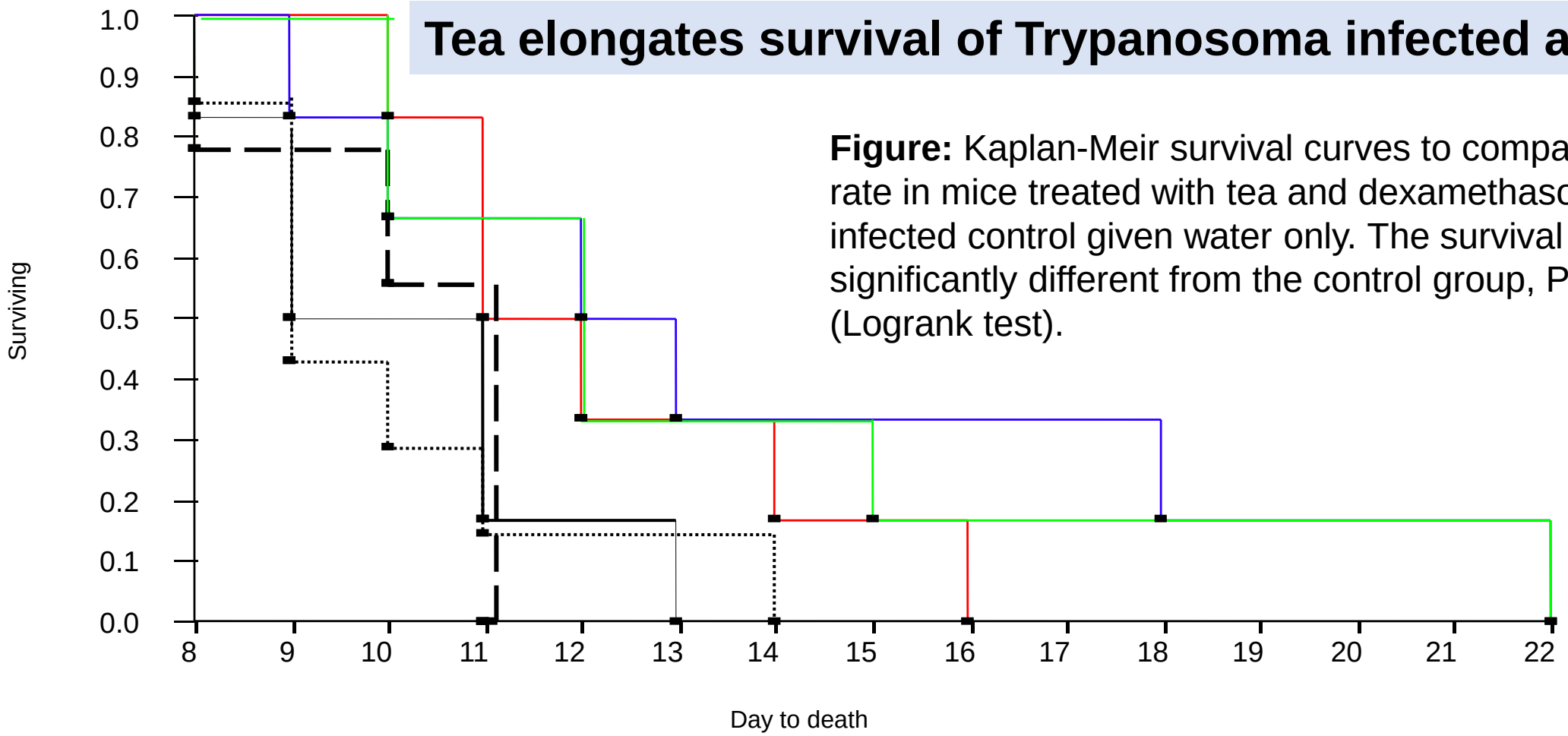
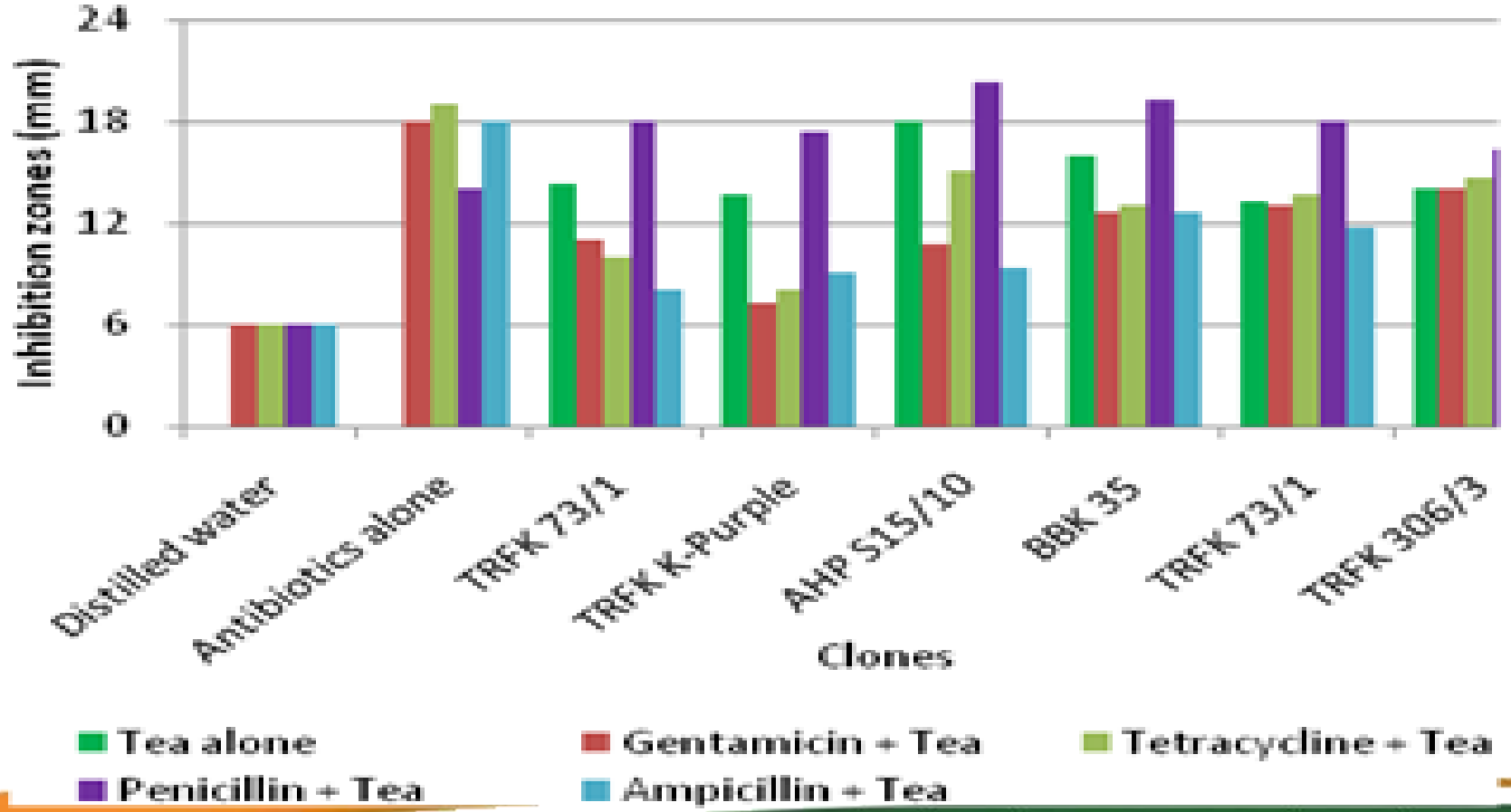


