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EFFECT OF SORBITOL ON DOUGH RHEOLOGY AND QUALITY OF SUGAR REPLACED COOKIES

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ABSTRACT
A high amount of sugar is used in bakery products, which may cause diabetes, high blood glucose levels and obesity. Due to these reasons, sugar is being replaced with substitutes. There is different carbohydrate-based sugar substitutes (polyols) that can efficiently replace sugar. Among polyols, sorbitol is an efficient replacer that can mimic sugar with minimal effects on cookie quality. Effects of different sorbitol levels (0 to 12.5%) were seen on the dough rheology. Mixographic studies showed that peak height and mixing time reduced with the addition of sorbitol. Farinographic studies showed that water absorption and the mixing tolerance index of dough reduced with the supplementation of sorbitol, whereas dough development time, arrival time, dough stability time and softening of dough increased. Extensographic studies revealed that sorbitol substitution produced hard, cohesive, adhesive and elastic dough. Sugar in cookies formulations was reduced from 100 to 50% by replacing with sorbitol 0 to 50%. Physical analysis of sorbitol containing cookies showed that the diameter and spread factor of cookies decreased with higher levels of sorbitol, whereas thickness, color, hardness and water activity of cookies increased. The calorific value of cookies decreased with the increasing levels of sorbitol. At upto 20% replacement of sugar, other parameters of cookies were not affected. Sensory evaluation of the cookies showed that hedonic points for sensory evaluation parameters reduced with the increasing levels of sorbitol, T_2 (20% replacement) showed maximum overall acceptability.

Keywords: calorific value; cookies; dough rheology; polyols; sensory evaluation

INTRODUCTION
Polyols are carbohydrates that are hydrogenated, meaning that a hydroxyl group replaces the aldehyde or ketone group found in sugars. These are also different from dense energy sweeteners such as cyclamate, polydextrose and aspartame aspartame, which are utilized in very low quantities so that their contribution to the calorific value of foods is very negligible. These sweeteners are 40% to 100% sweet as compared to sucrose and provide 0.2 to 3 kcal.g^{-1} energy as compared to sugars and starch. These are partially digested and absorbed by the human body. Some polyols, such as erythritol, sorbitol, and mannitol, occur naturally in foods **(Fitch and Keim, 2012)**. Some polyols can help retain moisture in foods, lower water activity to help to protect against spoilage, impart smoothness and creaminess by inhibiting sugar crystallization, provide viscosity, and/or assist in retaining flavor at high temperatures. They also provide bulkiness to foods once in the body. Most polyols are considered GRAS, specifically sorbitol, erythritol, isomalt, maltitol, lactitol, and polyglycitols. Xylitol and mannitol (special dietary purposes) are regulated as food additives. Excessive polyol load, more than 50 grams per day of sorbitol and/or more than 20 grams per day of mannitol, can create gastrointestinal disorders **(Kroger et al., 2006)**. Sorbitol is related to the family of sugar alcohols. The molecular formula of sorbitol is C6H14O6, molar mass 182.17 g.mol^{-1}, and density is 1.489 g.cm^{-3}. It is a colorless, odorless, and sweet-tasting liquid that is 60% sweet as compared to sucrose, and it provides 2.6 kcal.g^{-1} energy **(Fitch and Keim, 2012)**.

Bakery products continue to improve as the user becomes more conscious about the health benefits of consuming less supplemented sugars. Low sucrose or low calorie is a top-level marketing approach in bakery products and baking sectors. They do, however, provide functional benefits to bakery goods when sugars used are replaced with polyols. When used in place of sugar, polyols can make almost all bakery products healthier while still giving a sweet taste similar to sucrose. Bakery products prepared with polyols cannot become asslimy on the surfaces as early as products prepared with other sweeteners do. Microorganisms also cannot flourish well on these sweetening agents as they do on sucrose, and hence the shelf life of products is extended. However, unlike sugars, polyols do not normally develop crisp and colored surfaces on baked commodities. The non-coloring character can be beneficial where a disturbance in browning is not required. Along with the non-browning characteristic, polyols often affect the cooling rate of baked products. Isomalt is an exception; it does not provide any typical cooling effect in bakery foods **(Baek et al., 2004)**.

