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Functional food for better health and quality of Life

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Outline of my talk

- Functional food
- Natural food colors and bioactivity
- Amelioration of obesity and type-2 diabetes by anthocyanin, the red pigment in fruits and vegetables
- Summary

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Functional food

Food with health-benefits other than basic nutrition

Functional food contains bioactive secondary metabolites

- **Bioactive secondary metabolites have no nutritional value**
- **Participate in gene-regulation in vivo**
- **Mediate disease causing mechanisms in vivo**
- **Ameliorate debilitating diseases**

Agricultural produce:

Brightly colored fruits
Brightly colored vegetables
Generally regarded as safe plants (GRAS)
Herbs/botanicals
Spices
Pro- and prebiotics (edible mushrooms)
Soluble fiber (seeds and grains)

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Impact on quality of life by in vivo peroxidation, oxidative stress and inflammation

- Atherosclerosis
- Neurodegenerative diseases (Alzheimer's/Parkinson's/Huntington's)
- Traumatic Brain Injury (TBI)
- Chronic Traumatic Encephalopathy (CTE)
- Obesity/type-2 Diabetes
- Arthritis/Chronic pain
- Cancer

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Bioassays to determine functional food quality

- Antioxidant assay (LPO, MTT)
- COX-1 and COX-2 inhibitory assay
- Tumor cell proliferation inhibitory assay
- Insulin secretion assay
- Antimicrobial assay
- In vivo study using model mice

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Bioactive colors in fruits and vegetables

Fat-soluble or water-insoluble

Green: Chlorophylls (a, b, c and d)

Yellow: Xanthophylls, zeaxanthin, lutein, violaxanthin etc.

Orange: beta carotene, lycopene

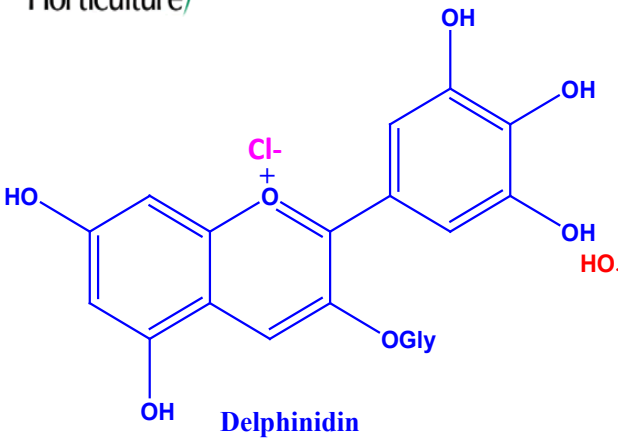
Red-Orange: Bixin

Fat-insoluble or Water-soluble

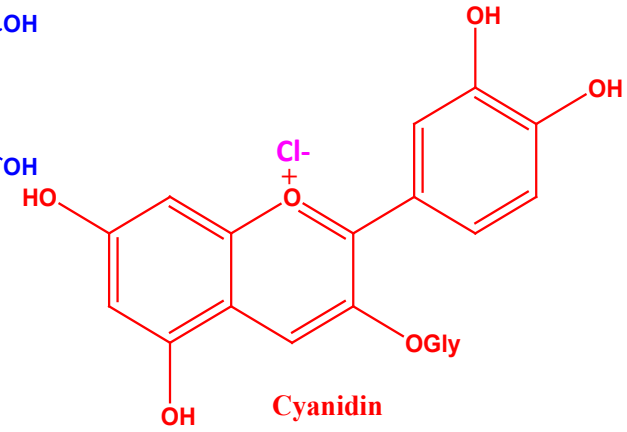
Red, Blue, Purple, Orange: Betacyanins and Anthocyanins

Natural colors are antioxidants, antiinflammatory and prevent tumor cell proliferation