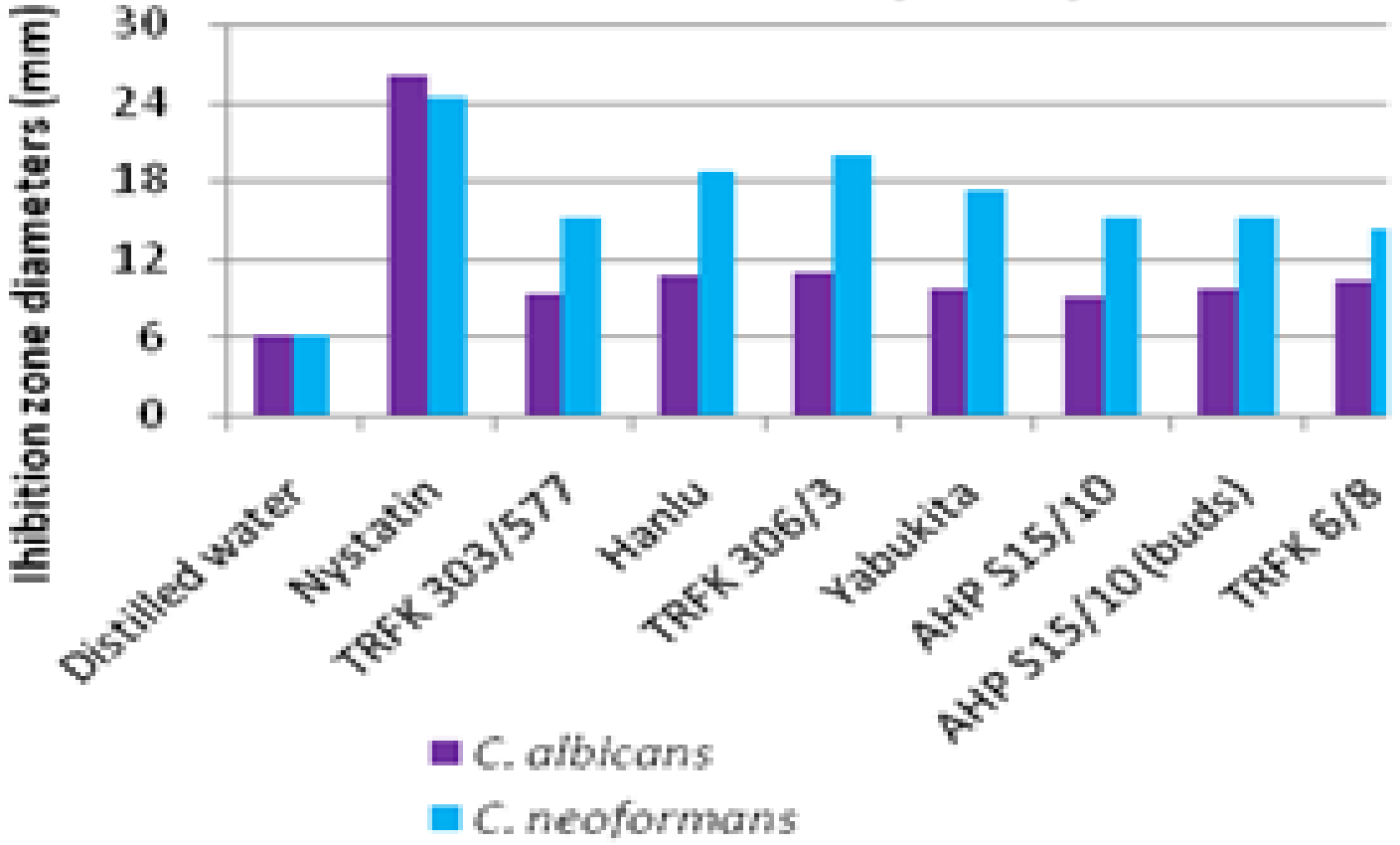
Figure: Kaplan-Meir survival curves to compare survival rate in mice treated with tea and dexamethasone with the infected control given water only. The survival rates are significantly different from the control group, $P<0.05$ (Logrank test).