Isomalt has a very low hygroscopicity compared with polyols, such as sorbitol, xylitol and maltitol, and has a very low glycemic index. In many baking formulations; substituting sugar with isomalt remains the color, aroma, taste, texture, appearance and volume of sugar **(Grabitske and Slavin, 2008)**. Maltitol, that is 90% sweet as compared to sucrose, is utilized as a sugar substituent in frostings, chocolate bars, low calorie muffins, icing creams, biscuits, breads and cakes. Malitol syrup is utilized to substitute maize syrup in similar bakery utilizations **(Nadji et al., 2005)**. Glucitol is the other name of sorbitol. The human body utilizes it very slowly. It can be produced by reducing glucose i.e. altering the functional group of glucose from aldehyde to hydroxyl. It is present in apples, plums and other stone fruits in appreciable quantities. Sorbitol provides bulk and functionality to bakery products but not as much sweetness **(Yan et al., 2010)**.

Scientific hypothesis

Bakery products are the most widely produced and consumed food items, after dairy products. Among the bakery products, cookies are the most significant. Cookies are famous and abundantly liked by all ages of people, including children. These are important bakery commodities that are used as snack foods by children and adults in Pakistan. Biscuits hold an important position in snack foods due to a variety taste, crispness, and digestibility. This project was selected to examine the influence of different sorbitol substitution levels on dough rheology and physio-chemical and sensory characteristics of cookies to reduce the total calories provided by the cookies and to improve their nutritional value.

MATERIAL AND METHODOLOGY

Procurement of Raw Materials

Raw materials used in the present study were purchased from local market. Wheat flour was purchased from “Farrukh Flour Mills” Jhang road, Fa cookies preparation. Sorbitol was purchased from local market. Sorbitol available in the market is basically imported from “India” a treatments plan has depicted in Table 1.

Analytical Methods for Wheat Flour and Treatments

Proximate Composition of Wheat Flour

Wheat flour was analyzed for moisture, total ash, crude protein, crude fiber and crude fat by using methods described in AACC **(AACC, 2000)**. The nitrogen free extract (NFE) was calculated by difference method.

Moisture Content

The moisture content in the flour sample was estimated according to the method mentioned in AACC method No. 44-15A **(AACC, 2000)**.

Total Ash

The ash content in flour sample was estimated by following the procedure given in AACC method No. 08-01 **(AACC, 2000)**.

Crude Fat

Flour sample was analyzed for crude fat according to the method No. 30-10 in **AACC (2000)**.

Crude Fiber

The crude fiber was determined by following the method No. 32-10 outlined in **AACC (2000)**.

Crude Protein

Kjeldahl apparatus (Model: D-40599, Behrs Labor Technik, Gmbh-Germany) was used to determine nitrogen % in the flour sample according to AACC method No. 46-10 **(AACC, 2000)**.

Nitrogen Free Extracts (NFE)

The nitrogen free extract (NFE) of wheat flour sample was calculated according to the following expression:

NFE (%) = 100 - (% Moisture +%Ash +%Crude Fat +%Crude Protein +%Crude Fiber).

Rheological Analysis of Treatments

The wheat flour sample was supplemented with sorbitol according to treatments (Table 1) respectively and effects of supplementation on flour rheology were studied as described below.

Mixographic Analysis

The mixographic studies were carried out by using mixograph equipped with 10g capacity bowl (National Mfg. Co., Lincoln, Nebraska). All the treatments were run through mixograph by adding 60% water to each sample according to the instructions given in AACC method No. 54-40A **(AACC, 2000)**. Each mixogram was interpreted for mixing time and maximum peak height percentage.

Farinographic Studies

The treatments were run through Brabender Farinograph equipped with 50 grams bowl capacity to assess the physical dough behaviour of different flour treatments according to AACC Method No. 54-21 **(AACC, 2000)**.

The parameters such as water absorption, dough development time, softening of dough, arrival time, departure time, dough stability time and mixing tolerance index were calculated from the farinograms as described below.

Extensograhic Analysis

All the treatments were analyzed through Brabender Extensograph according to the methods outlined in **AACC (2000)** separately.

Table 1 Treatment Plan.

Treatment	**Sorbitol %**
T_0	0.0
T_1	2.5
T_2	5.0
T_3	7.5
T_4	10.0
T_5	12.5

Legend: T_0 acts as control

Table 2 Cookies Recipe (T_0).