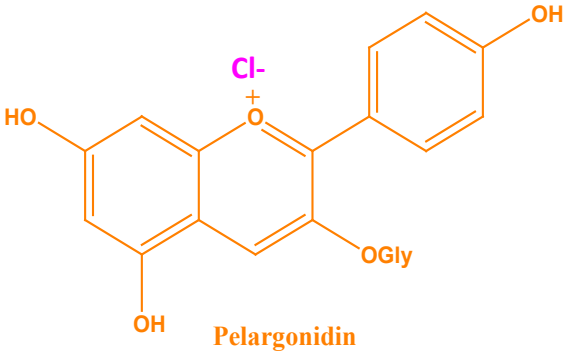
Major anthocyanins in fruits and vegetables



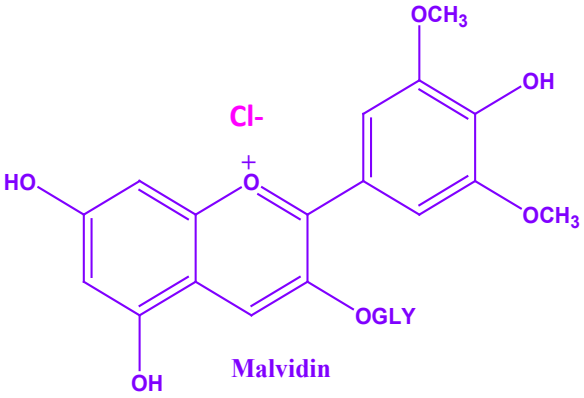
Delphinidin



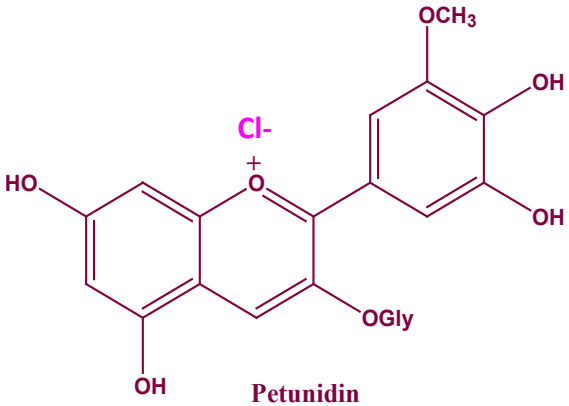
Cyanidin



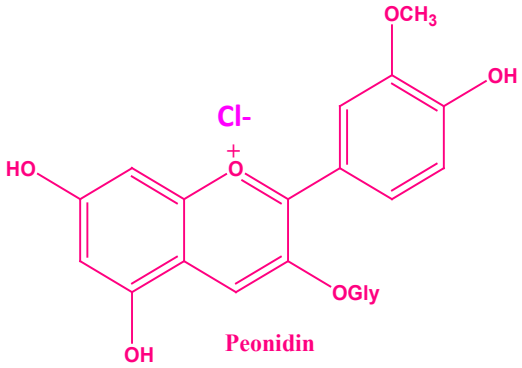
Pelargonidin



Malvidin



Petunidin



Peonidin

Fruits: Cherry sweet & sour, Blueberry, Red Grapes, Strawberry, Raspberry, Cranberry, other berries, Pomegranate, Apple, Peach, Plum and other brightly colored fruits

Vegetables: Red lettuce, Chicory, Red potato, Black carrot, Eggplant, Red onion

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Bioactivity of anthocyanin

Antioxidant

Antiinflammatory

Inhibit tumor cell proliferation

Prevent damage in brain resulting from stroke

Induce insulin secretion by pancreatic beta cells

Ameliorate weight gain, obesity, cholesterol, blood glucose and deposition of triglyceride in liver

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Amelioration of obesity and type-2 diabetes by anthocyanin, the red pigment in fruits and vegetables

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Obesity and type-2 diabetes

Sedentary life style and high calorie intake cause obesity

- **Obesity cause insulin resistance**
- **Insulin resistance leads to type-2 diabetes**