Evidence of antimicrobial properties of Kenyan tea

- Kenyan tea extract has antibacterial activity.
- Tea has synergistic properties when used with antibiotics (Tea + Penicillin) even against Antibiotic resistant bacteria e.g. methicillin and penicillin resistant *S. aureus*



Kenyan Tea extracts have antifungal properties



➡Kenyan tea extracts have antifungal properties against *Candida albicans* ATCC 90028 and *C. neoformans* were susceptible to tea extracts.

Tea inhibits proliferation of breast cancer cells

Control

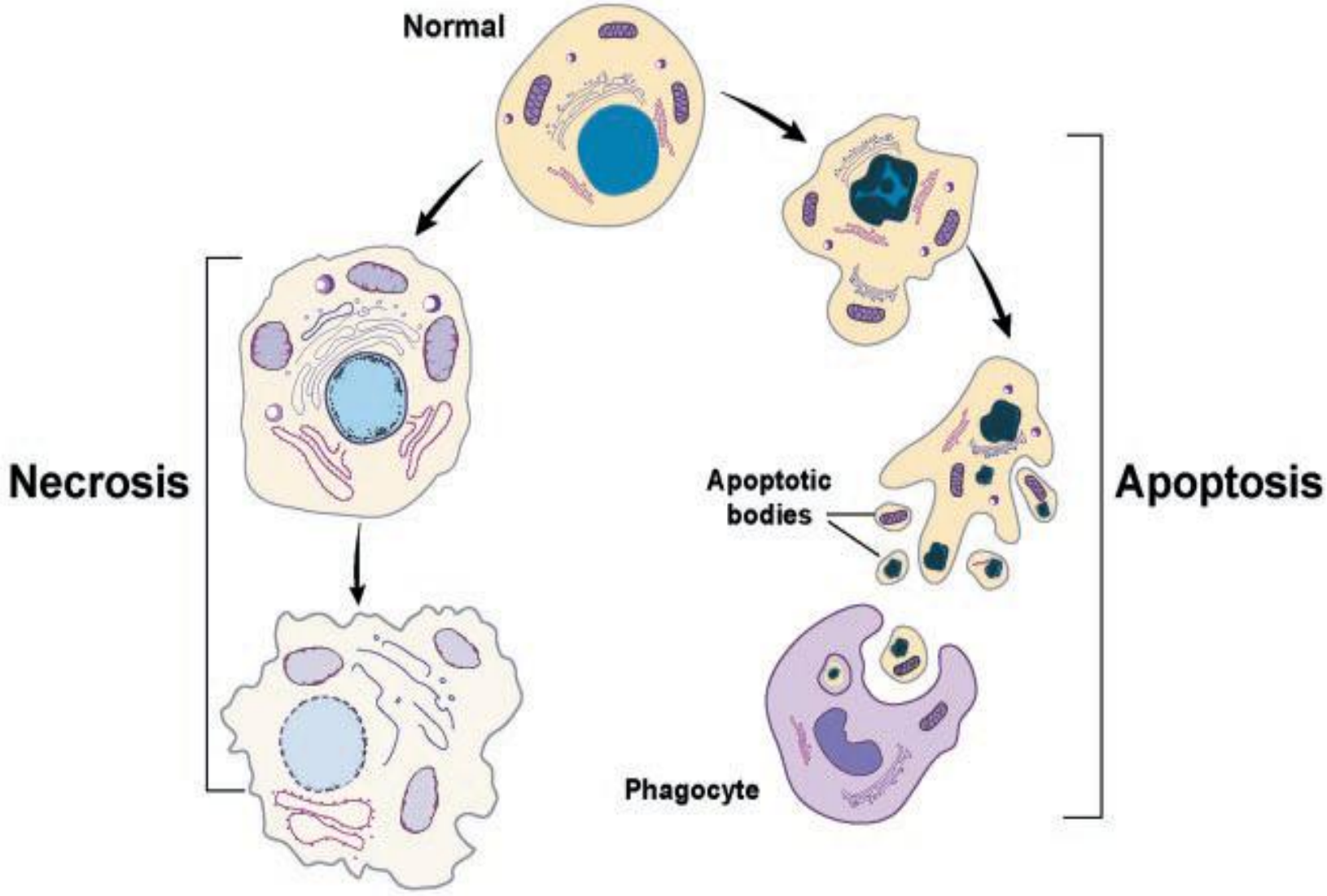
Black tea

Purple tea

Green tea

- Monolayer of *4TI* control cells after 48 hours
  - Disruption of monolayer
    - Reduction in cell to cell contact
    - Reduction in cell viability and proliferation