Ingredients	**Amount**
White flour	500g
Sugar	250g
Shortening	250g
Baking powder	7-8g
Egg	1
Cardamom Flavor	1 – 2mL

Water Hydration Capacity of Treatments

The water binding capacity or the amount of water retained by the flour has been subjected to centrifugation and was measured according to the procedures given in AACC method number 56-30 **(AACC, 2000)**.

Preparation of Cookies

Cookies of different treatments were prepared from the wheat flour according to methods 10-50 D **(AACC, 2000)**. Table 2 depicts used recipe for the preparation of control cookies (T_0).

Preparation Method

The ingredients weighed accurately. Dry ingredients were mixed thoroughly by mixer (Mod. A-200, Hobart, USA).

Analysis of Cookies

Physical Analysis of Cookies

Cookies of different treatments were analyzed firstly for their physical parameters after preparation. Cookies diameter, thickness and spread factor was measured according to their respective methods described in AACC **(AACC, 2000)**. Cookies treatments color was determined by methods described by **(Rocha and Morais, 2003)**. Texture and water activity was determined according to the methods described by **(Piga et al., 2005)**.

Calorific Analysis of Cookies

The amount of heat measured in calories that is released when a substance is completely oxidized in a bomb calorimeter is called the gross energy of substance. Calorific Value of the cookies treatments was estimated by using Oxygen Bomb Calorimeter (Werke IKA C200). The method of Krishna and Ranjhan with slight modifications was used in determination **(Krishna and Ranjhan, 1981)**.

Proximate Analysis of Cookies

Cookies of different treatments were analyzed for moisture, total ash, crude protein, crude fibre and crude fat by using methods described in AACC **(AACC, 2000)**. The nitrogen free extract (NFE) was calculated by difference method.

Sensory Evaluation of Cookies

The cookies of different treatments were rated using 9-point hedonic score system (9 = like extremely; 1 = dislike extremely) by taste panel **(Meilgaard et al., 2004)**.

Statistical Analysis

The results obtained from different parameters of all the treatments were exposed to statistical analysis. Completely Randomized Design (CRD) was used, followed by the Analysis of Variance Technique (ANOVA) and the results were interpreted according to the Least Significant Difference Test (LSD) at 5% level of significance as described by **(Steel et al., 1997)**.

RESULTS AND DISCUSSION

Chemical Composition of Wheat Flour

The results regarding the chemical composition of wheat flour indicated that it contains 12.70% moisture, 10.8% crude protein, 0.86% crude fat, 0.24% crude fiber, 0.56% ash and 74.74% nitrogen free extract. The results are in close agreement with the findings of others in the literature **(Ahmad, 2011; Mushtaq et al., 2010)**.

Rheological Analysis of Treatments

Mixographic Analysis

The statistical data regarding the mixographic parameters showed that mixing time and peak height of treatments decreases with the increasing levels of sorbitol (Table 3). T_5 showed minimum mixing time 3.2 minutes and minimum peak height 33%, whereas T_2 showed maximum mixing time 7 minutes and maximum peak height 63%, showing an overall decreasing trend. The decrease in mixing time and peak height was due to fact that in present study flour blended with different levels of sorbitol was run through mixograph rather than plain flour. These results were in close agreement with the findings of others in literature **(Asghar, 2004; Farooq, 1996)**.

Table 3 Effect of different treatment on mixograph parameters of dough.

Treatments	Mixing Time (minutes)	Peak Height (%)
T_0	5.50[b]	55[b]
T_1	6.60[a]	60[a]
T_2	7.00[a]	63[a]
T_3	4.80[c]	49[c]
T_4	3.80[d]	42[d]
T_5	3.20[e]	33[e]

Table 4 effect of different treatment on farinograph parameters of the dough**.**

T	W.A (%)	D.D.T (min)	A.T (min)	D.T (min)	D.S.T (min)	S.O.D (B.U.)	M.T.I (B.U.)
T0	57.20[a]	7.30[f]	1.25[d]	16.50[a]	15.25[a]	60.00[d]	40.00[a]
T_1	56.20[ab]	8.50[c]	2.75[a]	16.75[a]	14.00[d]	72.50[bc]	38.00[ab]
T_2	54.60[b]	7.75[e]	2.25[b]	16.90[a]	14.65[bc]	71.00[bc]	28.50[d]
T_3	52.80[c]	8.00[d]	2.70[a]	17.00[a]	14.30[cd]	78.00[a]	32.50[c]
T4	49.60[d]	9.50[a]	1.30[d]	16.00[a]	14.70[bc]	75.00[ab]	36.50[b]
T5	48.00[d]	9.00[b]	1.75[c]	16.80[a]	15.05[ab]	70.00[c]	27.50[d]

Table 5 effect of different treatment on extensograph parameters of dough.