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Obesity and type-2 diabetes

Body mass index (BMI) is a measure of overweight and obesity

BMI	**< 18.5 kg/m^2**	**Under weight**
	18.5-24.9 kg/m^2	**Normal**
	25-29.9 kg/m^2	**Over weight**
	≥ 30 kg/m^2	**Obese**

21-25 kg/m^2 BMI is ideal for better health

Association of BMI with overall and cause-specific mortality: a population-based cohort study of 3·6 million adults in the UK. Lancet Diabetes Endocrinol. DOI: 10.1016/S2213-8587(18)30309-7

BMI [kg/m^2] = Weight in kg / Height in meters^2

BMI [lb/inches] = [Weight in lbs/(height in inches^2] x 703

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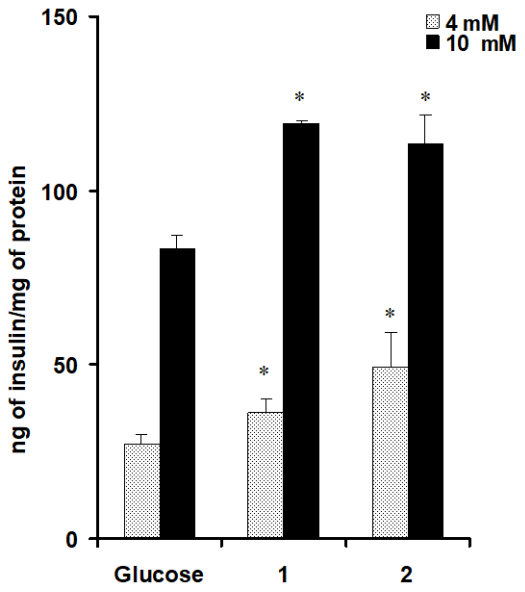
Insulin resistance/type-2 diabetes

MRI studies in human with type-2 diabetes showed defective glucose metabolism in skeletal muscle due to insulin resistance

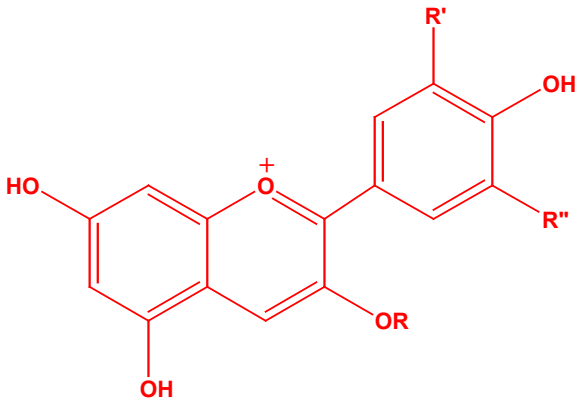
1. **Chronic inflammation and activation of inflammatory signaling pathways cause insulin resistance**

2. **Lipid peroxidation causes insulin resistance. That is, acquired or inherited defects in mitochondrial fatty acid oxidation increase fatty acid delivery to muscle and liver**

Induction of insulin secretion by anthocyanins in rodent pancreatic beta cells



	R	R'	R''
1	Glc	OH	H
2	Glc	OH	OH
3	Gal	OH	H
4	Gal	H	H
5	H	OH	H
6	H	OH	OH
7	H	H	H
8	H	OCH_3	OCH_3
9	H	OCH_3	OH



The amount of insulin secreted per milligram of protein by anthocyanins in the presence of 4 and 10 mM glucose. The amount of insulin secreted was normalized to milligram protein.