Tea induces apoptosis- programmed cell death of cancerous cells



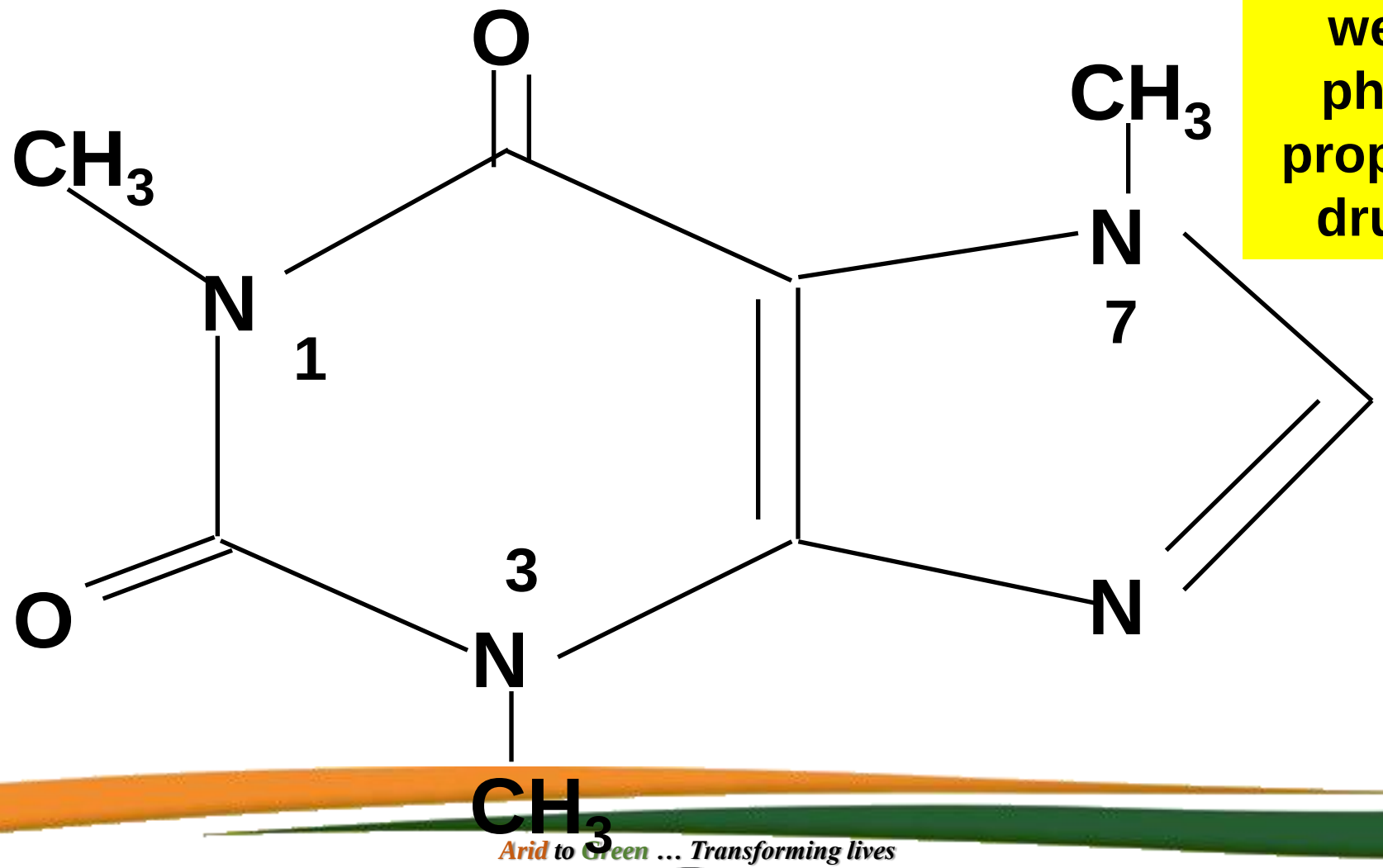
Tea induces caspases

- Caspases
  - Significant induction.
  - Executioners of apoptosis cascades

Transcriptome analysis indicating genes affected by green, black or purples teas

Gene ID		Green tea	Black tea	Purple tea
Casp8		p≤0.008, F=625.98 R=83.87	p≤0.007 F=703.49 R=24.30	p≤0.02 F=246.72 R=59.58
Casp8ap2		p≤0.03 F=13.05 R=27.46	p≤0.03 F=60.98 R=11.97	p≤0.05 F=43.51 R=15.71
Casp3		p≤0.005 F=15.82 R=15.21	p≤0.08 F=9.4 R=9.27	p≤0.05 F=15.38 R=12.69
Casp6		p≤0.06 F=9.956 R=26.306	p≤0.02 F=93.96 R=100.01	p≤0.05 F=323.98 R=26.59
Apopt1		p≤0.03 F=10.69 R=23.06	p≤0.04 F=1.53 R=16.46	p≤0.02 F=3.19 R=29.12
Aifm1		p≤0.03 F=5.65 R=54.76	p≤0.03 F=95.20 R=8.86	p≤0.04 F=36.55 R=2.80
Aifm2		p≤0.05 F=33.68 R=27.54	p≤0.03 F=5.65 R=54.76	p≤0.03 F=5.77 R=47.61
Casp9		p≤0.01 F=472.34 R=56.78	p≤0.02 F=281.03 R=26.33	p≤0.01 F=426.82 R=35.11

Stimulant Caffeine – 1,3,7 trimethylxanthine



Tea owes its wealth to the physiological properties of the drug caffeine.