T	Energy (cm^2)	Resistance to Extension (B.U.)	Extensibility (mm)	Maximum (B.U.)	Ratio No (B.U./mm)	Ratio No Maximum (B.U./mm)
T_0	49[c]	28[f]	51[d]	803[b]	0.50[f]	15.60[a]
T_1	48[c]	260[d]	55[d]	759[c]	4.70[b]	13.80[b]
T_2	45[d]	398[a]	63[c]	586[d]	6.30[a]	9.20[c]
T_3	48[c]	56[e]	52[d]	824[a]	1.10[e]	15.80[a]
T_4	57[a]	370[b]	107[b]	378[e]	3.50[c]	3.50[d]
T_5	55[b]	286[c]	126[a]	302[f]	2.30[d]	2.40[e]

Farinographic Studies

The statistical analysis regarding the farinographic characteristics showed that water absorption, dough stability time and mixing tolerance index of treatments decreases with the increasing levels of sorbitol, whereas arrival time, dough development time and softening of dough increases with increasing levels of sorbitol (Table 4). T_5 showed minimum water absorption and mixing tolerance index 48% and 27.5 B.U. respectively, whereas T_0 showed maximum water absorption and mixing tolerance index 57.2% and 40 B.U. respectively.

T_0 showed minimum arrival time, dough development time and softening of dough 1.25 minutes, 7.30 minutes and 60 B.U. respectively, whereas T_1, T_4 and T_3 showed maximum arrival time, dough development time and softening of dough 2.75 minutes, 9.50 minutes and 78 B.U. respectively. T_1 showed minimum dough stability time 14 minutes, whereas T_0 showed maximum dough stability time 15.25 minutes.

The decrease in water absorption trend is due to reduction in protein and complex carbohydrates contents in treatments respectively. The increase in dough development time and arrival time trend is due to less mixing behaviour of sorbitol as compared to wheat flour. The decrease in dough stability time and increase in softening of dough trend is also due to the less resistance of sorbitol to over mixing as compared to the wheat flour. The results are in close agreement with the findings of others in literature **(Rashid, 2007; Rakha, 2006)**.

Extensographic Analysis

The statistical data regarding the extensographic analysis of the treatments showed that work needed to deform the dough, resistance to extension of dough, dough extensibility and ratio no of dough increases with the increasing concentration of sorbitol; whereas maximum force required breaking the gluten strands and the ratio no maximum reduces with the increasing sorbitol contents (Table 5).

T_0 showed minimum values for energy, resistance to extension, dough extensibility and ratio no 49 cm2, 28 B.U., 51 mm and 0.5 B.U. /mm whereas T_4, T_2, T_5 and T_2 showed maximum values 57 cm2, 358 B.U., 126 mm and 6.5 B.U. /mm respectively. T_5 showed minimum values for maximum force and ratio no maximum 302 B.U. and 2.40 B.U. /mm whereas T_3 showed maximum values 824 B.U. and 15.80 B.U. /mm respectively.

Sorbitol (polyol) lowers the water absorption, increases the sliminess and hardness of the dough and hence increases the energy required to deform the dough, dough resistance to extension and dough extensibility. Maximum force required for breaking the gluten strands and ratio no maximum shown decreasing trend because as the flour is replaced with sorbitol the gluten content of treatment lowers and hence the concentration of gluten strands lowers, overall needing less force for breakage. The results are in close agreement with the findings of **(Alava et al., 2007; Akthar, 2011)**.

Table 6 effect of sorbitol on the physical charachteristic of cookeis.