Active: 1 (C3G), (2) D3G, (3) C3Gal

Mouse feeding study

Composition of normal (10% K. Cal.) and high fat (60% K. Cal.) diets for C57BL/6J mice

Ingredients	Normal	High fat
Casein	200	200
L-Cystein	3	3
Corn Starch	315	0
Maltodextrin	35	125
Sucrose	350	68.8
Cellulose	50	50
Soybean oil	25	25
Lard	20	245

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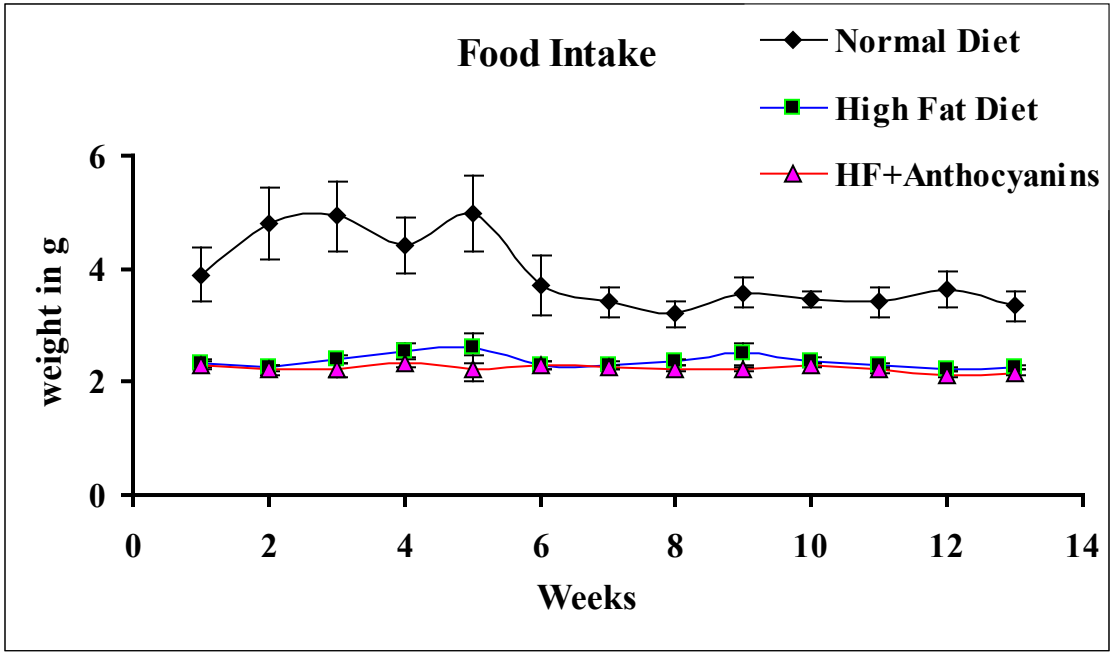
Food Intake by treated animals



The food intake (g) of C57BL/6J mice during the 12-week study period. Values are mean ±SEM, n=8. Food intake was measured every day and averaged for every week. There was no significant difference in consumption among the high fat, control and treatment groups. Treatment groups received high fat diet for 4 weeks before they were switched to diet mixed with anthocyanins (1g/Kg of high fat diet).

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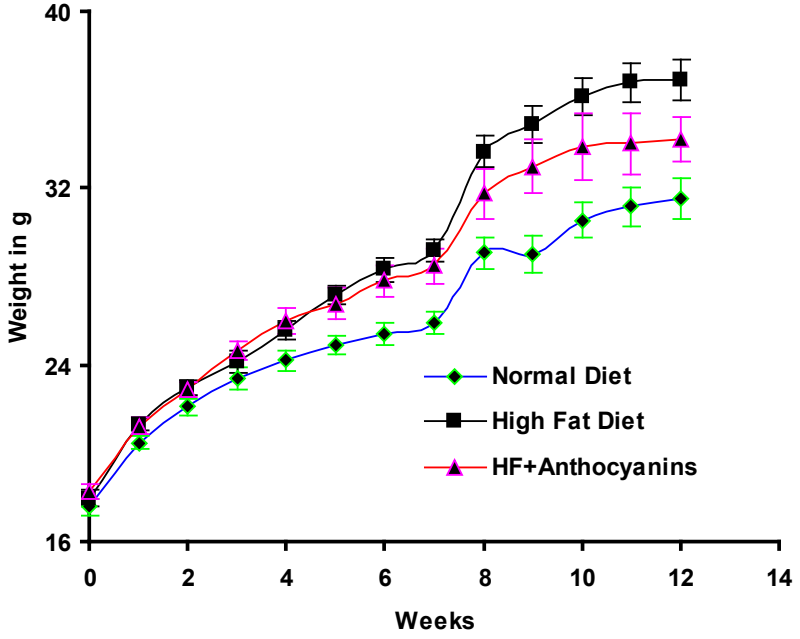
Body weight gain in 12 weeks after treatment