Caffeine and Society

- Most widely consumed stimulant drug in the world
- Many people start consuming caffeine at an early age
- Tea has moderate to high Caffeine Content

  1 Cup of coffee – 65-175 mg

  1 Cup of tea – 50 mg

  Can of soda (12 oz) – 40-50 mg

  Bar of chocolate (30 g) – 1-35 mg

Aspects of Caffeine

Desirable effects

Stimulant, increased alertness, concentration, energy, bronchial dilator

Negative effects

Restlessness, jitters, anxiety, insomnia, elevated or irregular heart rate

Withdrawal effects

Transient but persistent, headache, low energy, inability to concentrate

Absorption

Rapidly absorbed following oral consumption

Peak blood (plasma) levels usually with 30 minutes

Metabolism/Elimination

- **Metabolized in the liver**
- **Changed to di- and mono- methylxanthines**
- **Has very short half life (3-5hrs in adults)**
- **Excreted in the urine**

Caffeine is pharmacologically active

1. Pleasant stimulant effects
2. Short Half-life (you need to come back for more)
3. Can’t drink too much at any one time (non toxic)
4. Headache when you stop drinking it (withdrawal)
5. Used in pharmaceutical industry- analgesics
6. Potential for bioengineering tea to generate high or low caffeine genotypes
7. Caffeine extracts can be sourced from tea?

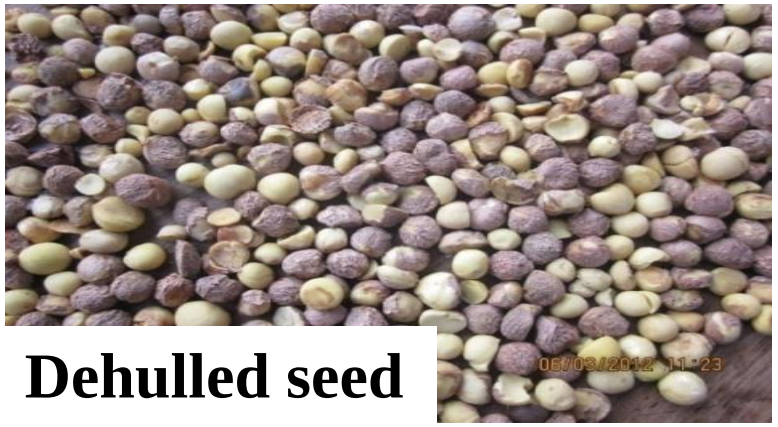
Research evidence of other health benefits of Kenya tea

Kenyan tea has;

- Anti-mutagenic properties
- Anti-diabetic properties
- Ant-obesity properties
- Anti-hypertensive properties
- Ability to enhance drug bioavailability when co-administered with drugs
- Potent anti-inflammatory activity
- Potential to protect against heavy metal poisoning
- Potential to fortify other foods for enhanced health benefits eg probiotic yoghurts, alcohol, confectionaries