T	Diameter (mm)	Thickness (mm)	Spread Factor	Color (CTn)	Hardness (g)	Fracturability (mm)	Water Activity
T_0	132.00[b]	33.00[d]	40.00[ab]	154.67[a]	1735.0f	20.39[e]	0.1800[e]
T_1	150.00[a]	36.00[b]	41.67[a]	147.67[ab]	3250.0d	21.37[c]	0.1940[de]
T_2	134.67[b]	34.01[cd]	39.54[b]	140.67[bc]	3045.0e	20.97[d]	0.2050[cd]
T_3	125.3[c]	35.40[bc]	35.42[c]	152.33[a]	4966.7b	21.49[b]	0.2200[bc]
T_4	127.33[c]	35.04[bc]	36.36[c]	152.67[a]	5450.0a	22.64[a]	0.2350[ab]
T_5	122.00[d]	37.80[a]	32.28[d]	134.67[c]	4125.0c	21.40[c]	0.2450[a]

Table 7 effects of sorbitol on the chemical analysis of cookies.

T	Moisture (%)	Ash (%)	Crude Protein (%)	Crude Fat (%)	Crude Fiber (%)	NFE (%)
T_0	3.30[bc]	0.49[f]	9.20[a]	21.50[a]	0.24[f]	65.27[a]
T_1	3.38[bc]	0.54[e]	9.12[a]	21.54[a]	0.27[e]	65.15[a]
T_2	3.50[b]	0.56[d]	9.05[a]	21.60[a]	0.30[d]	64.99[a]
T_3	3.60[ab]	0.60[c]	9.26[a]	21.40[a]	0.33[c]	64.81[a]
T_4	3.68[ab]	0.63[b]	9.32[a]	21.46[a]	0.37[b]	64.54[a]
T_5	3.80[a]	0.66[a]	9.05[a]	21.60[a]	0.40[a]	64.49[a]

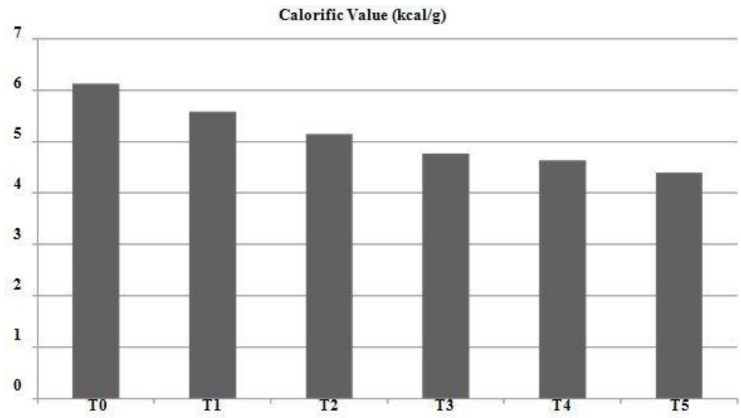

Figure 1 Effect of sorbitol on the calorific value of cookies.

Water Hydration capacity of Treatments

The statistical analysis revealed that water hydration capacity of treatments did not show significant effect of sorbitol replacement. T5 showed minimum (0.85 $g.g^{-1}$) water hydration capacity, whereas T0 showed maximum value (1.05 $g.g^{-1}$) respectively.

Proteins and fiber rich flours and meals show high water hydration capacity due to their more moisture retaining behavior. The results are in close agreement to the finding of others in literature **(Mahajan et al., 1999; Zoulias et al., 2002)**.

Analysis of cookies

Physical Analysis of cookies

The statistical analysis showed that diameter, spread factor and color of treatments decrease, whereas thickness, texture and water activity increases with the increasing concentration of sorbitol (Table 6).

T_5 showed minimum values of diameter, spread factor and color 122 mm, 32.28 and 134.67 CTn, whereas T_1 showed maximum values of diameter and spread factor 150 mm and 41.67 and T0 showed maximum value of color 154.67 CTn respectively. T0 showed minimum values of thickness, hardness, fracturability and water activity 33 mm, 1735 g, 20.39 mm and 0.18, whereas T_5 showed maximum values of thickness and water activity 37.80 mm and 0.24 and T4 showed maximum values for hardness and fracturability 5450 g and 22.64 mm respectively.