Body weight variation of C57 BL/6J mice during 12 weeks of feeding anthocyanins. The groups treated with anthocyanin were initially fed with high fat diet (60% K. Cal.) for four weeks and then switched to diet containing the treatment. Data represents SE, n=8.

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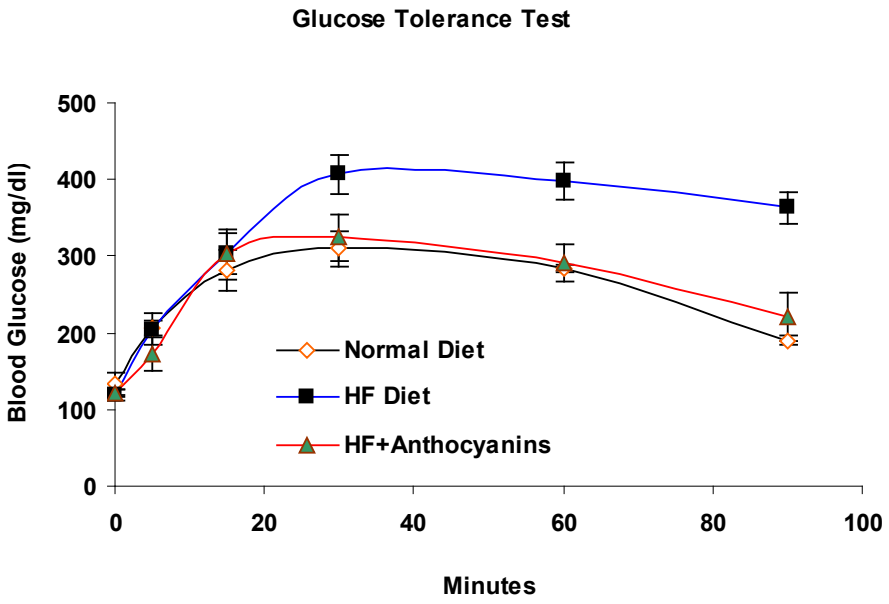
Glucose Tolerance Test



Results of Glucose Tolerance Test over a period of 90 min after the glucose load. The test was conducted during the 11th week of feeding. A solution of glucose (2 g/ Kg body weight) in water was administered intraperitoneally and the blood glucose level was measured at 0, 5, 15, 30, 60, and 90 min. The blood was collected from tail vein. Vertical bars represents SE at each data point n=5.