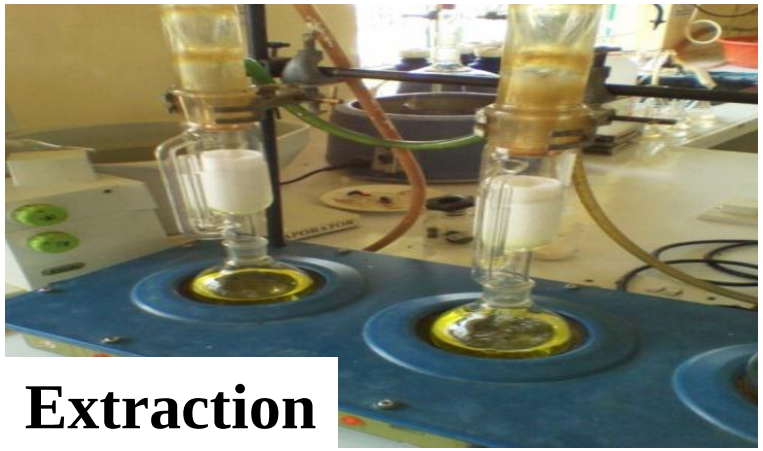
TEA SEED CONTAINS HIGH QUALITY OIL

Tea seed



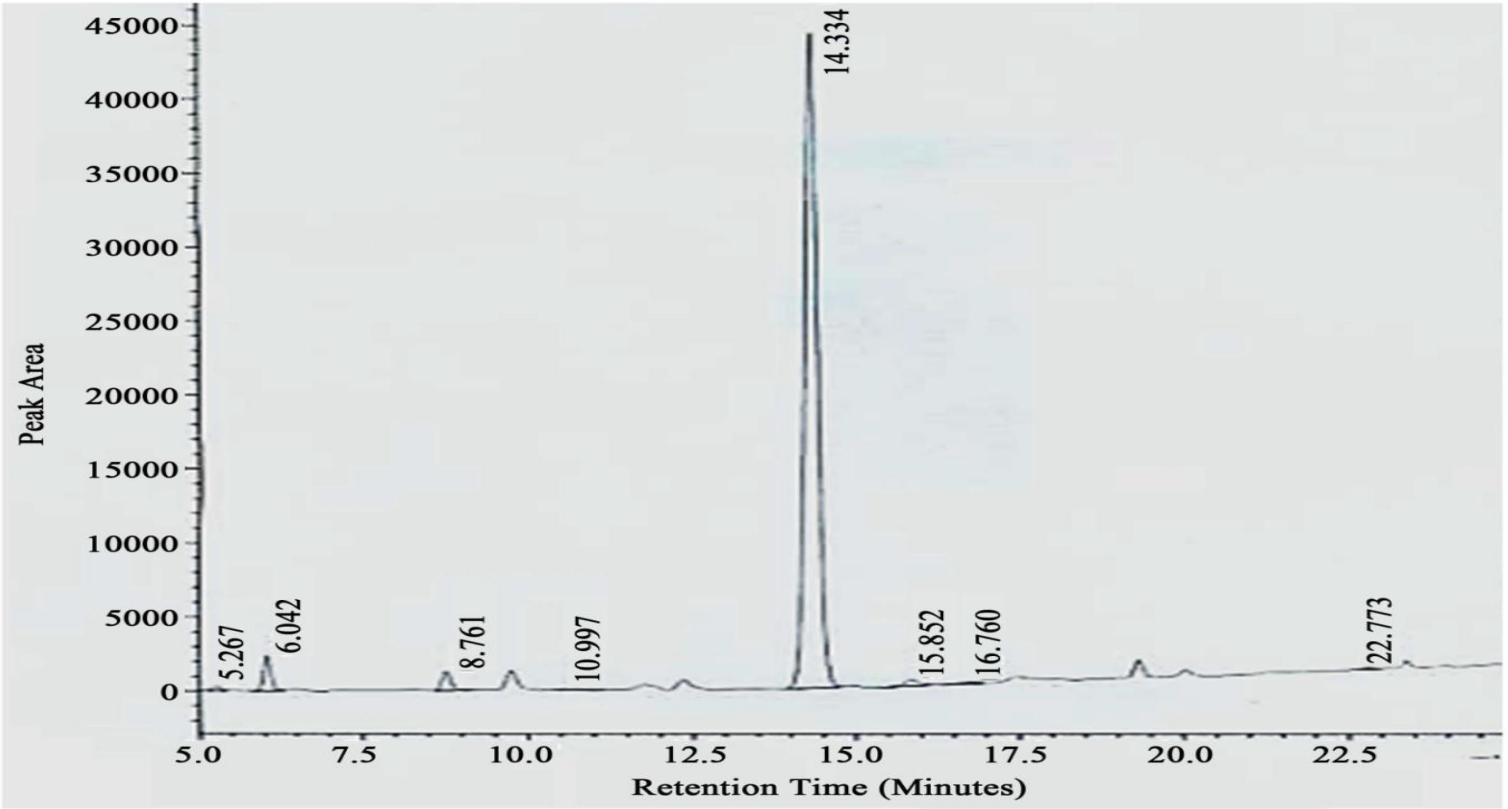
Dehulled seed

Tea seed oil



Extraction

TEA SEED OIL RETAINS CATECHINS- It is Healthful



- Oil content in tea seed is similar to that in corn and soybean – good for culinary use
- Tea seed oil (TSO) has low iodine value; more monounsaturated than polyunsaturated FAs
- TSO has similar shelf life to olive oil
- Tea seed oil has similar saponification value as corn, soy and sunflower oil

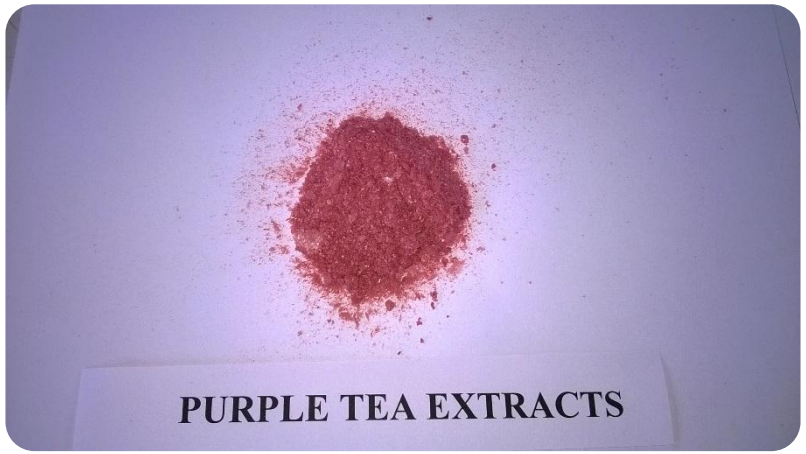
Is there potential to use Kenyan Tea extracts in FMCGs?

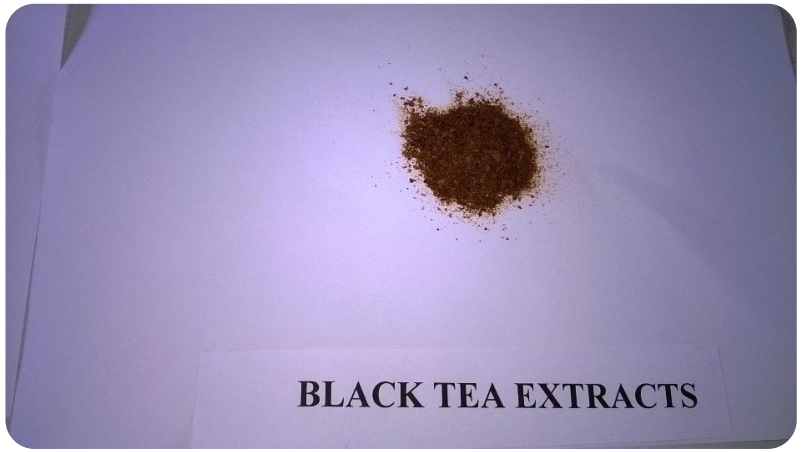
- Tea contains polyphenols- anti-inflammatory, anti-oxidant, anti-allergic, anti-bacterial, anti-septic properties
- Tea tannins- antiseptic and antioxidant properties
- Tea- a natural product with low mammalian toxicity
- Can be used in skin care products for conditions such as eczema, free radical scavenging, anti-inflammatory, anti-ageing, skin protection from photo-damage and antidandruff