The decrease in diameter and spread factor and increase in the texture of cookies with the addition of sorbitol is due to the elastic shrinkage of gluten network. The increase in water activity of treatments is due to more hygroscopic nature of sorbitol as compared to the sucrose. Basically, polyols reduce the Millard and Caramel browning reactions as compared to sugars. The color of cookies reduces with the addition of sorbitol (colorimeter reading increases), but here trend is slightly different due to less controlled cookies preparation and baking (time and temperature) conditions and due to not proper calibration of colorimeter and human reading measuring errors. The results are in close agreement with the findings of **(Mushtaq et al., 2010; Pasha et al., 2002; Siddique, 1995)**.

Calorific Analysis of Cookies

The statistical data regarding the calorific analysis of treatments showed that calorific value of treatments decreases with the increasing sorbitol content (Figure 1). T_5 showed minimum calorific value 4.40 $kcal.g^{-1}$, whereas T_0 showed maximum value 6.13 $kcal.g^{-1}$ respectively. The decrease in the calorific value with the increasing sorbitol levels was due to the less energy provided by the sorbitol as compared to the sugar. The results are in close agreement with the findings of **(Siddique, 1995; Bond and Dunning, 2006)**.

Chemical Analysis of cookies

Statistical data regarding the chemical analysis of cookie treatments revealed that moisture, ash, and crude fiber contents increase with the increasing sorbitol content, whereas increasing sorbitol levels have a non-significant effect on crude protein, crude fat, and nitrogen-free extract contents (Table 7).

T_0 showed minimum values of moisture, ash and crude fiber 3.30%, 0.49% and 0.27%, whereas T5 showed maximum values of moisture, ash and crude fiber 3.80%, 0.66% and 0.40% respectively. Crude protein ranged from 9.05 to 9.32%, crude fat ranged from 21.40 to 21.60% and nitrogen free extract varies from 64.49 to 65.27% between the treatments.

The moisture content of the treatments increases with the increasing sorbitol levels was due to more hygroscopic nature of sorbitol as compared to the sucrose. Ash contents of treatments increases with the increasing sorbitol levels are due to the higher ash content of sorbitol as compared to the sucrose. Crude fiber content of cookies increases with the higher concentration of sorbitol due to low digestion of sorbitol as compared to the sucrose. The results are in close agreement with the findings of others in the literature **(Mushtaq et al., 2010; Siddique, 1995; Winkelhausen et al., 2007)**.

Sensory Evaluation of Cookies

Statistical data showed that the hedonic points related to the sensory parameters of cookies decrease with the increasing levels of sorbitol in treatments (Table 8). T_5 showed minimum hedonic points related to taste and crispness at 6 and 6, respectively, whereas T_0 showed a maximum value of 6.75 and 6.90, respectively. T_4 showed minimum hedonic points related to mouth feel and overall acceptability of 6.20 and 5.75, whereas T0 and T2 showed maximum hedonic points of 7.05 and 7.32, respectively.

The hedonic points related to the treatments decrease with the increasing levels of sorbitol because sorbitol lowered the sweetness level, increased the hardness, and had an aftertaste in cookies as compared to sugar. The results are in close agreement with the findings of **(Mushtaq et al., 2010; Siddique, 1995; Rosell et al., 2001)**.

CONCLUSION

The present study showed that the dough rheology of wheat flour could not be significantly improved by sorbitol supplementation. Sorbitol lowered the mixographic and farinographic parameters values in the treatments. Sorbitol substitution also resulted in harder, cohesive, adhesive and elastic dough as compared to the control treatment. The physical properties of sorbitol-substituted cookies did not significantly improve, as replacement resulted in harder, more brittle, lighter in color, higher in water activity and lower in diameter and spread factor values. Calorific content of sorbitol-replaced treatments were lowered as compared to the control treatments. Chemical characteristics of sorbitol-containing treatments significantly improved with substitution, as moisture, ash, and crude fiber contents of sorbitol-containing cookies increased with the increasing levels of sorbitol. Crude protein, crude fat, and nitrogen-free extract did not significantly change with the sorbitol replacement in treatments. Sensory evaluation of treatments showed that sorbitol substitution lowered the hedonic points related to the sensory parameters with the increasing levels of sorbitol. T_2 (20% sugar replacement) showed hedonic points of all sensory parameters closest to the control (T_0). T_2 also showed maximum hedonic points related to the overall acceptability of all the cookie treatments, showing it as the best treatment of the research.

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