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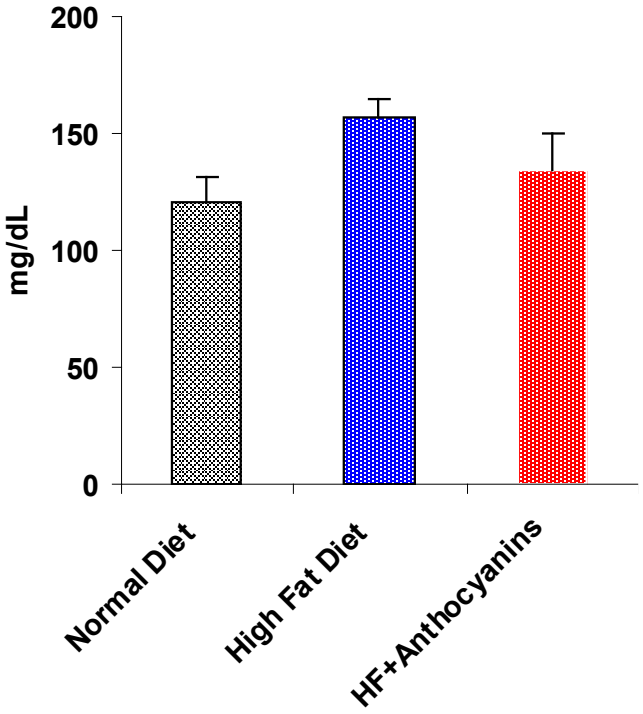
Plasma cholesterol level



Plasma cholesterol level of mice in the plasma collected at the end of the feeding study and represented in mg/dL. The values represent SE for n=5.