COSMECEUTICALS FROM KENYAN TEA EXTRACTS

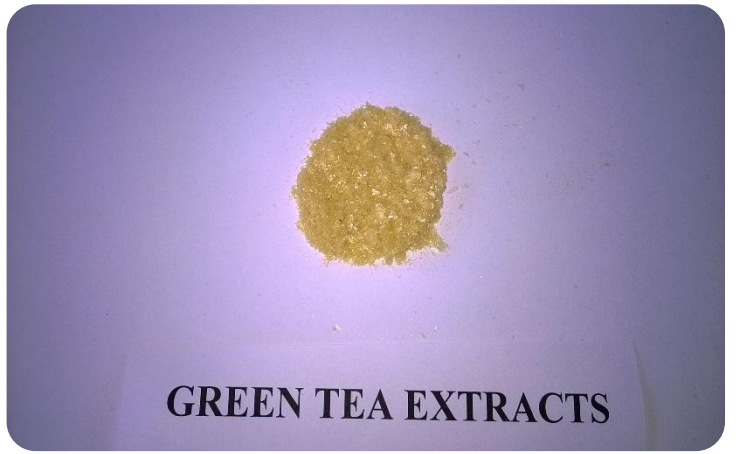
Catechin and Tea Skin and Hair products

Methodologies for isolating stable Tea extracts developed

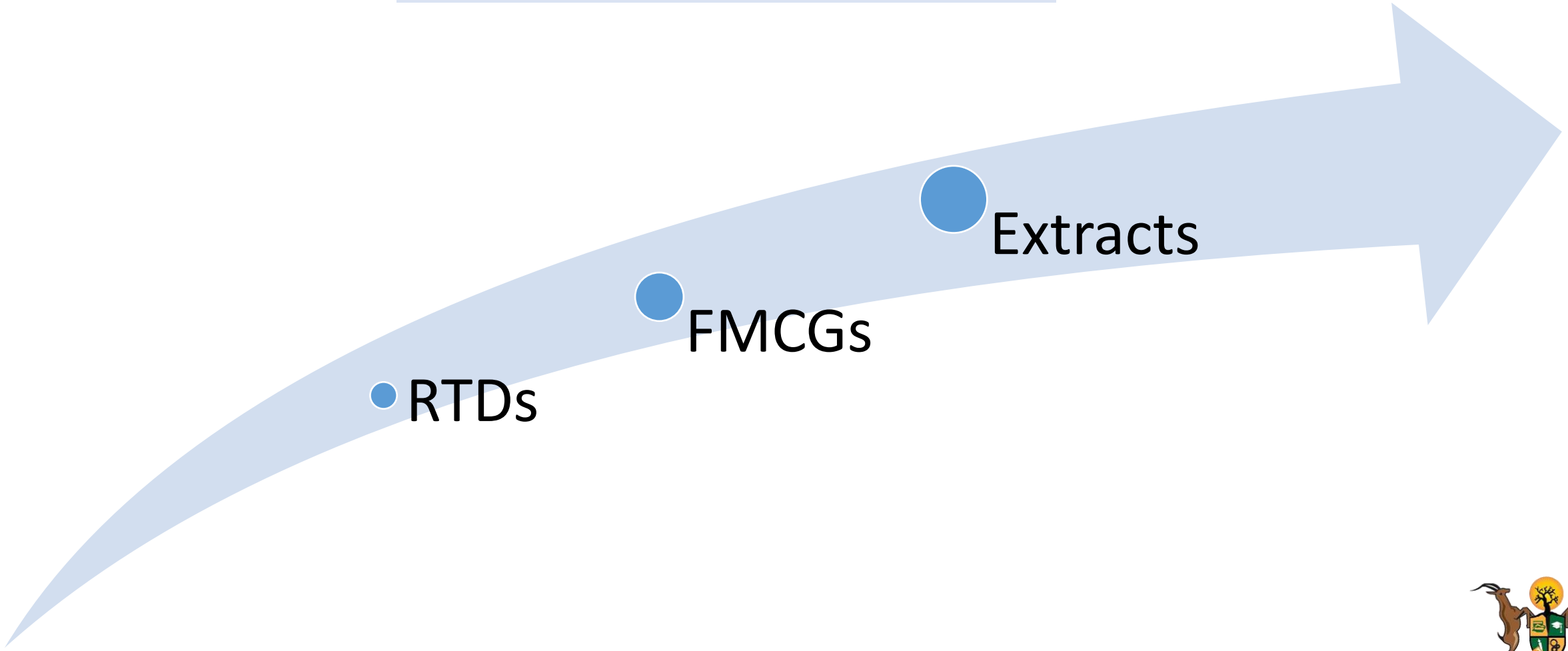


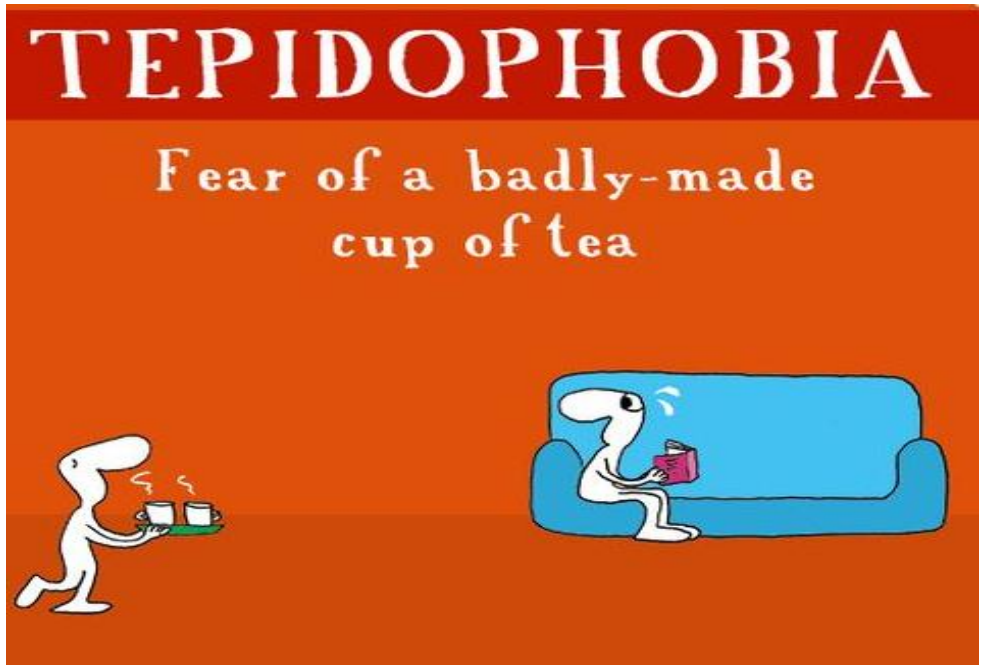


Patent application process is ongoing

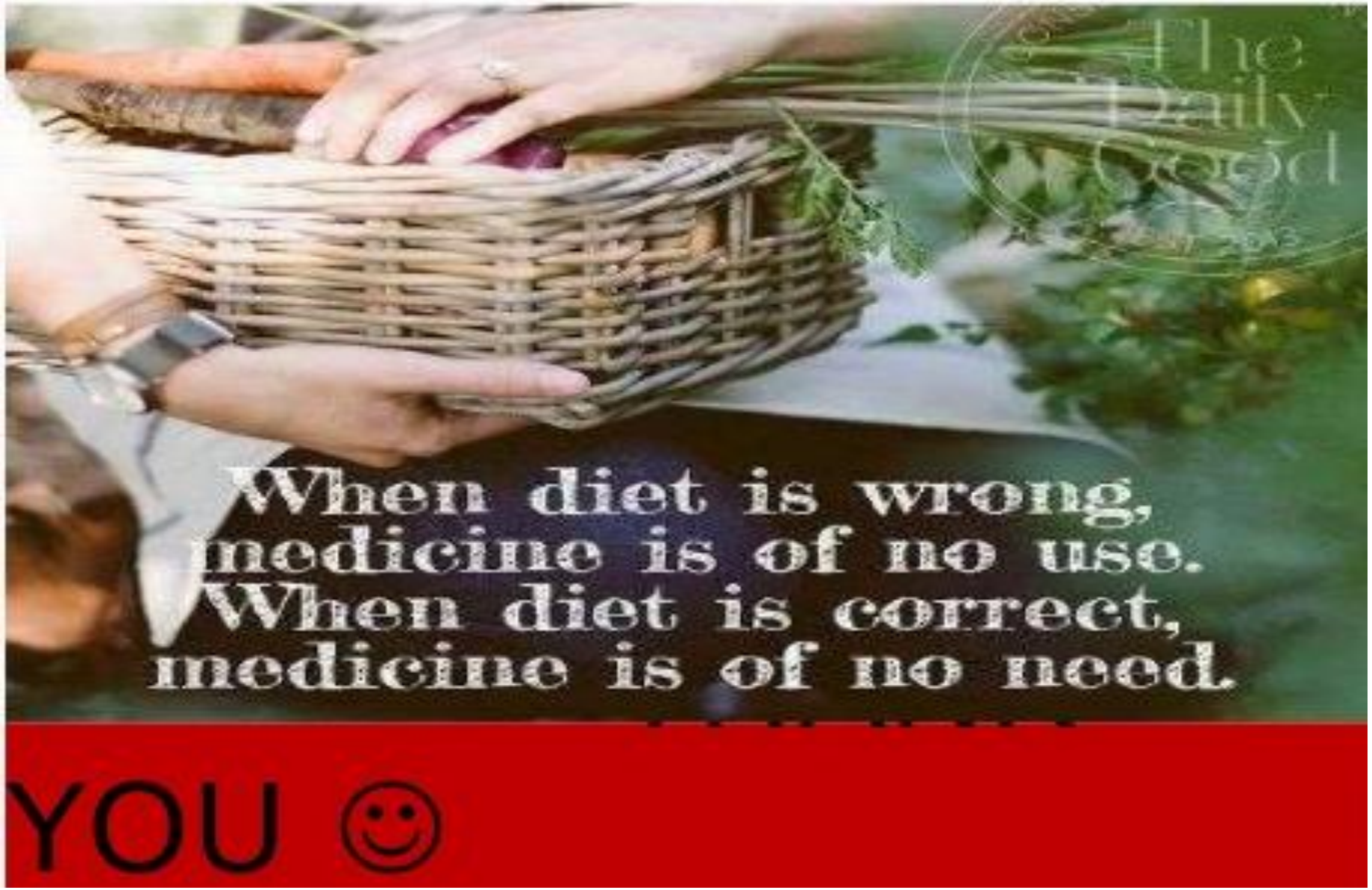


The future of tea





Tea for better health


When diet is wrong,
medicine is of no use.
When diet is correct,
medicine is of no need.
YOU ☺