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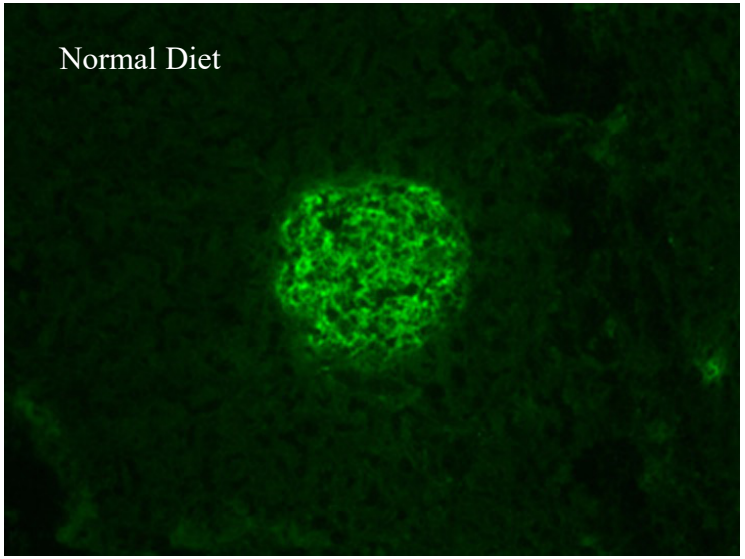
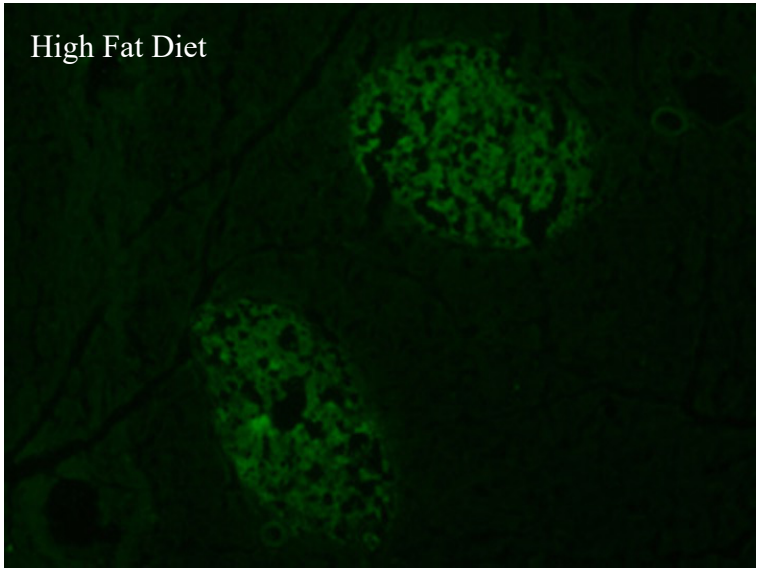
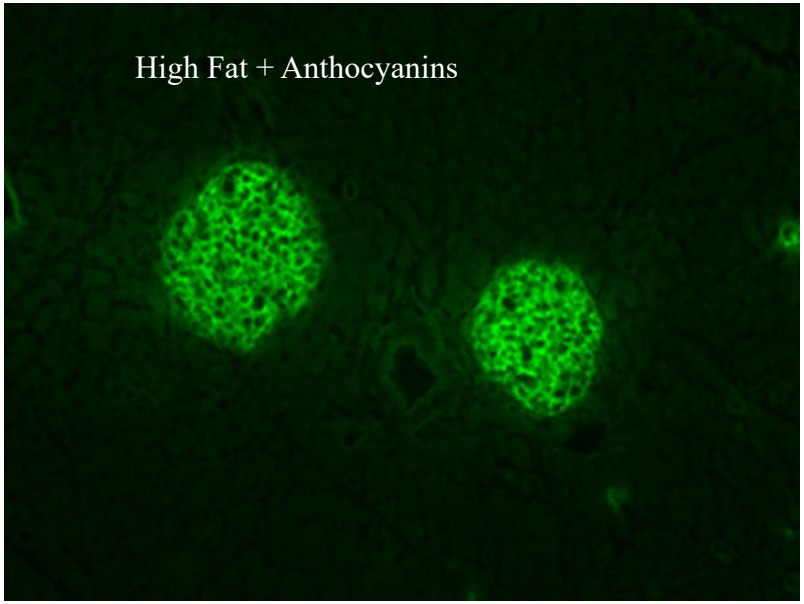
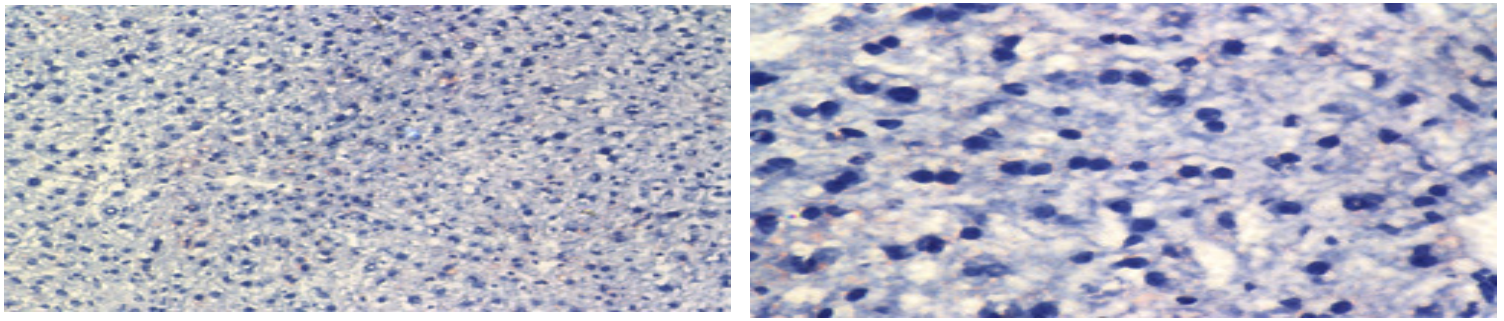
Insulin secretion and integrity of pancreatic beta cells





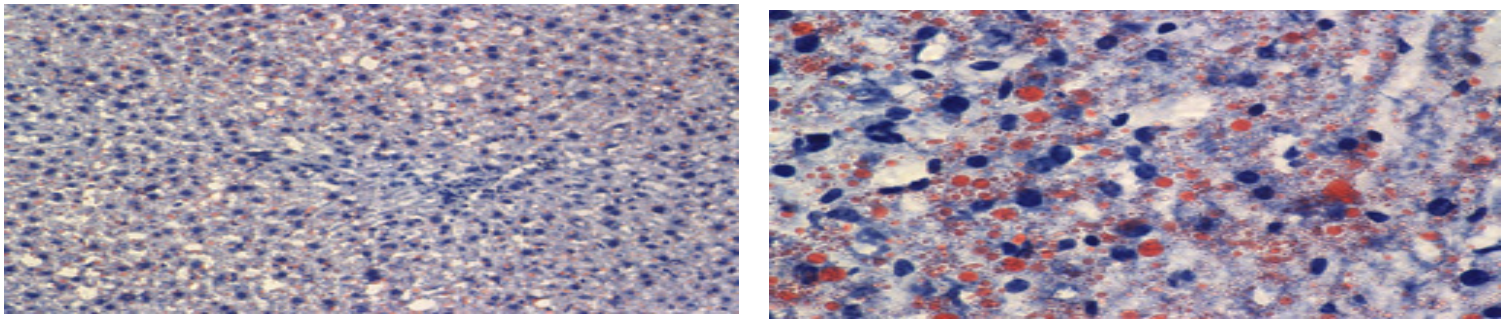


Triglyceride deposition in liver



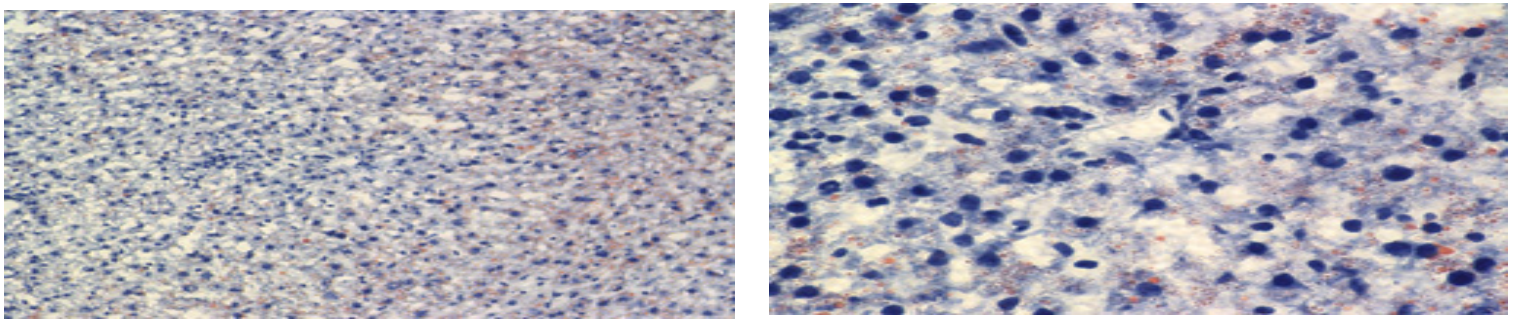
Normal Diet

20x



60x

High Fat Diet



High Fat Diet + Anthocyanin

Oil O red staining of liver sections of mice. Lipid droplets (TG) appeared as red spots. Sections were stained with 0.2% Oil Red O solution for 30 min.

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Conclusion

Anthocyanin lowered blood glucose, total cholesterol, weight gain and triglyceride deposition in liver in mice under high-fat feeding and obese conditions

Summary: Fruits and vegetables are important functional foods

- Inhibit lipid peroxidation and reduce fat deposition and triglycerides in liver
- Inhibit production of inflammatory intermediates
- Reduce weight gain
- Lower total cholesterol
- Sensitize insulin, modulate obesity and type-2 diabetes
- Prevent diseases caused by oxidative stress

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Suggestions

- Include functional food crops in food security and diversify food production by including horticultural crops
- Emphasize daily consumption of a variety of brightly colored fruits and vegetables
- Add functional food compounds in the list of recommended daily allowance (RDA)
- Promote functional food consumption for better living and aging

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So, ask everyday-

How many food containing natural colors did I eat today?

Teşekkürler ederim